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Michigan's forest development fund: Assessing investment risks

Catlin, Carter, Jr., Ph.D.

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U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

MICHIGAN'S FOREST DEVELOPMENT FUND: ASSESSING INVESTMENT RISKS

By

Carter Catlin Jr.

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ABSTRACT

MICHIGAN'S FOREST DEVELOPMENT FUND:
ASSESSING INVESTMENT RISKS

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Michigan's Department of Natural Resources Forest Management Division, which is responsible for managing the state-owned forest resources, has developed a unique approach for financing investments in forestry. This approach involves using funds from private sources for investments on public forest lands; it is based on legislation enacted in 1991.

Preliminary analyses of several timber investment opportunities, using a deterministic model, have shown favorable rates of return from 4 to 25 percent on public forest lands. These analyses omitted stochastic variables representing investment risks.

This study evaluates selected investments (i.e., red pine and improved aspen plantations) with the inclusion of biophysical risks associated with disease, insects, and weather, and the financial risks, represented by variability in timber prices and production costs. Data for determining the impacts of biophysical risks were obtained by the impacts of biophysical risks were obtained by questionnaire from Michigan Department of Natural Resources forest management experts.

Rates of return on investments are determined using the Monte Carlo simulation technique. Investment results, with the inclusion of risk, show a range of rates of returns and a probability of occurrence for each rate. The inclusion of risk in investment analysis provides managers with better information for decision-making.

Results of the survey questionnaire show high probabilities of attack for many insects and diseases on sited defined as high risk. Probabilities of attack for low risk sites were significantly lower. Rates of return that include risk for both aspen and red pine were approximately 1.0% lower than deterministic rates of return.

DEDICATION

To

My Wife Alma,

Daughter Katrina,

And

Son Kevin,

I dedicate this

and

all future works.

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Thanks to my family for their prayers and support during this effort. To my Mother and Father...

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CHAPTER I

INTRODUCTION

Background

Michigan has the fifth largest commercial forest[1] acreage in the United States, with 17.5 million forested acres covering 48 percent of the land base (James et al., 1982). Michigan's forest resources provide the basis for important timber products industries that directly employ an estimated 63,000 full-time workers (James et al., 1982). Secondary and induced industries employ many other workers.

State agencies are directly responsible for managing nearly 3.8 million acres of the commercial forest land in Michigan. Timber supplied from Michigan's state forests comprises 20 percent of the volume harvested in the state each year (Murray, 1987). Therefore, timber from state forests is important for expansion of the timber products industry. Many plants and firms rely on state forests for a significant portion of their timber requirements (Murray, 1986).

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[1]Forested areas at least one acre in size, not withdrawn from timber use by statue or administrative regulation, and capable of growing commercial timber crops at a rate in excess of 20 cubic feet per acre per year (James et al., 1982).

Effective land management is essential to sustain long-term timber production. Effective land management involves improving and harvesting existing timber stands and regenerating harvested stands. Improving existing stands requires controlling the density so that growth is concentrated on "higher-valued" trees. Establishing new stands requires site preparation and planting (Murray, 1986).

Most appropriated funds for state forest management activities come from timber sales receipts. Annual appropriations for investment activities depend upon the previous year's receipts. Timber revenues fluctuate annually because of changing market demands, weather and other natural factors, operating costs, technology, and other related events. Political, social, environmental and economic events unrelated to timber sales often influence annual appropriations, causing more uncertainty about funding for scheduled forest management activities.

Long-term, fluctuating appropriations may not be adequate for financially efficient forest management. The historic trend for funding forest management activities on state forest lands in Michigan during the period fiscal year (FY) 1978-79 through FY 1989-90 is shown in Table 1. The real level of funding expressed in 1982 dollars, has declined from $18.402 million in 1978-79, to $14.736 million in 1989-90. According to a Michigan Department of Natural

Resources (MDNR) report (1986), an annual expenditure of $3.00 per acre should be a minimum standard for investment in forest management practices. In 1986, the MDNR reported spending $0.40 per acre annually on their investments in forest management activities (MDNR Report, 1986).

Table 1. Forest Management Division Annual Appropriations, FY-79 through FY-90

Year	**Millions ($)**[a]
1978-79	18.402
1979-80	18.439
1980-81	15.043
1981-82	16.591
1982-83	15.130
1983-84	14.400
1984-85	14.302
1985-86	15.160
1986-87	13.536
1987-88	14.220
1988-89	14.255
1989-90	14.736

[a]1982 Dollars, Using GNP Price Deflator

Source: Forest Management Division Records

Failure to make the necessary investments in forest management activities results in lower yields, reduced timber quality, fewer desired products and lower revenues. Inadequate investments in forest management activities may have negative economic effects on the current and future timber-based economy of Michigan.

Forest Management Division (FMD) is responsible for managing the state-owned forest resources. The FMD goals are:

1. to intensify management through increased investments in forest management on certain highly productive forest lands where the purpose of management is timber production and where this purpose does not conflict with other recognized purposes,
2. to increase timber production,
3. to grow the required timber supply on fewer acres,
4. to promote economic development through more intensive use of forest resources, and
5. to provide an alternative source of funding for making investments on state lands (MDNR Report, 1986).

Michigan's Statewide Forest Resources Plan and the Governor's Target Industry Program require increased production of forest products and services through more intensive management of state lands (MDNR Report, 1986). Maintaining and expanding the state's forest product industry requires intensive management. Intensive management requires increased investments.

Funds to achieve the FMD goals could come from the traditional source (the state legislature) and/or new sources such as pension fund investors and other organizations or people seeking investment opportunities in enhanced forest management on state-owned lands. New institutional procedures, however, are necessary for investing private funds on public lands, and acceptable rates of return must be available to attract private investors.

To address low investments in forestry on state forest lands, the MDNR Forest Management Division and the Michigan Department of Commerce (MDOC) developed a proposal called the Forest Development Fund (MDNR Report, 1986). The objective of the Forest Development Fund (FDF) is to create a permanent and reliable future source of funding for long-term investments in more intensive management of certain highly productive, state-owned forest lands (MDNR Report, 1986). Through the issuance of bonds, this fund would allow borrowing against anticipated returns on investment in selected timber management improvements.

House Bill No. 4688 was passed by the State of Michigan 85th Legislative Regular Session of 1990. This bill created the Michigan Forest Finance Authority and prescribed as its powers and duties: (1) to provide for the issuance of certain revenue obligations by the authority to be paid for with revenues from the sale of timber; (2) to provide for the acquisition of standing timber and timber cutting rights in standing timber on state tax-reverted lands; (3) to provide for certain forest management operations and practices; (4) to provide for disposition of proceeds received by the authority from the sale of timber; (5) to prescribe the powers and duties of certain state agencies and officials; and (6) to repeal certain acts and parts of acts. With the passage of this bill, a mechanism was created to allow investments of funds from private sources on state forest lands or in the management of state forest lands.

Taking a deterministic (complete knowledge and certainty of events are assumed) approach, the FMD conducted analyses of several management regimes using a computer program called "Quicksilver."[2] Estimated returns on investments in more intensive management ranged from 4 to 25 percent per acre. Rates of return were calculated for several investment alternatives and tree species, e.g., native aspen, improved aspen, European larch, northern hardwoods, red pine, red oak, red maple and white pine.

Management alternatives and rates of return varied and included: (1) northern hardwood thinning with a 25% return, (2) red pine release in 20-year old stands overtopped by 40-year old oak with a 16% return, (3) monitoring and controlling of redheaded pine sawfly in red pine stands yielding a 13% return, (4) pruning white pine pole stands with a 11% return, (5) monitoring and controlling of

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[2]Developed by J. Michael Vasievich, R. Frebis, and R.W. Wiethe, USDA Forest Service Southeastern Forest Experiment Station.

Saratoga spittlebug populations in high and moderate risk red pine plantations with a 10% return, (6) planting improved aspen with an average yield of 8% return, (7) site preparation and planting red pine with an average return of 7%, (8) aspen timber stand improvement to remove competing hardwood and improve regeneration with a 5% return, and (9) planting European larch on medium hardwood sites that yields a 4% return.

A portfolio of investments will be used to determine the acceptable investments. To be acceptable investments, the portfolio must earn an acceptable real rate of return. The standard against which investments will be judged will be long-term, tax-free government bonds which currently earn 6.5 to 7.5% (Wall Street Journal, July 16, 1992).

Problem

Projected returns on investment estimated by the Forest Management Division were assumed to be risk free. These returns did not explicitly include risks that may affect investment returns and the total level of investments in forest management activities. Selecting opportunities for capital investments requires a method of analysis that incorporates into the analyses biophysical, financial, institutional and technical risks.

Biophysical risks (e.g., insects, diseases, fire, and weather) may cause direct changes in timber volume/yield or quality. Financial risks (e.g., timber prices, production costs and general economic trends) may have direct effects upon the total investments in timber production. Some biophysical and financial risks are manageable, however, either in the timber stand or in the marketplace. Careful silviculture and early detection, for example, can help keep insects under control. Timing timber sales to coincide with favorable markets can reduce price risks (Shearer et al., 1987).

Institutional risks (e.g., government policies, customs, property rights and trade policy) and technical risks (e.g., harvesting and transportation systems, processing, biotechnology, and utilization standards) also affect investments in forestry. This study is designed to focus on biophysical (i.e., diseases, insects and some weather-related factors) and financial risks (i.e., timber prices and production costs) and to calculate rates of return on investments with the inclusion of biophysical and financial risks.

Objectives

The primary objectives of the study are:

1. to identify biophysical risks associated with growing improved aspen *(Populus tremuloides x tremula)* and red pine *(Pinus resinosa)*, and

2. to estimate rates of return for red pine and improved aspen, after the inclusion of risk (biophysical and financial).

After incorporating risk into the calculations for rates of return (risk included), results will be compared to deterministic results (risk not included) previously derived by Forest Management Division.

A study including risk in the analysis of forest investments is superior to conventional deterministic analyses in many ways. First, an analysis that includes risk may utilize quantitative information available on variability of costs, returns, and other factors. Second, a risk analysis technique allows the use of all possible values weighted by their probabilities. Third, results show not only the conventional "most likely" outcome, but show the chances of that result occurring. Finally, results show a range of outcomes and the probability of occurrence for each outcome within the range.

Analyses that include risk can also be used with either of the two types of investment decisions forest managers often make. One is to accept or reject a particular project. The other is to choose among alternative projects, which involves comparisons of investment alternatives. The decision maker can learn the chances of earning at least some particular rate of return given the magnitudes and probabilities indicated for various prices and other factors. This approach is helpful, especially when the analysis can focus on a specific factor as the cause of most of the uncertainty (Engelhard and Anderson, 1983).

Rates of return that include risk show a minimum and maximum range of expected returns (e.g., 2.5% to 7.5%) and a probability of achieving each rate of return (e.g. 0.0% to 100%) within the range. The range of rates of return that include risk can be used to determine the probability of earning the deterministic rate of return. Analyses that show a range of rates of return and a probability of occurrence allow the decision maker to recognize that some outcomes are more likely to occur than others, and should be given more weight during an evaluation.

Knowing the chances of earning a given rate of return provides decision makers with more meaningful information than an average estimated return. Also, expected rates of return with the inclusion of risk can be compared to estimated rates of return that do not include risk.

An analysis procedure including risk gives decision-makers a more realistic measure of the investment outcome and provides a better picture of possible returns for the alternatives being reviewed. Given this information, the decision maker has more knowledge upon which to make a choice. The final decision, however, may be a function of the manager's aversion to risk. Results obtained through a risk analysis must be interpreted by each individual decision maker, therefore, the same results given to different decision makers may be interpreted differently and lead to different courses of action. This occurs because individuals have different risk preferences.

Scope

Only biophysical and financial risks are considered in this study because of limited time and resources. The biophysical risks considered are insects, diseases and weather. Financial risks include timber prices and production costs.

The study deals with improved aspen and red pine only, in the Northern Lower and Upper Peninsulas of Michigan. Management strategies for the selected species will parallel the FMD management strategy.

Limitations

This study does not include institutional and technical risks. Institutional and technical risks are important, but they are difficult to measure and beyond the scope of this study. Further, risk-averting and risk-taking behavior are not examined.

Also, financial risks in this study are limited to the variability in planting costs and timber prices. Other production costs such as thinning/harvesting, management, site preparation and environmental protection (with aspen) are included in the analysis, but variability is not, because of a lack of historical data. Though a market analysis of prices and costs would be desirable, to do so is beyond the scope of this study. Another limitation of this study is its focus on the analyses of stands which exclude treatments for insects and diseases. The limitation of analyses of stands with treatment for insects and diseases is caused by of a lack of respondent data on treatment costs.

Although investment opportunities on state-owned forest lands are available for several timber species, this study focuses on analyses of long-term investments in improved aspen and red pine for several reasons: (1) the MDNR Forest Management Division has targeted aspen and red pine as two of their primary hardwood and softwood species for investment opportunities, (2) markets are available in Michigan for aspen and red pine, (3) aspen and red pine are best suited for even-aged management, (4) aspen and red pine stands are abundant in Michigan, and (5) data on aspen and red pine are available. The data available for aspen is for native aspen; therefore, for this study it is assumed that biophysical risks that attack native aspen stands will also affect improved aspen stands in a similar manner. Throughout the remaining chapters of this study the data reported are for native aspen, except for yields.

The investment alternatives for the study are based on site index and limited to three site indices (60, 70 and 80) for aspen and four site indices (50, 60, 70 and 80) for red pine. Analyses are conducted for each site index and for three site characteristics, defined as high risk, moderate risk and low risk sites. Therefore, the total number of investment alternatives are nine for improved aspen and twelve for red pine.

One dimension of this study involves comparing the FMD deterministic rates on return with rates of return that include risk. By replicating the FMD investment alternatives and incorporating risks, rates of return that include risk can be compared with rates of return that do not include risk. Rates of return that include risk are not strictly comparable to deterministic rates of return because of higher real price increases for both aspen and red pine.

Organization of Dissertation

The study is divided into six chapters. Chapter II has a review of the literature on studies that have attempted to incorporate risk into the analysis of investments in forestry. Chapter III is the methods chapter. It provides a detailed explanation of procedures used in the study. Chapter IV identifies investment risks associated with growing aspen and red pine. Chapter V compares deterministic rates of return (i.e., results that exclude risk) with rates of return that include risk. Finally, Chapter VI has the summary, conclusions, and recommendations. Improved aspen and red pine are two key species in the FMD portfolio of investment alternatives. Throughout the remaining chapters, improved aspen will be referred to simply as "aspen."

CHAPTER II

LITERATURE REVIEW

The review of literature focuses on forestry applications incorporating risk into investment analyses. It is divided into two major topic areas (i.e., approaches to incorporating risk and biophysical risk studies) that are relevant to this research effort.

Approaches to incorporating risk examine various techniques economists have used to incorporate risk into investments related to forestry. The section on biophysical risks examines studies that have focused on the impacts of insects and diseases on growth and yield in forest stands. A section on assessing risk in production agriculture is included, too. The purpose of the section on risk in production agriculture is to identify useful approaches by agricultural economists for incorporating risk into analyses of agricultural investments.

A review of literature that summarizes effects of insects, diseases and weather-related risks is included in Chapter IV. Additional citations are provided in (Hyldahl and Baumgartner, 1991) which is an annotated bibliography of theory and applications on risk analysis and timber investments. The bibliography included most of the small, but rapidly growing, material directly related to risk in forestry in the United States. It provided valuable leads in locating literature on studies incorporating risk in timber investments on both public and private lands.

Approaches to Incorporating Risk

Uncertainty of outcome increases with the time required to produce a product (Knight, 1921). Because timber growing involves a long production process, uncertainty is inherent in forestry. The longer the production period, the less certain is the outcome. Knight (1921) noted that uncertainty takes one of two forms: "risk" or "uncertainty." Risk is an outcome whose probability of occurrence is quantifiable. Uncertainty is an outcome whose probability of occurrence is not quantifiable.

Marty (1964) noted that an investment is risky if it leads to one of several outcomes, each of which occurs with a known probability. Uncertain investments may lead to one of many different outcomes also, but outcome probabilities are unknown.

Several approaches have been used to deal with risk in forest investment analyses. They range from ignoring risk to the use of stochastic variables representing investment risks (Duerr et al., 1950). For purposes of this study, literature will be presented in four sections; they are:

(1) deterministic-ignore risk,

(2) deterministic-sensitivity analysis, and

(3) stochastic.

Deterministic-Ignore Risk

Foresters have recognized risks associated with investments in forestry for many years. They have tried various ways of adjusting a return estimated with deterministic investment models to include risk. Deterministic models assume complete knowledge and certainty of events. However, complete knowledge of complex systems is not possible, and future events are rarely certain.

Traditional investment analysis ignores risk by assuming fixed prices, costs and yields. Flora (1964) suggested that it is unnecessary to include any allowance for risk and suggested we ignore uncertainty if certain assumptions are reasonable and if decisions are between forestry investments whose returns are about equally distant in time. He cited some analyses of forestry rates of return, excluding risk, as a yardstick for profitability.

Deterministic-Sensitivity Analysis

Guttenberg (1950) and Foster (1979) accounted for risk by adjusting returns estimated with a deterministic model by adding a percentage point or two to the rate of interest used for discounting future returns. Duerr et al. (1950) noted that where the interest rate is low and duration of the investment is short, adding a risk premium is an acceptable and reliable method. When interest rates are high and the investment period is long, this allowance for risk is often too great (Duerr et al., 1950). A similar approach was used to adjust costs and returns in future years.

Dowdle (1962) evaluated an approach to forestry investment analysis in which economic uncertainty and other sources of variation associated with expected investment returns could be set forth. He estimated expected returns and variation of returns and applied these to the problem of determining cutting age for eastern white pine timber. He also defined and discussed what is relevant and how much information is needed to analyze forestry investment opportunities.

Marty (1964) incorporated risk and uncertainty into forest investment analysis by using multiple estimates of project profitability stemming from different assumptions about the true values of uncertain factors such as yields and prices. His procedure required screening competing projects to eliminate those that are proven unprofitable, or less profitable than some other project, regardless of the assumptions made about the values of certain factors. He used the outcome of pruning an eastern white pine crop tree to illustrate his procedure.

Dane (1965) used a hypothetical logging problem to illustrate the application of statistical decision theory and Bayesian statistics to a forest engineering problem. He noted that the decision maker does not have a horizontal attitude toward money in a risk situation; therefore, the "expected utility" decision rule would replace that of "expected value." He proposed that forest engineers may determine whether additional information is desirable by incorporating the Bayesian approach to probability with statistical decision theory.

Teeguarden (1969) reviewed the use of economic criteria in making reforestation investment decisions. He stated that because of major long-term uncertainties, economic criteria define the problem but provide little help to land managers who wish to test the economic desirability of reforestation investments. He demonstrated an application of alternative rules for decision-making when outcomes are uncertain. He recommended the expected value rule for large-scale reforestation programs.

Fight and Bell (1977) presented an overview of various approaches to decision-making that explicitly recognize risk and uncertainty. A framework was presented for making a consistent set of timber management planning assumptions.

Caulfield et al. (1988) used the mean-variance rule and stochastic dominance analysis to show how risk can be included in species site selection.

Each of the foregoing approaches calculated rates of return based on high and low values. These approaches did not show the probability of occurrence for the variables included in the analyses.

Stochastic

Engelhard and Anderson (1983) noted that conventional (deterministic) techniques did not provide decision makers with a realistic measurement of the risks involved in selecting opportunities for capital investment. They concluded that although the pessimistic and optimistic estimates suggest a possible range of results, these estimates do not show which rate was most likely to occur or the probability of the estimated rate occurring.

Hertz (1964) described the use of Monte Carlo simulation to evaluate capital investment profitability using risk information. Monte Carlo simulation is a technique for numerically exploring a system by repeatedly sampling probability distributions of the variables specified in the model (Engelhard and Anderson, 1983). The use of Monte Carlo simulation differs from other risk investment analyses by its use of ranges of possible costs and values for each significant variable and the likelihood of a specific value occurring.

The use of sensitivity analysis allows for considering the effects of changing one variable at a time. By looking at an investment under alternative scenarios, the effects of a limited number of variables can be considered. Monte Carlo simulation, however, is a tool for considering all possible combinations. Results of a Monte Carlo simulation enables one to inspect the entire distribution of investment outcomes.

Bentley and Kaiser (1967) used the decision-tree approach and illustrated the use of this technique for ranking alternative investment paths with a case study of Christmas tree production in Iowa. They integrated technical information, economic analysis, and expert and managerial judgement. Sensitivity analysis was used to determine the importance of key decision factors, such as expected price and growth rate.

Thompson (1968) investigated the compatibility of Bayesian decision theory and forest management decision-making problems under uncertainty. He presented examples of two possibilities for applying Bayesian decision theory in forest management. The first example was a pruning decision, the second involved deciding the optimum size of a fire suppression crew. He concluded that Bayesian decision theory is appropriate when the uncertainty in decision-making is characterized by partial rather than complete ignorance and that the theory is intuitively compatible with reality.

Binkley (1981) reported that it is not sufficient to simply adjust the discount rate for timber investments to reflect the maximum rate of return available for that duration. He suggested that the analyst must consider the probability distribution of returns from the timber investment and compare the expected return with that available in other competitive instruments.

Several studies, including Mills and Hoover (1982), Millick (1982), Lothner et al. (1986), Engelhard and Anderson (1983), and Anderson et al. (1987) used Monte Carlo simulation as a vehicle to incorporate risk into forest investment analysis.

Mills and Hoover (1982) used Monte Carlo simulation to incorporate the riskiness of catastrophic events (fire, tornados, defoliating insects, oak wilt, dutch elm disease and elm phloem) into a portfolio analysis containing financial investments of farm options and hardwood timber. Engelhard and Anderson (1983) showed the application of Monte Carlo simulation by using a hypothetical investment in slash pine. Results from their hypothetical investment showed a return of 5.1% using conventional deterministic analysis. The result of a risk analysis showed that a return of 5.1% occur only about 5% of the time. They concluded that the use of Monte Carlo simulation in risk analysis provides a formal procedure for quantifying risk in forest investments. When properly used, Monte Carlo simulation enables forest managers to make better investment choices.

Millick (1982) used Monte Carlo simulation to assess the profitability of four investment alternatives in jack pine (50 and 70 year rotations) and aspen (40 and 60 year rotations). Composite Internal Rates of Return (CIRR) were 9.6% for jack pine (50 year rotation) with a 59% chance of occurring (i.e., 9.6% or higher) and 7.0% for jack pine (70 year rotation) with a 74% chance of occurring. The CIRR for aspen 40 year rotation was 6.7% with a 36% chance of occurring. For aspen 60 year rotation, three rates of return 7.8, 8.8, and 9.2% were calculated each with an equal chance of occurring (26%). Results from this analysis produced a most likely (average) rate of return on the investment, but also showed all other possible outcomes and their probability of occurring. Although Millick study incorporated risk into investment analysis, the study did not present the technique or procedure used to develop probability distributions for risks.

Lothner et al. (1986) examined and compared short-rotation hybrid poplar investments using standard discounted cash flows and stochastic simulation. Triangular probability density functions were used to describe the values for three important uncertain factors: product price, product yield, and harvest and transportation costs. They found that the net present value per acre ranged from a minus \$310 to a positive \$1,010 with a mean value of about \$140, using a 4% discount rate. Product price uncertainty was found to be a major cause of uncertainty surrounding the financial returns from a short-rotation system. They noted that because information on future prices is limited, decisions about short-rotation systems should be made carefully. Also, they noted that analyzing uncertainty by using imprecise input data cannot produce both accurate and precise results, but thinking through the uncertainties and collecting information should help investors make better choices.

Anderson et al. (1987) used Monte Carlo simulation to determine if landowners could obtain a reasonable return on investments in loblolly pine plantations subject to attack by the southern pine beetle. Results of the analysis showed that stands would earn at least a 9.5% rate of return, with a 97% probability of occurring.

Hof and Pickens (1988) used a Monte Carlo simulation approach to describe the distribution of total output when the individual production (yield) coefficients in a harvest scheduling model are random. They developed an iterative procedure for "chance-constraining" feasibility and demonstrated this with a random A-matrix. This required an iterative approach because the mean and variance of total output are unknown functions of the random A-matrix coefficients and the level of output required. They formulated a case study model using data collected by the USDA Forest Service.

Thomson (1989) examined financial uncertainties of a west coast Douglas-fir tree improvement program. Some were judged to be nonmarket uncertainties *a priori*; others were shown (by sensitivity analysis) to not be financially important; still others had low market risks. He found that market uncertainties of tree improvement are reasonable and less risky than other investments. He concluded that the tree improvement investment is worthwhile, considering its risk as well as its return.

Hof and Pickens (1991) discussed a broad range of approaches to optimizing natural resource allocation in the situation where amounts of available input(s) and/or amounts of desired output(s) are random. They reviewed the classic approach to this class of problems, "chance-constrained programming," and a new alternative "total probability chance-constrained programming." They developed specific formulations for excluding these approaches in natural resource management problems that explicitly include the cumulative probability density functions. They also demonstrated solution procedures with a forestry case example and showed that the different approaches can yield substantially different results.

Risk in Production Agriculture

Risk is also a perennial problem faced by farmers in production agriculture. Many investments in agriculture differ from investments in forestry because the cycle of production in agriculture is usually one year. The investment period in forestry, on the other hand, usually covers several decades. Agricultural economists, like forest economists, recognize risk and the limitations of using deterministic models in investment analyses. They are now using dynamic investment models which show the effects of the passage of time on variables incorporating risk. Many factors interact to create a unique decision-making environment for the agricultural producer. These factors include the weather, diseases, insect infestations, general economic conditions, the development of technological innovations, and public and private institutional policies. Institutions and the uncertainty surrounding the development and implementation of their policies have become increasingly important to farm operators (Antle, 1983). Several approaches are used by agricultural economists to assess and respond to production, markets, and financial risks in agriculture.

One approach is quadratic risk programming (Fruend, 1956; Kliebenstein and Scott, 1975). Researchers using this approach usually assume that the decision maker maximizes expected utility and either the utility function is quadratic with respect to expected income and variance of income, or net returns of the production activities follow a multivariate normal distribution. Historical price, yield, and cost data provide the basis for calculating net returns associated with each production activity. The model is solved to determine the set of production activities that minimizes variance of net returns subject to receiving a specified level of income or to develop the efficiency frontier showing tradeoffs between expected income and variance of income.

Hazell (1971) developed an approach which minimizes total absolute deviation rather than variance. This problem is solved using a linear programming algorithm. It yielded results remarkably similar to those of quadratic programming. This approach, referred to as MOTAD, has been applied to several different types of problems (Brink and McCarl, 1978; Nieuwoudt et al., 1976; Simmons and Pomareda, 1975; Schurle and Erven, 1979).

Another approach to studying the effects of risk at the firm level involves developing firm-level simulation models. Patrick (1979) studied the effects of debt levels and loan arrangements on a farm firm survival and growth. Held and

Helmers (1978) developed a financial simulation model to investigate firm growth, income, and survivorship relationships in wheat farming. Harding (1978) also developed a simulation model to evaluate risk and financial management implications of major capital investments in an uncertain environment.

Antle (1983) discussed incorporating risk into production analysis by incorporating probability distribution parameters in decision models. He noted that static (deterministic) models have serious limitations; they imply risk matters only if decision makers are risk adverse, and they cannot be used to model cost uncertainty. Dynamic models, in contrast, show that input and output price risk and production risk generally affect productivity and optimal resource allocation whether the decision maker is risk averse or risk neutral. He concluded that all farmers, whether risk neutral or risk averse, can gain from information about price and production risk.

Biophysical Risk Studies

Many studies have investigated the impacts of various biophysical risks (insects and diseases) on the growth and yield of timber stands. However, most are not species and stand specific. Most studies do not focus on the impacts of insects or diseases on specific tree species, but on forest stands in general.

MacLean (1990) assessed the impact of fire and several forest pests (with special emphasis on spruce budworm (*Choristoneura fumiferana*)) on stand growth and timber yield in Canada. MacLean concluded that damaging agents reduce tree growth, kill trees, destroy the commercial value of stands, and sometimes reduce yield in subsequent rotations. Sustainable harvests may be reduced by up to 60% by a severe spruce budworm outbreak and up to 40% by a 1% per annum loss to fire. He also concluded that research is needed to quantify and forecast the effects of forest pests and fire on growth and yield at the stand level.

Several other studies (Errico, 1990; Schabel and Raffa, 1990; Gottschalk, 1990; Fowler and Wilson, 1971; Dempster and Stevens 1987; Brace, 1971; Reed, 1984; Reed and Errico, 1987; Van Wagner, 1979 and 1983; and others) dealt with the effects of various insects and diseases on the growth and yield of various timber species. These studies did not address specific impacts of insects and diseases on aspen and red pine.

Summary

Three basic approaches to assessing risk in forest investments are given. These include (1) deterministic approaches that ignores risk, (2) deterministic approaches that makes use of sensitivity analysis, and (3) stochastic approaches. The traditional deterministic approach to risk assessment does not provide decision makers with realistic measurements of the risks involved in selecting forest investments.

Since an assessment of the likelihood of returns is desired in this study, a stochastic approach was used. The primary objectives of this study are to identify the significant biophysical risks affecting investments in aspen and red pine and to estimate rates of return after the inclusion of risk. The Monte Carlo simulation technique is better suited for incorporating risk in investment analysis because it includes the probability of occurrence for variables.

This study differs from Millick (1983) and all others because it deals specifically with determining the impact of specific biophysical risks on the growth and yield of aspen and red pine. These impacts are analyzed along with price and cost risks.

Studies that dealt with the impact of insects and diseases on forest resources focused on the impacts on forest stands in general. Such studies have not focused on impacts of insects and diseases on specific tree species (e.g., red pine). Therefore, it is important to get data from experts to quantify impacts. It was essential to turn to other sources to gather species-specific data for this study.

Chapter III presents a specific technique for this study to solicit subjective probabilities estimates on the impact of insects, diseases, animals, and weather on the growth and yield of aspen and red pine in Michigan. A subjective (i.e., professional judgment) approach is used because little empirical data are available.

CHAPTER III

METHODS

The purpose of this study is to identify significant biophysical and financial risks that affect investments in improved aspen and red pine and to calculate rates of return with the inclusion of risk. Stochastic rates of return are compared with rates of return calculated by Forest Management Division (FMD) using a deterministic model.

Several approaches to adjusting for risk have been used to aid decision makers in evaluating long-term investments in forestry. The use of risk premiums (Foster, 1979 and Guttenberg, 1950) for adjusting the discount rate is one approach to adjusting for risk. Using high and low values for input variables (Marty, 1964) is another commonly used approach. Both approaches attempt to adjust for risk by using deterministic variables, where complete knowledge and certainty of events are assumed. The chance, however, of incurring a most-likely cost for each input variable or estimating the correct volume of timber in a stand is highly unlikely in a long-term investment analysis.

The weakness of these approaches is that values of variables used in calculating the rates of return are subject to high levels of risk, yet values are assumed to be known with certainty. A more appropriate approach for accounting for risks includes probability distributions associated with various risks.

Monte Carlo Simulation

David B. Hertz (1964) described the use of Monte Carlo simulation to evaluate capital investment profitability using risk information. Hertz analysis procedure is distinguished from other risk investment analyses by its use of ranges of all possible costs and values for each significant factor and the likelihood or probability of each specific value occurring. The significant factors for this study include timber yields, costs and prices.

The analysis procedure for this study parallels the method developed by Hertz (1964), commonly called the "Hertz Method." Hertz's method is a computer-based capital investment risk analysis procedure involving Monte Carlo simulation. Monte Carlo simulation is a technique for numerically exploring a system by repeatedly sampling probability distributions of the variables specified in the model (Engelhard and Anderson, 1983).

Hertz's analysis procedure is a four-step process that:

1. identifies significant risks affecting investment outcomes,
2. develops probability distributions for each variable,

3. randomly and repeatedly selects one value for each independent variable, and
4. combines selected values to calculate rates of return on the investment.

Although Hertz's analysis procedure is a powerful and highly useful method of risk analysis, it is often based on subjective estimates of the probability of occurrence of various values for determining variables. Also, the assumption that the results of a risk analysis are representative of the "real world" may be incorrect. An example of the how the process is based on subjective estimates is discussed in the next section of this chapter.

The use of Hertz's analysis procedure requires developing a probability distribution for each variable. Developing a probability distribution require data on historical trends, management records and experienced judgements, or data from other sources. These kinds of data on risk variables may not always be available, thus limiting the ability to develop the required probability distributions for an analysis.

Hertz's method of risk analysis, however, does provide a formal procedure for quantifying risk in forest investments. It is a tool for major decisions. When properly used, it will enable forest managers to make better choices (Engelhard and Anderson, 1983).

Risk Identification

Biophysical Risks

Many biophysical risk factors can affect growth and yield in aspen and red pine stands. Data on (1) the impacts of biophysical risks on the growth and yield of aspen and red pine and (2) the probability of occurrence for those risks are unavailable in literature or inventory records. Thus, subjective judgements of experts with first-hand knowledge of the effects of biophysical risks on aspen and red pine must be sought in order to use this approach. Moreover, the means for determining the effects of biophysical risks is to solicit the professional judgements of experts in the MDNR with extensive knowledge of the risks and timber species. This involves a two-step process that requires (1) asking experts to identify the biophysical risks that would affect aspen and red pine stands, and (2) answering follow-up questions with more specific details about the effects of each risk.

Delphi Process

The procedure used in this study to obtain information on biophysical risks followed the basic Delphi process. The Delphi process may be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem (Linstone and

Turoff, 1975). This process systematically combines expert knowledge and opinions to derive a group consensus. Baughman (1991) reported that the Delphi process has been used in forestry in several ways including allocating a forest fire prevention budget among various media; defining road construction standards for high mountain areas that would be acceptable to a wide array of interest groups; forecasting events in natural resource management and wildland recreation; estimating the loss in forest production from acid rain; formulating and analyzing county forest land policy alternatives for funding, timber sale procedures, and land ownership; and forecasting ecological and institutional change in the Lake States forest environment. In this study the Delphi process is used to identify biophysical risks that are most likely to attack aspen and red pine stands.

The Delphi process is a combination of public opinion poll and committee meeting. It is similar to a poll because it involves having a group of individuals respond to questions that seeks personal opinions about a specific area. It differs from a poll because of the feedback of information and the opportunity for individuals to modify their judgements. Delphi panels are usually carefully chosen and the panel responses are not a random sample from a population, therefore, many statistical tests that would be applied to data from a poll are not appropriate for a

Delphi (Baughman, 1991). The Delphi is similar to a committee in that it often involves a relatively small group of carefully selected people, but it differs from a committee because sometime it may not permit face-to-face meetings of the participants.

Strengths of the Delphi technique are: (1) its ability to provide feedback on individual contributions of information and knowledge; (2) some assessment of the group judgement or view; (3) some opportunity for individuals to raise views and some degree of anonymity for the individual responses; and (4) the ability to expose uncertainty and divergent views.

Linstone (1975) and Baughman (1991) noted several potential problems associated with the Delphi technique of which users should be aware. They include: (1) Judgements that typically survive a Delphi procedure may not be the "best" judgements but, rather the compromise position. This may occur if there is a wide divergence in opinions or positions of the participants. (2) When Delphi is used to elicit value judgements or subjective opinions involving the future, the practice of applying a "discount" rate to the future arises, for example, because most people have a short planning horizon and short memory. They tend to place less value on the future or future events. (3) Individuals asked to list their preferences on paper may give significantly different responses from that which would be given in a real-life/real-time setting. (4) A reasonable sounding (no element of surprise) scenario is usually judged "more likely" to occur than an unfamiliar one even if there is no evidence to support such a differential evaluation. (5) Panelists may reply hastily without adequate thought or reference to available materials. (6) Specialists may not be the best forecasters if accustomed to focusing on a narrow field or subsystem and not taking into account the larger system and its interactions. And, (7) all respondents and designers have biases both conscious and unconscious. Most humans have a strong preference for certainty and a dislike for uncertainty.

The Delphi process is applicable to a number of problems and can be applied in many ways. Baughman (1991) noted that a Delphi process often involves three sets of actors--a sponsor, monitor and panel. The sponsor may be an individual and should be involved in the study design to insure that the relevant problem will be analyzed. The monitor is responsible for coordination with the sponsor. Panel members are seldom selected at random, but they are carefully screened and selected because of special knowledge or skills. Baughman also stated that a panel size can vary from a few individuals to several hundred members. Small groups are suitable for deriving a consensus on a few very specific and technical questions. For example, a Delphi panel of three individuals was used to estimate the number of elm trees that would be killed in the following year by Dutch elm disease in Minneapolis, Minnesota (Baughman, 1991). The use of the Delphi in this study is similar in that a small panel (4 individuals) is used to identify biophysical risks that would attack aspen and red pine stands in Michigan.

Biophysical risks that would probably affect growth and yield in aspen and red pine stands in Michigan were discussed in a meeting with a carefully selected panel of Forest Management Division personnel[3]. The meeting was held at the FMD office in Lansing, Michigan on November 17, 1989. Prior to this meeting, a list was compiled consisting of all known biophysical risks that were considered potential threats to aspen and red pine stands. At this meeting, the experts in the group were asked (1) to identify those risks on the list that they thought would attack aspen and red pine stands in Michigan, and (2) to provide an initial estimate of expected loss in yield if the risk occurred in a stand. The panel consensus responses and comments are summarized in Appendix C, Tables C1 through C8. The risks identified as significant by the panel are listed in Appendix C, Table C9. Risks are identified as significant when (1) predicted losses as the result of an

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[3]William Botti, Program Leader Timber Management; Ronald Murray, Forest Management Analyst and Frank Sapio, Program Leader Forest Pest Management are located in the MDNR Lansing office. Robert Heyd, Regional Pest Specialist is at the MDNR Regional office in Marquette.

attack are more than zero and (2) the panel of experts agreed that losses would occur as the result of an attack, but they could not estimate the expected loss. Only the risks identified as significant are included in the survey questionnaire where specific estimates are requested from a group of forest management experts.

Survey of Forest Management Experts

Biophysical risks identified as significant by the panel of experts were used in developing a questionnaire in which specific questions were asked about each risk. The overall objective of the questionnaire is to obtain data needed to develop probability distributions for reductions in timber yields. Development of the questionnaire took place over a four-to-six month period. Though there was no pretesting of the questionnaire given the small number of experts in this area, it was developed in consultation with several individuals and was reviewed by pest specialists in Forest Management Division, USDA Forest Service, and Michigan State University. Their recommendations and comments are incorporated in the questionnaire which is in Appendix D. The questionnaire is designed to obtain the professional judgement of forest management experts on the impact biophysical risks have on the growth and yield of aspen and red pine. The questionnaire also sought data on the cost of treating some of the various pests.

Questionnaire respondents were asked to give answers based on three site characteristics (high, moderate and low risk site). A high-risk site is defined as a site where known risks are present in abundance and not treated; a moderate-risk site is where some of the known risks are present or are expected to occur; and a low-risk site is where known risks are few. Officials at the Forest Management Division stated that aspen and red pine will not be planted on sites classified as high risk. This analysis includes high risk sites for comparison purposes only.

The questionnaire contains specific questions about the potential impact of a specified risk on the growth and yield of aspen and red pine. Key questions included the following:

1. Consider 100 recently planted stands on high, moderate and low risk sites. During the rotation of these stands, what percent of stands (assume 100 stands) would you expect to see attacked (e.g., by armillaria)?
2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?
3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of an attack (with and without treatment)?

4. What treatment(s) would you recommend to reduce losses?

These questions were designed to obtain data on:

1. number of stands the experts believed would receive an attack by a specific risk for each of three sites,
2. total reduction in volume over the length of the rotation, if a stand is attacked,
3. total reduction in grade because of an attack,
4. possible treatment costs, and
5. insects and diseases that may attack a stand as a result of an attack by other insects, diseases, animals, weather or fire.

Results of the questionnaire are summarized in Chapter IV, Tables 2 through 19.

The face-to-face interview method was selected as the best approach for obtaining the required data. This interview method is best suited for this task because of the nature of the questions asked and the need to insure that the respondents fully understood the questions. In addition, the face-to-face method provided opportunities for an exchange of questions and comments between interviewer and interviewee.

Forest management experts from the timber industry, the USDA Forest Service, Michigan State University, the University of Michigan and Michigan Technological University were initially considered as potential respondents for the survey questionnaire. But, because of the high cost of conducting face-to-face interviews, it was decided to restrict survey respondents to MDNR experts. The rationale for this restriction was: (1) it was easier to identify experts within the MDNR because of prior contacts in the MDNR with individuals who could help identify expert personnel, (2) the required survey data can be more readily addressed by expert personnel with extensive "on-the-ground" experience with aspen and red pine, (3) it was thought that an adequate number of experts could be found among MDNR personnel since the state manages nearly 22.0% of the commercial forest land in Michigan (James et al., 1982).

Restricting survey respondents to MDNR experts limited the number of potential respondents and potential sources of professional judgements. However, limiting the survey to MDNR experts allowed the opportunity to focus specifically on impacts of biophysical risks on state-owned forest lands. Further, by limiting the contact persons to MDNR experts, it is possible to focus on the specific stands that may comprise the FMD investment alternatives.

Twelve forest management experts were interviewed using the face-to-face data collection method. Forest management experts included highly-trained and experienced forest and pest management specialists from the MDNR's Forest Management Division, and a plant geneticist at with

Minnesota's Department of Natural Resources. This group of experts averaged 21.3 years of experience working with aspen and/or red pine in the Lake States (see Appendix F).

Forest Management Division personnel identified the contact persons classified as experts. The individuals chosen to respond to the survey questionnaire were selected on the basis of their broad knowledge and/or experience working with aspen and red pine in Michigan. The plant geneticist was added because of his extensive experience in the development of improved aspen.

The survey questionnaire was administered during a ten-day period in late August, 1990. The first interviews were held at the Department of Natural Resources headquarters in Lansing, Michigan. The second series of interviews took place in Roscommon, Michigan at the MDNR regional office. The last group of interviews were held at the MDNR regional office in Marquette, Michigan. The average length of the interviews ranged from two to four hours, depending upon the amount of information given.

Results of the questionnaire are discussed in Chapter IV. How the questionnaire data are used to develop probability distributions is discussed in another section of this chapter.

Financial Risks

Financial risks examined in this study include timber prices and planting costs. Variability of prices and costs are based on data from the MDNR. Costs for which variability is not considered include harvesting/thinning, environmental protection, management and site preparation. Historical trends and/or spatial patterns for these costs are not available.

Probability Distribution for Variables

Risk profiles are used to show the probability of occurrence for variables. A risk profile is developed by assigning a probability to each variable. It is represented as a probability distribution curve with a range of outcomes measured along the horizontal axis, and the probability of occurrence for each value measured along the vertical axis (Engelhard and Anderson, 1983). Risk profiles representing input variables may be shown graphically with curves that are, for example, triangular, bell-shaped, vertical lines, horizontal lines, and arcs. There are other forms and types of probability distributions, each of which describes a range of possible values and their likelihood of occurrence.

Probability distributions are used as the vehicle for presenting the quantified risk for variables in this study. Risk for variables are represented by normal (bell-shaped curves), triangular, and discrete probability distributions.

These distributions use a set of arguments to specify a range of actual values and distribution probabilities.

The normal distribution uses a mean and standard deviation as its arguments. The mean defines the value around which the bell-shaped curve will be centered, and the standard deviation defines the range around the mean. A triangular distribution uses minimum, most likely, and maximum values as its arguments. The direction of the "skew" is determined by the size of the most likely value relative to the minimum and maximum values. By standard convention, the probability of occurrence for the minimum and maximum value is zero. A discrete random distribution specifies that the possible outcomes are limited to certain "discrete" values, each with some assigned probability of occurring.

Figure 1 shows an example of a risk profile for sawtimber price represented by a triangular distribution with a minimum, most likely, and maximum price of $10, $20, and $30, respectively. Probability of occurrence (given in percentage) is shown on the vertical axis and sawtimber price (given in dollars) is shown on the horizontal axis. The horizontal axis shows that the probability of a price of $15 per MBF at harvest is 5%, while the chance of the price being $20 is 10%. The probability of a price of $10 or $30 is equal to zero, with very low probabilities of being slightly higher or lower than these values, respectively.

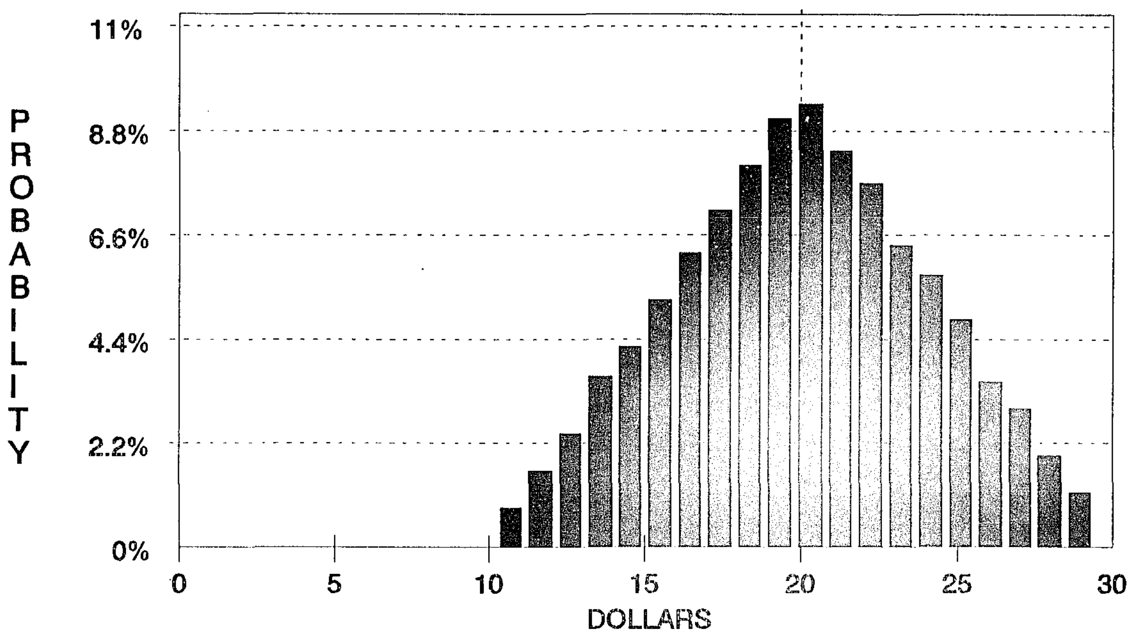

Figure 1. Sawtimber Price Showing a Triangular Probability Distribution.

Timber Volume

The probability distribution for volume is based on data obtained from the survey questionnaire. A discrete random probability distribution is used to determine the probability of attack by a given risk agent. It is used because only a finite number of discrete values are possible between the minimum and maximum values (i.e., attack or no attack). Developing risk profiles for yield required (1) obtaining initial or starting point yield data for aspen and red pine, and (2) using results from the questionnaire to show the impacts of biophysical risks on yield.

Yields projected for aspen and red pine by the Forest Management Division in their analyses are the yields used for this study (see Appendix A, Tables A1 and A2). Officials at the FMD reported that the projected yields for red pine are based on actual yield data from red pine sites (Murray, 1986). Projected yields for improved aspen are based on the expected yield for improved aspen. Starting point volumes for aspen and red pine play a decisive role in the this risk analysis, since reductions for biophysical risks are subtracted from starting point yields.

The projected yields for red pine may not be completely risk-free, but would be very low risk. The yields used by the FMD in their analyses were average yields for red pine on state forests for their "best" sites only. Consideration was given to using TWIGS[4] to project risk-free yields for this study. But, when mortality equations were removed from the TWIGS model, yield results were determined to be unrealistic by experts familiar with red pine yields. Therefore, it was decided to use the FMD projected yields. It is recognized that by using projected "best" yields, some accumulated losses for pests may be included and there is the potential for double counting. It was believed however,

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[4]TWIGS (The Woodsman's Ideal Growth Projection System) is micro-computer program that offers a flexible, generalized approach to simulating the growth and mortality and management of trees in forest stands. TWIGS was developed by David Belcher, Kevin Low, Tim Krohn, and Michael Steinbach at the North Central Forest Experiment Station, USDA Forest Service, St. Paul, Minnesota.

that yield projections based on actual yield data from FMD sites are the best data available to use for this study.

The projected yields for improved aspen are consistent with expected growth rates based on replicated trials and field plantings (Hansen, 1990). A study by the University of Minnesota Institute of Paper Science and Technology Aspen/Larch Genetics Cooperative, shows expected average growth rates for improved aspen were 2.0 to 3.0 cords/acre/year. For a rotation age of 20 years, the study reported expected average growth rates of 2.0 to 2.5 cords/acre/year (40 to 50 cords for a 20 year rotation). These estimates are comparable to FMD estimates ranging from 32 to 46 cords/acre (Murray, 1986).

Analysis of Questionnaire Data

Data from the questionnaires are used to determine reductions in aspen and red pine yield due to biophysical risks. Since risk occurrence and impacts are probability-based, they are used to create risk profiles. Several calculations are required to incorporate the results of the questionnaire, thereby determining the reduction in yield caused by the occurrence of a risk.

Data from questionnaires were used to calculate (1) mean or average probability of attack (MPOA), (2) mean percentage reduction in yield (MPRY) and, (3) mean percentage reduction in grade (MPRG). Responses were recorded in integer format.

The MPOA, MPRY and MPRG are calculated by recording values from the questionnaire for each response, obtaining a sum and dividing the sum by the number of responses using the formula:

$$MPOA,\ MPRY,\ or\ MPRG = \frac{\sum_{i=1}^{n} y_i}{n}$$

Where:

MPOA	=	mean probability of attack
MPRY	=	mean percentage reduction in yield
MPRG	=	mean percentage reduction in grade
y_i	=	individual responses (i = 1, 2, ..., 12), and
n	=	total number of responses for individual questions.

Results of the survey questionnaire are given in Chapter IV, Tables 2 through 19. These tables were developed using the formulas given above, that is, by calculating (1) the mean probability of attack by a risk, (2) the mean percentage reduction in yield, and (3) the mean percentage reduction in grade. The MPOA, MPRY and MPRG are used to determine the impact of biophysical risks on aspen and red pine yields.

Secondary Risks

Tables 7 and 19 in Chapter IV show the probability of attack associated with secondary risks. A secondary risk is defined as a risk that occurs as a result of the presence of other risks; that is, it is based on conditional probabilities. Only a limited number of risks include secondary impacts. In those instances, the MPOA was replaced by the total probability of attack including primary and secondary risks (TPSR). For a given risk, the TPSR (in decimal format) is calculated using the formula:

$$TPSR_a = MPOA_a + (PPR_1 * PSR_a) + (PPR_2 * PSR_a) + (PPR_3 * PSR_a) + \ldots (PPR_n * PSR_a)$$

Where:

$TPSR_a$ = total probability of attack for primary and secondary risks for primary risk <u>a</u> (percentage),

$MPOA_a$ = mean probability of attack by risk <u>a</u> (percentage),

PPR^i = probability of other risks (<u>i</u>) occurring as primary risk (percentage), and

PSR^a = probability of risk <u>a</u> occurring as a secondary risk (percentage) associated with PPR_i.

For example, the TPRS for hypoxylon is 40% and is calculated as follows:

TPSR(hypoxylon) = MPOA(hypoxylon 10%) +

PPR(Gypsy Moth 10%) * PSR(hypox 10%) +
PPR(Forest Tent 20%) * PSR(hypox 20%) +
PPR(Poplar Bore 30%) * PSR(hypox 30%) +
PPR(Drought 40%) * PSR(hypox 40%)

Volume Reduction for Risks. To determine the final reductions in yield caused by the occurrence of risks (primary and secondary), formulas were developed that calculated the adjusted yield (AY) using the MPRY and MPRG. The adjusted yield is simply the starting point yield minus reductions caused by risks (summed over all risks). The AY is calculated using the formula:

$$AY = SPY - (RIY +/- RIG)$$

Where:

AY = adjusted yield (cords or board feet)

SPY = starting point yield (cords or board feet)

RIY = reduction in yield caused by risk (cords or board feet), and

RIG = reduction in grade caused by risk (cords or board feet).

RIY and RIG are calculated using the formula:

$$RIY = SPY * MPRY$$

$$RIG = SPY * MPRG$$

The formula for adjusted yield (AY) is used to subtract from the starting point yield (e.g., yield/volume at age 20) all reductions caused by the occurrence of risks. Volume loss due to reduction in grade is added to the next lower grade, e.g., reduction in grade from sawtimber to pulp is added pulp.

The probability of attack by a risk is based on the mean probability of attack (MPOA). Each risk included in the analysis has a unique average probability of occurrence (see Table 2 and Table 8 in Chapter IV). For example, if the average probability of occurrence for Risk 1 is 100% and Risk 2 is 50%, during a simulation run Risk 1 will occur twice as often as Risk 2. However, both Risk 1 and Risk 2 will occur simultaneously 50% of the time.

Discrete Probability

A discrete random probability distribution is used to incorporate the probability of occurrence for yield reductions into the analysis. It is used because only a finite number of discrete values is possible between the minimum and maximum values. The discrete random probability allows each risk to occur at random based on the MPOA. Therefore, for a given iteration, zero, one, two, three or all risks may randomly occur. The number of risks that occur is a function of the MPOA for each individual risk. Also, for a given iteration, the adjusted yield (AY) is calculated from reductions in yield and grade resulting from the occurrence of risks.

A test was conducted to examine the use of the actual distribution of individual responses from the questionnaire rather than the mean of the responses (MPOA, MPRY and MPRG). The conclusion from the test was there is little variation between the two. Therefore, mean responses are used to develop probability distributions. Weighted means (with individual responses) were also examined, but the simple means yielded similar results with simpler model formulation.

Timber Prices

In calculations, a starting point price is selected along with a real increase for each model iteration. Average stumpage price data from FMD timber sales in the Upper and Lower Peninsulas of Michigan are used to project the rate of real price increases for aspen pulpwood, red pine pulpwood, red pine sawtimber, and red pine poles. These data covered the period 1954-1989 for aspen pulp, 1972-1989 for red pine pulp, 1965-1989 for red pine sawtimber, and 1984-1989 for red pine poles. These data are used to determine the annual real rate of price increase and to determine variability in the deterministic starting point prices.

The annual real rate of price increase is determined by (1) converting nominal prices to constant 1982 dollars (real prices) using the annual Producer Price Index for all commodities, (2) taking the natural log of the real prices, and (3) running a regression analysis on the logarithmic data to determine the rate of real price increase (presented as percentage/year in Appendix A, Table A4). The calculated rates of real price increase are assumed to be normally distributed and are used as the bases for price trend variability. Thus, the probability distributions for annual price increases are modelled as normally distributed with means and standard deviations. The normal distribution is used because of the unavailability of data for more sophisticated probability distributions which can be used if data are available.

The annual rate of real price increase is calculated using the formula:

$$Ln(P) = a + R * t$$

Where:

a	=	constant
R	=	slope of the regression line (rate of price increase), and
t	=	years (e.g., 1954-1989).

For each year in which data are available, a low, moderate and high price is reported. These data provide a triangular distribution of likely prices. Triangular probability distributions are used in this study because, as noted by Lothner et al. (1986), they are simple to use and are flexible enough for the precision represented in the available data. Variability in future prices is based on the annual rate of price increase and the starting point prices. Variability in starting point prices was determined by normalizing MDNR stumpage data to calculate mean low and mean high price for end points in a triangular distribution. Prices used in FMD's deterministic analyses were used as the most likely starting point prices in triangular distributions.

To calculate the end points, the following process was used. First, the moderate MDNR price paid for stumpage was converted to the most likely starting point prices (e.g., $10/cord) to obtain a normalizing factor for each year. Second, the low and high MDNR price are multiplied by the normalizing factor to determine the normalized low and high price. Third, the mean low and mean high price is calculated for each time series data set. The calculated means are used as end points in triangular distribution (see Table A5 in Appendix A). The procedure given above incorporates starting point price variability into the analysis.

<u>Costs</u>

Due to a lack of historical data, probability distributions for site preparation costs, management costs, thinning/harvesting costs, and treatment costs were not developed. However, a probability distribution for red pine planting costs were developed using FMD historical data.

A triangular distribution for red pine planting costs was developed using MDNR planting cost data from several sites throughout the state. The data covered the period 1982-1990. Nominal planting costs were converted to constant 1982 dollars (real prices) by using the annual Producer Price Index for all commodities. The mean and standard deviation for all planting costs were calculated.

From a percentage standpoint, one standard deviation from this data was subtracted from and added to the starting point planting cost (from FMD deterministic analyses), creating a triangular distribution (see Appendix A, Table A6). Thus, the probability distribution used for red pine planting cost is triangular.

Costs are one standard deviation because sites will be selected to avoid high planting costs situations. On the low cost side, this assumption may be conservative in that the MDNR may try to identify more lower cost sites. Higher cost sites will be avoided, therefore the use of a narrow range of costs.

A triangular probability distribution uses minimum, most likely, and maximum values as its arguments. Triangular distribution is used in this study because the end points (minimum and maximum) are known, but the mathematical distribution of values included in the range is not known.

Though historical data were not available for improved aspen planting costs, a probability distribution was derived using the historical data for red pine planting costs. Cost variability in establishing an aspen stand is reasonably represented by the percentage variability of red pine establishment costs (pers. comm., Ronald Murray, MDNR, 1987).

A triangular probability distribution for aspen planting costs is determined by first dividing the expected low planting cost by the starting point planting cost for red pine. A similar division is made for high planting costs. The percentages obtained for these calculation are multiplied by the starting point planting cost for aspen. The result is a triangular probability distribution for aspen planting costs with identical percentage variability.

Calculating Rates of Return

Computer Software (Spreadsheet)

A spreadsheet template was developed that replicated the deterministic analyses that were performed previously by FMD. Appendix G shows an example of spreadsheet tables used in this study. Templates for aspen and red pine were used: (1) to insure that investments were analyzed exactly as done by the MDNR in their investment portfolio and (2) to provide a framework for linkages with Monte Carlo simulation software.

The templates were developed by listing the various activities for each management alternative. These activities included site preparation, planting, management and harvesting. Per unit costs or prices (e.g., $/acre or $/MBF) associated with each activity and the year(s) of occurrence were listed. These per unit costs or prices are multiplied by the various management activities (e.g., per acre or per unit volumes) to determine total revenues and costs. Undiscounted costs and revenues are used to determine the internal rate of return (IRR) on the investment. The standard formula for calculating IRR is discussed in another section of this chapter; it is the principal investment criterion of interest in this study.

The Monte Carlo simulation technique was used to calculate expected rates of return on investments, given probability distributions associated with different risk variables. Using a random number generator, Monte Carlo simulation randomly selects one value from the probability distribution for each risk variable and combines the selected values to calculate a rate of return on the investment.

For this study, 1,000 rates of return (iterations) were calculated for each investment alternative using 1 as the random seed number. The random seed number controls the sequence of random numbers returned by the random number generator. These pseudorandom numbers are real values between 0 and 1. A pseudorandom number is a number taken from a set of numbers which are not truly random, for example, because they are self-repeating or degenerate (O'Muircheartaigh and Francis, 1981). However, many computer-based random-number generators have been developed which produced numbers that appear to have desired distributions and are not statistically correlated (Law and

Kelton, 1982) Results of a specific analysis may be reproduced at any time by using the same seed number and software.

Rates of return on the investment are calculated using a risk analysis and simulation add-in for Lotus 1-2-3[3] called @Risk[4]. This computer program internally:

1. lists the range of results,
2. selects the percentage of total situations falling within given ranges of rates of return, and
3. derives a risk profile for the proposed investment.

A risk profile is represented as a probability distribution curve with a range of outcomes measured along the horizontal axis, and the probability of occurrence for each value measured along the vertical axis. Figure 2 shows an inverted cumulative probability distribution curve with a probability of achieving a range of rates of returns on an investment. The range of returns in Figure 2 is zero to 8.0%. This can be interpreted to show that there is approximately a 100% probability of earning a positive rate of return. Reading along the horizontal axis, it is shown that there is 0% chance of earning a return greater than 8.0%. The dashed vertical line indicates a 50% probability

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[3]Lotus 1-2-3 is a registered trademark of Lotus Development Corporation.

[4]@Risk is a registered trademark of Palisade Corporation.

of earning 4.0% or more; this is the expected value of the IRR. This curve can be transformed to show a probability of occurrence for each rate of return. It is also possible that an analysis may show a range including negative returns; this indicates that the rate at which costs grow toward the returns created is negative. The possibility of negative returns can occur even if the mean return is positive.

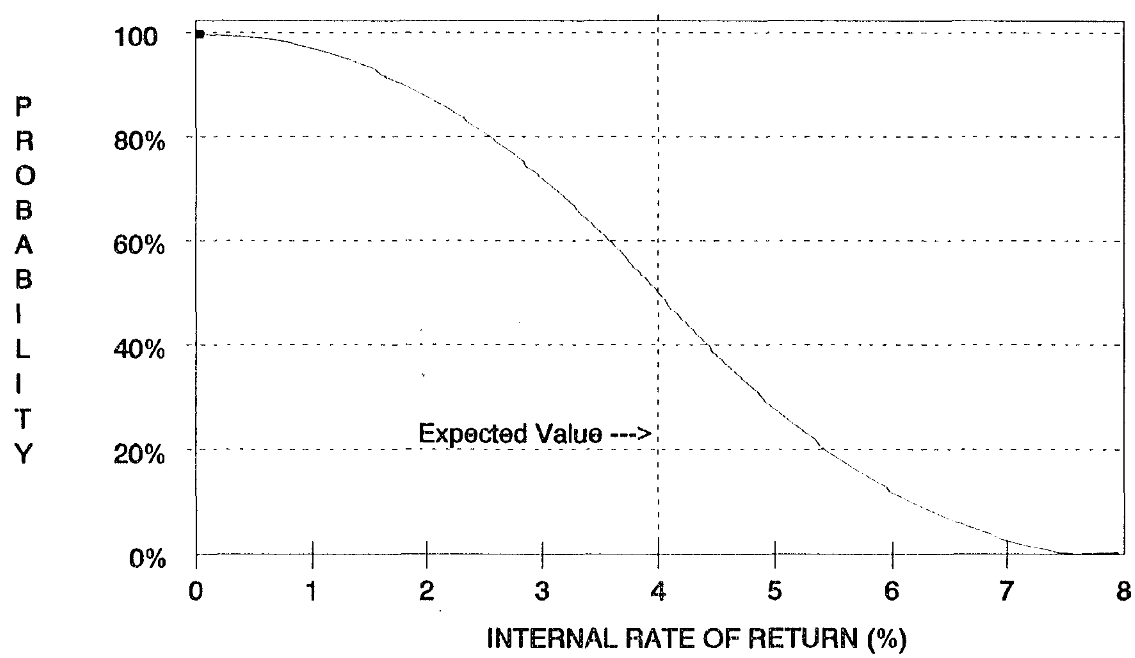

Figure 2. Inverted Cumulative Probability Distribution Curve.

A cumulative probability distribution curve can be used to compare deterministic results with stochastic results. A deterministic analysis, for example, may show an expected rate of 6.0% with 100% probability of occurrence. A stochastic analysis (risk included in analysis) may show an expected rate of at least 4.0% that is expected to occur with 20% probability. It can also be shown from Figure 2 that the deterministic rate of 6.0% or more is expected to occur approximately 10.0% of the time. Risk profiles are also used to compare different investment alternatives.

Internal Rate of Return

The financial criterion for this analysis is the internal rate of return (IRR). The internal rate of return is defined as the compound rate of interest that equates the present value of expected future returns with the present value of expected future costs. It is the interest rate at which net present value (NPV) is zero (Pappas and Hirschey, 1985). IRR is represented by the equation:

$$PNV = \sum_{t=o}^{n} \frac{FV_t}{(1 + i)^t} = 0$$

Where:

PNV	=	present net value
FV_t	=	future net revenue occurring in year t
i	=	rate of interest, and
t	=	years to discount.

The equation is solved for the interest rate, i, which causes the present net value to equal zero. Using Hertz's four-step process, the internal rate of return is calculated repeatedly, then combined to provide a risk profile for results as shown in Figure 2. The calculated measure of profitability gives the rate of return and the probability of obtaining any specified rate of return.

Although the internal rate of return is a commonly used measure of an investment's financial efficiency, many other measures are available. Examples include the composite internal rate of return (CIRR), annual equivalent value, net present value (NPV) and benefit-cost ratio (B/C).

The internal rate of return was chosen for this study because Forest Management Division selected internal rate of return as the financial criterion for their investment analyses. Two problems are associated with using internal rate of return as an investment criteria: (1) multiple internal rates, which happens when net costs and incomes alternate more than once during an investment period, and (2) when the IRR is used as a ranking device for several investment alternatives. It can be shown that such rankings are not consistent with present net value ranking unless the comparisons are among alternate sets of investments with identical present net values of costs and identical investment periods. The average IRR for a given project depends on the project scale, which in turn is a function of the alternate rate of interest (Marty, 1970). It is not likely that these two problems will occur in this study.

The internal rate of return for an investment project can be calculated without knowing the firm's guiding rate. However, to obtain a profit on a capital investment, the return on the capital (internal rate of return) must be greater than the cost of capital or the guiding rate of return (Duerr, 1985).

Flow Chart for Calculating IRR

Figure 3 presents a flow chart of how the IRR is calculated for each investment alternative. The initial required settings include selecting the random seed number and the number of iterations.

During each iteration the computer software internally will (1) generate a random number and then (2) select the occurrence of primary and secondary risks based on the mean (discrete) probabilities of attack, (3) reduce starting point yield and quality for risks that occur, (4) select a starting point timber price based on the triangular probability distribution, (5) select a real price increase based on a normal distribution, (6) select a planting cost based on the triangular probability distribution for planting, (7) include other costs, and (8) calculate the IRR. This sequence of events is repeated 1,000 times.

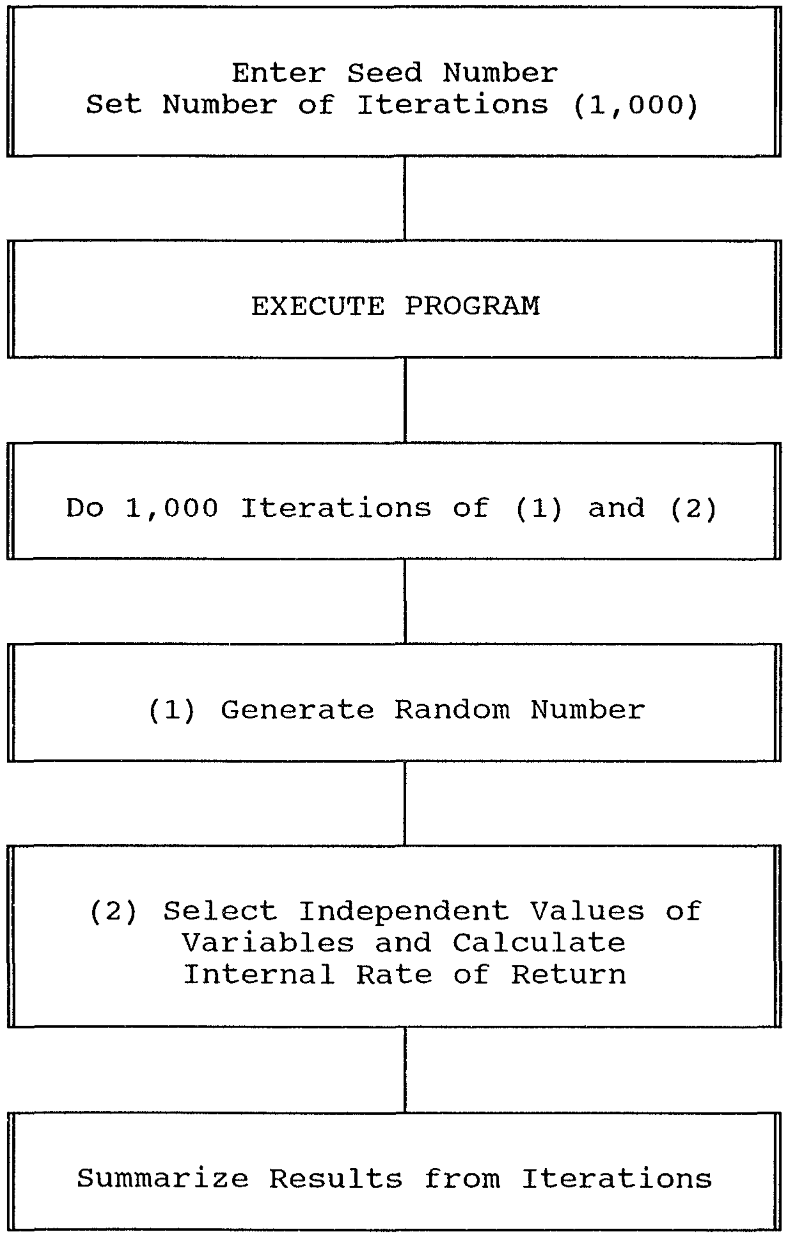

Figure 3. Flow Chart for Calculating IRR

CHAPTER IV

INVESTMENT RISKS

Many biophysical risks (including insects, diseases, animals and other natural factors) affect the growth and yield of aspen and red pine trees. Although the potential for damage to stands exists, biophysical risks historically have not caused significant damage to stands in Michigan.

This chapter includes a brief discussion of several biophysical risks that may cause damage to aspen and red pine stands in Michigan. The discussion of the various risks is based on a literature review and comments from MDNR experts concerning potential damages risks may cause. Included in the discussion is a brief description of damage caused by the various risks, treatments to reduce losses, and results of the survey questionnaire on the probability of attack and the impact of biophysical risks on growth and yield of aspen and red pine. Appendix Table A12 shows the approximate stage when the various risks may occur in both aspen and red pine stands. Also, some comments from MDNR Forest Management Division experts are included.

Results of the survey questionnaire are based on responses from eleven (11) forest management experts. One completed questionnaire is not included in the analysis because some responses given are internally inconsistent. Results of the survey questionnaire for probability of attack by a risk is given using the mean probability of attack (MPOA). Percentages for reduction in volume and grade are given as the adjusted mean reduction in volume or grade (MPOA), with and without treatment.

Several risks described in this chapter are not included in the survey questionnaire. However, these risks are noted to provide information on some of the other risks that may impact aspen and red pine stands, but, in the past have not caused any significant damage to stands in Michigan. Many of the non-important primary pests are weakening factors influencing attack by secondary pests. The chapter is divided into several sections. The first four sections deal with disease and insect risks. The next three sections deal with weather, fire and animal risks. And finally, the last section deals with financial risks.

Disease Risks for Aspen

Bronze Leaf Diseases (Viruses, Mycoplasmas, Rickettsia, Spiroplasmas

These systemic pathogens cause degenerative diseases that can result in diebacks, declines, and reductions in growth and yield potential. Once infected, trees remain infected through their life cycle. Systemic pathogens should not be a serious problem in trees grown on short rotations except when the stumps and roots systems decline in vigor, reducing coppice reproduction (Berbee et al., 1976)

Results of the survey questionnaire show 92.5% of aspen stands on high risk sites, 57.5% of stands on moderate risk sites, and 27.0% of stands on low risk sites are subject to attack by bronze leaf diseases. The survey also indicates that if stands are attacked, reduction in volume (without treatment) is 97.5% on high risk sites, 47.5% on moderate risk sites, and 10.8% on low risk sites. When stands are treated, volume loss is zero (Tables 2, 3 and 4).

Reduction in grade from pulpwood to cull (without treatment) is 5.0% for a high risk site, 2.6% for a moderate risk site and 1.4% for a low risk site. Reduction in grade is zero when stands are treated (Tables 5 and 6).

Hypoxylon Canker *(Hypoxylon mammatum)*

Trees with trunk cankers may die within 3-8 years as the result of girdling, trunk breakage due to wood decay, or borer activity at cankers. Branches girdled during dormancy do not produce leaves in spring. Wood (several years old) beneath a canker is always invaded by boring insects and fungi (Sinclair et al., 1987).

The survey of MDNR forest management experts show 52.1% of stands on high risk sites, 31.7% of stands on moderate risk sites, and 21.6% on low risk sites are subject to attack by hypoxylon. Reduction in volume (without treatment) is 37.1% for high risk sites, 15.8% for moderate risk sites and 9.3% for low risk sites. Reduction in volume with treatment is zero (see Tables 2, 3 and 4).

Reduction in grade without treatment is 26.4% for a high risk site, 9.2% for a moderate risk site and 5.0% for a low risk site (see Tables 5 and 6). The recommended treatment by MDNR experts is harvesting injured trees.

Shoot Blight *(Venturia populina)*

During wet seasons, shoot blight may kill many terminal shoots that are regenerating by sprouts after mature trees have been harvested. This damage reduces total height growth and deforms trees by causing a bend in the stem. Trees less than 3 meters tall are at greater risk, but, damage becomes negligible as trees attain heights greater than 3 meters (Sinclair et al., 1987).

Results of the survey questionnaire show 9.8% of stands on high risk sites are subject to attack. Shoot blight is not expected to occur on moderate and low risk sites; therefore, moderate and low risk sites are not a part of the survey questionnaire. Reduction in volume (without treatment) is 5.7% for high risk sites (see Tables 2 and 3). Reduction in volume (with treatment) is 0.0%. The reduction in grade with and without treatment is zero.

Table 2. Mean Percentage of Aspen Stands Attacked By Biophysical Risks

Biophysical Risk	High Risk Site		Moderate Risk Site		Low Risk Site	
	%	Sd[a]	%	Sd	%	Sd
Bronze Leaf	92.5	2.5	57.5	37.5	27.0	23.0
Hypoxylon	52.1	35.6	31.7	34.2	21.6	33.9
Shoot Blight	9.8	6.3	--[b]	--	--[b]	--
Gypsy Moth	100.0	0.0	88.6	13.3	54.0	35.7
Forest Tent	71.3	30.9	--[b]	--	--[b]	--
Poplar Borer	35.0	5.0	--[b]	--	--[b]	--
Drought	21.7	10.3	21.7	10.3	21.7	10.3
Frost	10.7	8.2	10.7	8.2	10.7	8.2
Deer, Elk	100.0[c]	--[d]	100.0	--[d]	100.0	--[d]
Rabbit	100.0[c]	--[d]	100.0	--[d]	100.0	--[d]

[a] Sd = standard deviation.
[b] -- = data not collected for this site.
[c] Determined that all stands are subject to attack.
[d] Calculated percentage, thus no standard deviation.

Table 3. Mean Percentage of Total Reduction in Volume for Aspen (Without Treatment)

Biophysical Risk	High Risk Site		Moderate Risk Site		Low Risk Site	
	%	Sd[a]	%	Sd	%	Sd
Bronze Leaf	97.5	2.5	47.5	47.5	10.8	40.0
Hypoxylon	37.1	28.0	15.8	11.3	9.3	12.9
Shoot Blight	5.7	6.6	--[b]	--	--[b]	--
Gypsy Moth	30.0	18.7	16.3	8.2	6.3	4.1
Forest Tent	8.3	6.0	--[b]	--	--[b]	--
Poplar Borer	0.0	0.0	--[b]	--	--[b]	--
Drought	33.3	31.8	33.3	31.8	33.3	31.8
Frost	23.0	27.0	1.8	27.0	1.8	27.0
Deer, Elk	16.0[c]	--[d]	16.0	--[d]	16.0	--[d]
Rabbit	5.8[c]	--[d]	5.8	--[d]	5.8	--[d]

[a] Sd = standard deviation.
[b] -- = data not collected for this site.
[c] Weighted average.
[d] Calculated percentage, thus no standard deviation.

Table 4. Mean Percentage of Total Reduction in Volume for Aspen (With Treatment)

Biophysical Risk	High Risk Site[a]	
	%	Sd
Bronze Leaf	0.0	0.0
Hypoxylon	0.0	0 0
Shoot Blight	0.0	0.0
Gypsy Moth	8.8	7.4
Forest Tent	1.3	2.0
Poplar Borer	0.0	0.0

[a] Data collected for high risk site only.

Table 5. Mean Percentage of Total Reduction in Grade, Pulp to Cull for Aspen (Without Treatment)

Biophysical Risk	High Risk Site		Moderate Risk Site		Low Risk Site	
	%	Sd[a]	%	Sd	%	Sd
Bronze Leaf	5.0	5.0	5.0	5.0	5.0	5.0
Hypoxylon	26.4	31.5	9.2	7.9	5.0	7.1
Shoot Blight	0.0	0.0	--[b]	--	--[b]	--
Gypsy Moth	3.8	6.5	2.5	4.3	0.0	0.0
Forest Tent	3.6	6.9	--[b]	--	--[b]	--
Poplar Borer	0.0	0.0	--[b]	--	--[b]	--

[a] Sd = standard deviation.

[b] -- = data not collected for this site.

Table 6. Mean Percentage of Total Reduction in Grade, Pulp to Cull for Aspen (With Treatment)

Biophysical Risk	**High Risk Site**[a]	
	%	**Sd**
Bronze Leaf	0.0	0.0
Hypoxylon	0.0	0 0
Shoot Blight	0.0	0.0
Gypsy Moth	3.8	2.0
Forest Tent	1.3	0.3
Poplar Borer	0.0	0.0

[a] Data collected for high risk site only.

Ink spot leaf blight *(Ciborinia whetzelii)*

Ink spot leaf blight kills leaves in late spring. It is sporadic in young stands, killing 25-100% of the foliage in localized outbreaks but not causing long-term or consistent suppression of tree growth. Repeated defoliation may kill saplings in dense thickets, but this mortality is a natural thinning required for normal development of the survivors (Sinclair et al., 1987). FMD panel members concluded that ink spot leaf blight will not cause damage to aspen stands in Michigan. Leaf blight is not included in the survey questionnaire.

Cryptosphaeria canker *(Cryptosphaeria populina)*

Cankers on branches may girdle the branch and spread into the trunk. These cankers may kill trees up to 15 centimeters in diameter within 3 years because a large volume of the sapwood is killed (Sinclair et al., 1987). FMD experts on the panel do not think this disease will cause damage to stands in Michigan. Therefore, this disease is not included in the survey questionnaire.

Ceratocystis canker *(Ceratocystis fimbriata)*

These cankers originate at trunk wounds and at junctions of the trunk with small branches. Individual cankers rarely girdle trees, but multiple coalescing cankers may do so, or disease trees may break because of cankers (Sinclair et al., 1987). Ceratocystis canker is not expected to attack stands in Michigan; therefore, it is not included in the survey questionnaire.

Insect Risks for Aspen

Gypsy moth *(Lymantria dispar (Linnaeus))*

Larvae of the gypsy moth cause damage to trees, especially during the last 2 weeks of feeding. Trees in the infested area are completely stripped of their foliage during severe outbreaks. Despite their ability to produce new foliage during the season, trees suffer a reduction in growth, but may survive 2 or 3 years of total defoliation (Johnson and Lyon, 1976).

The results of the survey questionnaire show gypsy moths are expected to attack 100% of stands on high risk sites, 88.6% of stands on moderate risk sites, and 54.0% of stands on low risk sites. Reduction in volume without treatment on high risk sites is 30.0%, 16.3% on moderate risk sites, and 6.3% on low risk sites. If stands are treated, reduction in volume on a high risk site is 8.8% (see Tables 2, 3 and 4). Reduction in grade without treatment is 3.8% on a high risk site, 2.5% on a moderate risk site and 0.0% on a low risk site. Reduction in grade with treatment is 3.8% on a high risk site (Tables 5 and 6).

When populations are very large, spraying the foliage during the feeding period with a chemical stomach insecticide destroys gypsy moth larvae (Johnson and Lyon, 1976). After young larvae are hatched in the spring, experts recommend applying Bacillus thuringiensis (Berl.) or Dimilin (Diflubenzvion).

Forest tent caterpillar *(Malacosoma disstria Hbn.)*

During a severe outbreak, trees may be completely defoliated. Severely defoliated trees usually are not in danger of dying because typical forest tent invasions in a given location do not last more than 3 years. Severe defoliation weakens the vitality of infested trees, causing a decrease in annual incremental growth (Sinclair et al., 1987).

Results of the survey show the forest tent caterpillar attacks 71.3% of stands on high risk sites, causing 11.7%

reduction in volume (without treatment). Reduction in volume when the stand is treated is 1.3% (see Tables 2, 3 and 4). Reduction in grade is 3.6% without treatment and 1.3% with treatment (see Tables 5 and 6). Moderate and low risk sites are not included in the survey questionnaire.

Treatment requires spraying the foliage of infested trees with an effective chemical stomach insecticide or a biological insecticide such as Dimilin or Bt (Sinclair et al., 1987). According to FMD forest management experts, control of the forest tent caterpillar over large areas is usually not cost effective.

Poplar borers *(Saperda populnea moesta [Lec.]),(S. concolor [Lec.]), ([S. calcarata Say])*

Damage to trees includes holes dug into the bark by females when laying their eggs and swelling of twigs around the larval tunnels. Occasionally, damage may occur by breakage of branches at the point of attack when blown about by wind (Burns, 1983).

The survey questionnaire shows 35.0% of stands on high risk sites are subject to attack, causing no reduction in yield or grade (see Tables 2, 3, 5 and 6). Artificial treatments are difficult to apply because the poplar borers are usually hidden inside tunnels.

Large aspen tortrix *(Choristoneura conflictana [Wlk])*

Damage caused by larvae of the large aspen tortrix is negligible. However, larvae feeding on the buds in the spring may have serious consequences, because the buds are often destroyed. Defoliation reduces annual incremental growth and inhibits the growth of twigs, but rarely does it kill the tree. Panel members do not think that this insect will cause significant damage to stands on state forest land.

Treatment of the large aspen tortrix is usually unnecessary because natural factors generally are successful in wiping out populations after 2 or 3 years of infestation (Blanchard and Tatter, 1981). The large aspen tortrix was not included in the survey questionnaire.

Aspen twoleaf tier *(Engargia decolor [Wlk.])*

During severe epidemics, trees may be entirely defoliated. This damage is of little consequence because natural factors usually control the insect populations. Outbreaks are short-lived (Johnson and Lyon, 1976). Panel members do not think this insect will cause damage to stands in Michigan, thus it was not included in the questionnaire.

Secondary Pests for Aspen

Secondary pests are insects and diseases that attack a stand following a primary attack by other insects and diseases or weather-related risks. Few participants were willing to speculate on secondary relationships. Therefore, probability of occurrence for secondary risks is based on only one response (except deer) because respondents did not have answers. Results of the survey questionnaire show a wide range of probabilities of occurrence between some primary biophysical and secondary risks (see Table 7). Hypoxylon is a common secondary pest. For example, respondents believed hypoxylon will attack 98 percent of stands attacked by forest tent caterpillar. Tertiary effects were not solicited and are not calculated.

Table 7. Mean Probability of Occurrence for Secondary Pests on Aspen Sites

Primary Biophysical Risk	Secondary Biophysical Risk	Probability of Occurrence %	Sd
Hypoxylon	Deer, Elk, Rabbit	10.0	0.0[a]
Gypsy Moth	Poplar Borer	30.0	0.0
	Hypoxylon	8.0	0.0
Forest Tent Caterpillar	Poplar Borer	30.0	0.0
	Hypoxylon	98.0	0.0
Poplar Borer	Hypoxylon	30.0	0.0
Drought	Poplar Borer	30.0	0.0
	Hypoxylon	70.0	0.0
Deer, Elk	Shoot Blight	14.5	5.5

[a] A standard deviation of 0.0 indicates only 1 response.

Disease Risks for Red Pine

Armillaria root rot (Shoestring), *(Armillaria mellea)*

Armillaria causes rotting of the root collar and root system, and it is common to most forest soils. It can persist indefinitely in dead roots and then migrate to roots of healthy trees. Affected trees usually exhibit decreased crown growth, dieback, and general decline as initial responses to the disease. Sometimes, an apparently healthy tree may die within a few weeks. Infected trees are also subject to windthrow because of weakened support of the root system (Stevenson, 1964).

Results of the questionnaire show 49.1% of stands on high risk sites, 26.3% on moderate risk sites, and 15.0% on low risk sites are subject to attack by armillaria (Table 8). Reduction in volume (without treatment) is 18.6% on high risk sites, 6.5% on moderate risk sites, and 1.3% on low risk sites (Table 9).

Reduction in grade without treatment, poles to sawtimber is 11.7% on a high risk site, 1.7% on a moderate risk site and 0.0% on a low risk site (Table 10). Reduction in grade from sawtimber to pulpwood is 1.9% on a high risk site, 0.3% on a moderate risk site and 0.0% on a low risk site (Table 11). Reduction in grade from sawtimber to cull and from pulpwood to cull is 0.0% for all site characteristics (see Tables 12 and 13).

According to MDNR forest management experts, armillaria is present in most red pine stands in Michigan but damage caused to stands is usually small. High risk sites are usually where damage occurs.

Diplodia shoot blight *(Diplodia pinea)*

Diplodia kills current year shoots on trees of all ages, and usually kills nursery seedlings within the first year. Repeated infections eventually kill old trees. Trees stressed because of poor sites, drought, snow damage, or insect activity are very susceptible to injury. Wounds caused by hail, shearing, or insects serve as entry points for diplodia (Sinclair et al., 1987).

Results of the survey show 13.8% of stands on high risk sites, 5.5% on moderate risk sites, and 1.3% on low risk sites are subject to attack (Table 8). Reduction in volume (without treatment) for three site characteristics is, 13.3% for high, 2.3% for moderate, and 0.0% for low risk sites (Table 9). Reduction in grade (without treatment) is insignificant for all site characteristics (see Tables 10, 11, 12 and 13).

Diplodia is cyclical and regional in nature. It may occur due to weather conditions, usually during periods of high moisture. MDNR forest management experts reported that diplodia is not a problem in red pine stands on state forests.

Table 8. Mean Percentage of Red Pine Stands Attacked by Biophysical Risks

Biophysical Risk	High Risk Site		Moderate Risk Site		Low Risk Site	
	%	Sd[a]	%	Sd	%	Sd
Armillaria	49.1	32.1	26.3	27.8	15.0	32.2
Diplodia	13.8	15.6	5.5	8.4	1.3	2.2
Bark Beetle	50.0	34.4	28.8	30.4	15.8	32.1
J. Pine Budworm	53.8	40.1	43.1	44.6	28.1	42.0
R. C. Weevil	72.3	27.4	38.1	22.2	7.3	6.2
R. Pine Sawfly	53.8	32.0	22.8	14.6	3.8	3.3
S. Spittlebug	82.5	24.5	44.4	30.8	10.0	16.9
White Grubs	76.4	23.6	43.6	25.5	4.7	3.0
Drought	39.3	37.0	39.3	37.0	39.3	37.0
Flood	0.8	1.6	0.8	1.6	0.8	1.6
Frost	22.8	30.4	22.8	30.4	22.8	30.4
Lightning	3.9	6.6	3.9	6.6	3.9	6.6
Deer	100.0[b]	--[c]	100.0	--[c]	100.0	--[c]
Porcupine	100.0[b]	--[c]	100.0	--[c]	100.0	--[c]

[a] Sd = standard deviation.
[b] Determined that all stands are subject to attack.
[c] Calculated percentage, thus no standard deviation.

Table 9. Mean Percentage of Total Reduction in Volume for Red Pine (Without Treatment)

Biophysical Risk	High Risk Site		Moderate Risk Site		Low Risk Site	
	%	Sd[a]	%	Sd	%	Sd
Armillaria	18.6	13.5	6.5	6.3	1.3	1.7
Diplodia	13.3	6.2	2.3	2.1	0.0	0.0
Bark Beetle	23.4	13.5	8.8	6.5	1.8	2.0
J. P. Budworm	20.1	22.8	12.3	23.9	2.8	6.5
R. C. Weevil	16.3	9.6	7.0	6.5	1.9	3.2
R. P. Sawfly	39.4	21.1	14.5	11.4	1.4	1.6
S. Spittlebug	47.1	27.0	19.3	13.5	2.1	3.6
White Grubs	59.0	27.6	24.0	15.0	3.0	4.0
Drought	19.0	17.8	19.0	17.8	19.0	17.8
Flood	16.7	29.2	16.7	29.2	16.7	29.2
Frost	4.4	7.2	4.4	7.2	4.4	7.2
Lightning	0.6	1.4	0.6	1.4	0.6	1.4
Deer	14.1[b]	--[c]	14.1[b]	--[c]	14.1[b]	--[c]
Porcupine	4.6[b]	--[c]	4.6[b]	--[c]	4.6[b]	--[c]

[a] Sd = standard deviation.
[b] Weighted average.
[c] Calculated percentage, thus no standard deviation.

Table 10. Mean Percentage of Total Reduction in Grade, Poles to Saw, Red Pine (Without Treatment)

Biophysical Risk	High Risk Site		Moderate Risk Site		Low Risk Site	
	%	Sd	%	Sd	%	Sd
Armillaria	11.7	18.6	1.7	3.7	0.0	0.0
Diplodia	0.3	0.5	0.3	0.5	0.0	0.0
Bark Beetle	20.7	29.3	3.6	4.4	0.7	1.7
J. Pine Budworm	18.1	34.1	8.1	17.2	0.3	0.7
R. Collar Weevil	5.0	7.1	2.9	3.6	1.0	1.7
R. Pine Sawfly	37.5	40.2	25.8	37.7	14.2	29.5
S. Spittlebug	52.5	29.5	27.4	18.9	1.3	2.2
White Grubs	40.0	42.4	22.5	22.8	6.3	10.8

Table 11. Mean Percentage Total Reduction in Grade, Saw to Pulp, Red Pine (Without Treatment)

Biophysical Risk	High Risk Site		Moderate Risk Site		Low Risk Site	
	%	Sd	%	Sd	%	Sd
Armillaria	1.9	0.8	0.3	0.7	0.0	0.0
Diplodia	3.3	4.7	1.7	2.4	0.0	0.0
Bark Beetle	3.6	5.8	1.4	2.3	0.0	0.0
J. Pine Budworm	2.4	3.5	1.0	1.8	0.1	0.3
R. Collar Weevil	2.3	3.6	0.9	1.7	0.4	0.9
R. Pine Sawfly	26.7	30.4	7.5	9.0	1.2	1.9
S. Spittlebug	30.0	35.2	13.0	18.9	1.0	2.0
White Grubs	0.0	0.0	0.0	0.0	0.0	0.0

Table 12. Mean Percentage Total Reduction in Grade, Saw to Cull, Red Pine (Without Treatment)

Biophysical Risk	High Risk Site		Moderate Risk Site		Low Risk Site	
	%	Sd	%	Sd	%	Sd
Armillaria	0.0	0.0	0.0	0.0	0.0	0.0
Diplodia	0.0	0.0	0.0	0.0	0.0	0.0
Bark Beetle	4.3	5.6	2.9	3.6	0.7	1.7
J. Pine Budworm	1.0	1.8	0.4	0.7	0.0	0.0
R. Collar Weevil	1.4	2.3	0.5	0.9	0.2	0.4
R. Pine Sawfly	4.7	9.2	1.8	3.7	0.2	0.4
S. Spittlebug	7.0	9.8	2.2	3.9	0.2	0.4
White Grubs	17.5	30.3	15.0	26.0	13.3	18.9

Table 13. Mean Percentage Total Reduction in Grade, Pulp to Cull for Red Pine (Without Treatment)

Biophysical Risk	High Risk Site		Moderate Risk Site		Low Risk Site	
	%	Sd	%	Sd	%	Sd
Armillaria	0.0	0.0	0.0	0.0	0.0	0.0
Diplodia	0.0	0.0	0.0	0.0	0.0	0.0
Bark Beetle	6.4	10.3	3.6	5.2	0.7	1.7
J. Pine Budworm	1.7	2.2	1.0	1.8	0.1	0.3
R. Collar Weevil	4.3	8.6	1.9	3.4	1.0	1.7
R. Pine Sawfly	5.8	9.3	3.8	7.3	0.2	0.4
S. Spittlebug	14.0	19.6	6.6	11.8	0.4	0.8
White Grubs	0.0	0.0	0.0	0.0	0.0	0.0

Annosus root rot *(Heterobasidium annosum (Fr.) Bref.*

Damage to pines includes cambial death. Root rot kills some trees outright while they are young; but, the heartwood in pine trunks usually resists decay. The most common means of initial entry of root rot into a stand is through freshly cut stumps or other wounds that exposes sapwood. Annosus root rot intensifies in a stand after the second and later thinning.

Treatment includes inoculating stumps with spores of a competitive saprophyte to prevent colonization of root rot (Sinclair et al., 1987). The panel of FMD experts does not consider annosus root rot to cause significant damage to stands in Michigan; therefore it is not included in the survey questionnaire. Annosus is common to stands in the Southern Lower Peninsula.

Needle blight *(Mycosphaerella dearnessii [pini])*

Needle blight kills foliage and retards growth. The disease has gained added notoriety in recent decades because of needle browning and defoliation of landscape and Christmas tree planting of ponderosa and scotch pines (Blanchard and Tatter, 1981). The panel of FMD experts does not consider needle blight a major disease in the state forests. Needle blight is not included in the survey questionnaire.

Scleroderris canker *(Gremmeniella abietina (Lagerb.)*

Scleroderris causes economic losses by: (1) killing seedlings and saplings, (2) causing growth loss and deformity of survivors as the result of trunk cankers and dead leaders, and (3) reducing log quality. Damage to red pine occurs often (Blanchard and Tatter, 1981). The FMD panel of experts does not think scleroderris will cause significant damage at this time due to prevention and control efforts in past and currently, by FMD personnel. This includes avoiding the planting of forest prone sites. Scleroderris canker is not included in the survey questionnaire.

Insect Risks for Red Pine

Bark beetles (Pine Engraver), *(Ips pini [Say])*

The bark beetle is a pest that comes to a stand after (1) an attack by other insects and diseases, (2) injury to trees, and (3) harvesting during a drought, or (4) during periods of extended drought. Young trees suffering from drought are occasionally attacked and killed. Most red pine stands are susceptible to an attack.

MDNR forest management experts reported attacks by bark beetles for Michigan's Lower Peninsula. Results of the survey questionnaire show 50.0% of stands on high risk sites, 28.8% on moderate risk sites, and 15.8% on low risk sites are subject to attack by bark beetles (Table 8). The survey also shows that reduction in volume (without treatment) is 23.4% for high risk sites, 8.8% for moderate risk sites, and 1.8% for low risk sites (Table 9).

Reduction in grade (without treatment) from poles to sawtimber is 20.7% on high risk, 3.6% on moderate risk and 0.7% on low risk sites (Table 10). Reduction in grade sawtimber to pulpwood is 3.6% on high risk sites 1.4% on moderate risk sites and 0.0% on low risk sites (Table 11). Reduction in grade from sawtimber to cull is 4.3% on high risk, 2.9% on moderate, and 0.7% on low risk sites (Table 12). Finally, reduction in grade from pulpwood to cull is 6.4% on high risk sites, 3.6% on moderate risk sites, and 0.7% on low risk sites (Table 13). Bark beetle treatments may be silvicultural, chemical or salvage operations.

Jack pine budworm *(Choristoneura pinus [Free])*

Larvae of the jack pine budworm defoliates red pine trees mainly in the upper crown of dominant and codominant trees. Often larvae destroy only the crown's upper half, but in severe infestitations all foliage is destroyed following repeated attacks. Entire trees may die. Lightly defoliated trees recover after a few years; but, heavily defoliated trees are degraded, attacked by other pests, or killed (Johnson and Lyon, 1976).

Budworms can attack both old and immature stands. Damage caused can vary; damage may kill trees in young stands, but in older stands damage reduces growth and wood quality as well as causing mortality in some cases. Volume loss is small if stands are ready for harvest and salvage is possible in a timely manner before bark beetle, stains, and wood rots can operate; if stands are not ready for harvest a significant volume loss may occur.

Results from the survey show 53.8% of stands on high risk sites, 43.1% on moderate risk sites, and 28.1% on low risk sites are subject to attack by budworms (Table 8). The reduction in volume (without treatment) is 20.1% on high risk sites, 12.3% on moderate risk sites, and 2.8% on low risk sites (Table 9).

Reduction in grade (without treatment) from poles to sawtimber is 18.1% on a high risk site, 8.1% on a moderate risk site and 0.3% on a low risk site (Table 10). Reduction in grade from sawtimber to pulpwood is 2.4% on high sites, 1.0% on moderate sites, and 0.1% on low risk sites (Table 11). Reduction from sawtimber and pulpwood to cull is 1.7% or less for all site characteristics (see Tables 12 and 13).

When treatment is used on high risk sites, total volume is reduced by only 2.5% (Table 14). Reduction in grade (with treatment) from poles to sawtimber is 2.1% on high risk sites. Reductions in grade from sawtimber to pulpwood, and from sawtimber and pulpwood to cull is insignificant (see Tables 15, 16, 17 and 18).

MDNR pest experts stated that treatment for budworms is often not recommended. But, when treatment is recommended Bacillus thuringinesis (Dipel, Thuricide) and Carbaryl (Sevin) are the recommended treatments. Budworms have not been a problem in red pine stands in Michigan's Upper Peninsula (MDNR Forest Management Experts).

Table 14. Mean Percentage of Total Reduction in Volume for Red Pine (With Treatment)

Biophysical Risk	**High Risk Site**[a]	
	%	**Sd**
Jack Pine Budworm	2.5	5.0
Root Collar Weevil	2.5	4.0
Red Pine Sawfly	1.3	3.0
Saratoga Spittlebug	3.4	4.0
White Grubs	1.0	1.0

[a] Data collected for high risk site only.

Table 15. Mean Percentage of Total Reduction in Grade, Poles to Saw for Red Pine (With Treatment)

Biophysical Risk	**High Risk Site**[a]	
	%	**Sd**
Jack Pine Budworm	2.1	3.6
Root Collar Weevil	2.0	4.0
Red Pine Sawfly	0.4	0.8
Saratoga Spittlebug	3.8	3.7
White Grubs	0.0	0.0

[a] Data collected for high risk site only.

Table 16. Mean Percentage of Total Reduction in Grade, Saw to Pulp for Red Pine (With Treatment)

Biophysical Risk	High Risk Site[a]	
	%	Sd
Jack Pine Budworm	0.1	0.3
Root Collar Weevil	1.0	0.2
Red Pine Sawfly	0.1	0.2
Saratoga Spittlebug	1.4	1.7
White Grubs	0.0	0.0

[a] Data collected for high risk site only.

Table 17. Mean Percentage of Total Reduction in Grade, Saw to Cull for Red Pine (With Treatment)

Biophysical Risk	High Risk Site[a]	
	%	Sd
Jack Pine Budworm	0.1	0.3
Root Collar Weevil	0.5	1.0
Red Pine Sawfly	0.1	0.2
Saratoga Spittlebug	0.0	0.0
White Grubs	0.0	0.0

[a] Data collected for high risk site only.

Table 18. Mean Percentage of Total Reduction in Grade, Pulp to Cull for Red Pine (With Treatment)

Biophysical Risk	High Risk Site[a]	
	%	Sd
Jack Pine Budworm	0.1	0.3
Root Collar Weevil	0.5	1.0
Red Pine Sawfly	0.1	0.2
Saratoga Spittlebug	0.0	0.0
White Grubs	0.0	0.0

[a] Data collected for high risk site only.

Pine root collar weevil *(Hylobius radicis [Buchanan])*

This insect attacks both young and old pines, especially those growing on poor sites. The root collar weevil feeds on healthy open-grown trees, a habitat found in nurseries and along the edges of pine plantations. Adults and larvae both feed at the root crown on the inner bark. Usually root collar weevils attack around the edge of stands. Stands 0-15 years old are most susceptible to attacks. Weevils usually appear as a secondary pest in older stands.

Results of the survey show 72.3% of stands on high risk sites, 38.1% on moderate risk sites, and 7.3% of stands on low risk sites are subject to attack. Reduction in volume (without treatment) is 16.3% for high risk sites, 7.0% for moderate risk sites, and 1.9% for low risk sites. Reduction in volume (with treatment) on a high risk site is 2.5% (see Tables 8, 9 and 14).

Reduction in grade from poles to sawtimber (without treatment) is 5.0% on a high risk site, 2.9% on a moderate risk site and 1.0% on a low risk site (Table 10). Reduction in grade from sawtimber to pulpwood is 2.3% on a high risk site, 0.9% on a moderate risk site and 0.4% on a low risk site (Table 11). Reduction in grade from sawtimber to cull and pulpwood to cull is less than 4.3% for all site characteristics (Tables 12 and 13). If stands are treated, reduction in grade is 2.0% or less for all site characteristics (see Tables 15, 16, 17 and 18).

MDNR forest management experts do not recommend treatment, except high value trees (e.g., Christmas trees) or if free inmate labor is available. The root collar weevil is not a threat to stands in Michigan's Upper Peninsula (MDNR Forest Management Experts).

Redheaded pine sawfly *(Neodiprion lecontei [Fitch])*

The pine sawfly is a voracious feeder that readily strips small (1-5 meters) trees of their foliage. Many young trees may be killed during an outbreak (Averill et al., 1982). The sawfly kills and deforms young red pine on high-stress areas that generally have site indices for red pine near or below 50. In well-stocked stands of site index 60 or higher, tree mortality and deformity appear insufficient to affect future sawlog harvest, and at most result in a slight reduction of pulp yield (Averill et al., 1982). They outbreak in 10-year cycles. Usually, its greatest impact is in stands less than 15 years old.

Results of the survey questionnaire show 53.8% of stands on high risk sites, 22.8% on moderate risk sites, and 3.8% of stands on low risk sites are subject to attack (Table 8). Reduction in volume (without treatment) is 39.4% for high risk sites, 14.5% for moderate risk sites, and 1.4% for low risk sites (Table 9).

Reduction in grade (without treatment) from poles to sawtimber is 37.5% on a high risk site, 25.8% on a moderate risk site and 14.2% on a low risk site (Table 10). Reduction in grade from sawtimber to pulpwood is 26.7% on a high risk site, 7.5% on a moderate risk site and 1.2% on a low risk site (Table 11). Reduction in grade from sawtimber and pulpwood to cull is 5.8% or less for all site characteristics (see Tables 12 and 13).

When high risk sites are treated, the reduction in volume is 1.3% (Table 14). Reduction in grade (with treatment) is insignificant for all site characteristics (see Tables 15, 16, 17 and 18). Carbaryl (Sevin), Malathion (Cythion) and Insectidal Soap are the recommended treatments for the pine sawfly.

Saratoga spittlebug *(Aphrophora saratogensis [Fitch])*

The Saratoga spittlebug requires an alternate host with a small woody stem to develop. Plants such as sweetfern, blueberry or some other alternate hosts. Heavy feeding on pine for one to two years or light to moderate feeding for several years kills branches, tree tops, and may kill the whole trees. Trees less than 5 meters tall are most susceptible to damage. Pole-sized trees in high risk stands are susceptible to injury because heavy populations kill and stunt trees, thereby maintaining openings for alternate hosts (Wilson, 1987). The spittlebug is a cyclical pest that occurs in 10-year cycles, with outbreaks lasting 2-4 years. An attack by the spittlebug usually affects form in injured trees.

Results of the survey show 82.5% of stands on high risk sites, 44.4% on moderate risk sites, and 10.0% of stands on low risk sites are subject to attack (Table 8). Reduction in volume (without treatment) is 47.1% for high risk sites, 19.3% for moderate risk sites, and 2.1% for low risk sites (Table 9).

Reduction in grade (without treatment) from poles to sawtimber is 52.5% on a high risk site, 27.4% on a moderate risk site and 1.3% on a low risk site (Table 10). Reduction in grade from sawtimber to pulpwood is 30.0% on a high risk site, 13.0% on a moderate risk site and 1.0% on a low risk site (Table 11). Reduction in grade from sawtimber to cull is 7.0, 2.2, and 0.2% respectively, on high, moderate and low risk sites (Table 12). Reduction in grade from pulpwood to cull is 14.0% on a high risk site, 6.6% on a moderate risk site and 0.4% on a low risk site (see Table 13).

Treatment on high risk sites reduces volume by only 3.4% (see Table 14). Reduction in grade (with treatment) is insignificant (see Tables 15, 16, 17 and 18). MDNR pest experts recommend pretreatment to remove alternate hosts (sweetfern). Historically, the spittlebug has not been a problem in the Michigan's Upper Peninsula (MDNR Pest Specialists).

White grubs *(Phyllophaga spp.)*

White grubs feed on the roots of tree seedlings, killing many seedlings, and slowing growth of the rest. Injury usually occurs during the first two growing seasons after planting. Normally white grubs feed on grass roots, but turn to seedling roots when grass roots are scarce. White grubs kill seedlings that are J-rooted because of careless planting. Replanting after pretreatment should occur when loss is severe. Pretreatment is recommended to prevent recurrence.

Results of the survey show 76.4% of stands on high risk sites, 43.6% on moderate risk sites, and 4.7% of stands on low risk sites are subject to attack by white grubs (Table 8). Reduction in volume (without treatment) is 59.0% for high risk sites, 24.0% for moderate risk sites, and 3.0% for low risk sites (Table 9).

Reduction in grade (without treatment) from poles to sawtimber is 40.0% on a high risk site, 22.5% on a moderate risk site and 6.3% on a low risk site (Table 10). Reduction in grade from sawtimber to pulpwood is 0.0% on high, moderate, and low risk sites (Table 11). Reduction in grade from sawtimber to cull is 17.5% on a high risk site, 15.0% on a moderate risk site and 13.3% on a low risk site (Table 12). Reduction in grade from pulpwood to cull is 0.0% on high, moderate, and low risk sites (Table 13).

Reduction in volume is 1.0% on high risk sites when stands are treated; reduction in grade is zero (see Tables 14, 15, 16, 17 and 18). For treatment against white grubs, Pike et al. (1977) recommend diazinon, carbofuran and trichlorforn. Proper site selection is essential to prevent infestation. Grassy sites should be avoided. White grubs are mainly a problem in stands located in the Michigan's Upper Peninsula (MDNR Forest Management experts).

Pine webworm *(Tetralopha robustella [Zeller])*

The webworm is most important to homeowners and Christmas tree growers. It builds web nests on terminal twigs; the loose webbing contains dead needles and brown frass. Usually, the webworm goes unnoticed until an injury has occurred and the nest is vacated.

Several parasites attack the webworm including wasps, tachinid flies and birds (Johnson and Lyon, 1976). The panel of experts do not think this insect will cause significant damage to stands in Michigan. The pine webworm is not included in the survey questionnaire.

European pine shoot moth *(Rhyacionia buoliana)*

European shoot moths cause damage to the tips of terminals and laterals. Larval boring, initially into the base of the needles or buds and then into the shoot itself, kills terminals and laterals.

Several parasites attack pine shoot moths and seem to help keep moth populations in check. Dry weather and poor soil conditions may encourage damage by tip moths (Martineau, 1984). The panel of experts thinks this insect will not cause significant damage to forest stands in Michigan. The European pine shoot moth is not included in the survey questionnaire.

Pine tussock moth *(Dasychira pinicola)*

The pine tussock moth defoliates conifers in Canada and the United States. It readily strips the needles from trees. Generally, this insect has been a problem in Wisconsin and Minnesota, although it is found throughout the Northeastern United States (Martineau, 1984). The panel of FMD experts does not think the pine tussock moth will cause significant damage to stands in Michigan. The pine tussock moth is not included in the survey questionnaire.

Secondary Risks of Red Pine

Results of the survey questionnaire show a range of probabilities between some primary and secondary risks (see Table 19). The highest probability of occurrence between primary and secondary is when armillaria is present as a primary risk. Then, there is 74.8% probability that bark beetles will attack the stand. Armillaria and bark beetle are the most common secondary pests. For example, respondents believed there is some probability that armillaria and bark beetle will attack stands whenever most primary biophysical risks occur. Tertiary effects were not solicited and are not calculated.

Weather Risks

Drought

Young trees are especially sensitive to drought because their root systems are less extensive than those of older trees (USDA-NCFES, 1983). Effects of drought on red pine include wilting, dying needle tips and discolored foliage on top branches, dead tree tops, shortened needles and sparse foliage. Drought also makes trees susceptible to injury by invading pests such as bark beetles, diplodia and armillaria (USDA-NCFES, 1983). Drought is more of a problem when establishing a stand, or for the first 2 years of a newly planted stand. In newly planted stands, drought may cause mortality.

Results of the survey show 100% of aspen stands are subject to drought injury, but only 21.7% are impacted significantly causing 33.3% reduction in volume (see Tables 2 and 3). For red pine, the results show 39.3% of stands are subject to drought, causing 19.0% reduction in volume (see Tables 8 and 9).

FMD experts reported that drought has affected the Baraga area of Michigan's Upper Peninsula 3 out of the last 5 years (1985-90). The experts also reported substantial drought has occurred throughout the 1980's in both Upper and Lower Peninsula of Michigan. Damage by drought has caused failure of planted stands and mortality in natural stands.

<u>Flood</u>

Roots in flooded or waterlogged soils often die of anoxia (oxygen deficiency). Trees with roots injured by waterlogged soil may subsequently suffer drought stress or death when, after the soil drains, the root system is unable to meet transpirational demands at the top. This condition has been noted in plantations of red pine on poorly drained soils. Trees stressed or injured by waterlogging also become susceptible to attack by certain fungal pathogens (Perala, 1977).

Table 19. Mean Probability of Occurrence for Secondary Pests, Red Pine Sites.

Primary Biophysical Risks	Secondary Biophysical Risk	Probability of Occurrence %	Sd
Armillaria	Bark Beetle	74.8	22.1
Diplodia	Bark Beetle	65.0	35.0
Bark Beetle	Armillaria	59.3	10.8
Jack Pine Budworm	Armillaria	39.0	16.9
	Bark Beetle	44.0	28.5
Root Collar Weevil	Armillaria	23.3	4.7
	Bark Beetle	61.8	24.5
Redheaded Pine Sawfly	Armillaria	25.0	4.1
	Bark Beetle	56.7	30.9
Saratoga Spittlebug	Armillaria	36.7	9.4
	Bark Beetle	40.0	10.0
White Grubs	Armillaria	23.3	18.9
	Bark Beetle	30.3	16.7
Drought	Armillaria	56.8	29.0
	Bark Beetle	63.4	19.1
	Jack Pine Budworm	45.0	35.0
	Redheaded Pine Sawfly	50.0	0.0
Flood	Armillaria	50.0	25.0
	Bark Beetle	40.0	17.7
Frost	Armillaria	27.5	22.5
	Bark Beetle	55.0	38.9
	Saratoga Spittlebug	30.0	10.0
Lightning	Armillaria	68.3	29.0
	Bark Beetle	62.8	26.5

Results of the survey showed 0.8% of red pine stands are subject to flooding, causing 16.7% reduction in volume (see Tables 8 and 9). Flood is not included in the survey questionnaire for aspen stands. MDNR forest management experts recommend avoiding areas with the potential for flooding.

Frost

The likelihood of damage by spring frost is related to the date when trees begins growth. Conifers that break bud earliest are most likely to sustain damage, which may involve browning of 1-year old needles or collapse of new growth. Damage by summer frost is less common and more serious than damage by spring frosts. In unusual cases, light frost during shoot elongation may damage stems enough to cause bending or drooping but not death. On most frost-prone sites, injury does not occur every year, and trees that grow above levels where cold air collects continue normal growth (Perala, 1977).

Frost may kill emerging shoots. Susceptible trees may become stunted or bushy if injured several years in a row. FMD experts reported that frost is a major problem in some areas of the state; however, frost pockets are easy to identify and avoid as potential planting sites. Frost can kill new spring growth, but growth resumes quickly and little permanent damage results.

Results of the survey show 23.0% of aspen stands are subject to frost damage, causing 10.7% reduction in volume (see Tables 2 and 3). For red pine, the results show 22.8% of stands subject to frost damage, causing 4.4% reduction in yield (see Tables 8 and 9).

Sunscald

Sunscald is an injury that develops on the south and southwest sides of the trunk or on the upper surfaces of limbs exposed to the sun. The cambial temperature of the sun-warmed sides of limbs of trunks may exceed 20 degrees Centigrade in late winter when the air temperature and the temperature of shaded bark barely exceed 0 degrees Centigrade (Sinclair et al., 1987). This heating causes deacclimation, followed by lethal freezing when the temperature drops at night. Damaged bark and cambium dry out, crack, separate from the wood, and eventually fall away, exposing dead sapwood. Trees with thin smooth bark (e.g., aspen) are most susceptible to this type of injury. The panel of experts did not think sunscald would cause major damage to stands. Sunscald is not included in the survey questionnaire.

Hail and Ice

Hailstones lacerate leaves, defoliate branches, remove twigs, bruise or break twigs and small branches, and kill small trees. Severe hail may kill all the bark on one side of a stem. In extreme cases, the bark is pounded off the windward side of stems. Bruised bark may crack after a hail storm because of drying and mechanical stress from callus growth at edges of the injured area. Bruises or wounds result in dieback of twigs and branches if tissues around the injury dry out. Dieback is more likely if injury occurs during dormancy rather than during the growing season. Similarly, secondary damage by canker fungi is more likely if the injury occurs during dormancy.

Ice is most destructive when a heavy glaze forms on trees during freezing rain. The weight of a glaze more than about 1 centimeter thick breaks twigs, branches, and trunks or uproots trees. Supple young trunks may become permanently bent. Sometimes glaze reaching 2.5 centimeters in thickness occurs and simply destroys trees. Damage increases if the wind rises before the ice melts. Severe breakage leads in turn to severe decay in surviving trees.

Aspen is prone to windthrow or breakage, particularly when weakened by boring insects or disease. Young sucker stands can be seriously damaged and sometimes killed by hail (Perala, 1977). The panel of FMD experts do not think hail and ice will cause significant damage to a significant number of stands in Michigan, therefore hail and ice is not included in the survey questionnaire.

Lightning

Lightning is most important as a cause of forest fires, but it also causes significant damage to forest trees without fire. Trees struck, but not killed, are occasionally disfigured by death of limbs. In addition, wounds and dead areas of tree provide entry for borers and for fungi that decay wood. Trees weakened by lightning strikes are susceptible to attacked by bark beetles. Lightning scars on surviving trees downgrade logs at harvest time. A high proportion of trees struck by lightning eventually die because of the injury or because of attack by opportunistic organisms such as bark beetles (Perala, 1987). Results of the survey show 3.9% of red pine stands are subject to lightning damage, causing 0.6% reduction in overall volume (see Tables 8 and 9). Lightning is not expected to be a significant problem in aspen stands, therefore it is not included in the survey questionnaire.

Wind

Windthrow is most common in thinning where more than 30% of the basal area is removed in a single unit. It is a result of poor logging and silvicultural practices. Red pine has a wide, spreading root system and is very wind firm, but sometimes suffers losses from wind, especially in old even-aged stands on exposed sites, such as along lake shores (Benzie, 1977). The panel of FMD experts do not think wind will cause significant damage to stands in Michigan. Wind is not included in the survey questionnaire.

Fire Risk

Aspen stands are low in flammability and fires are easily controlled. However, surface fires can either kill or injure aspen and cause significant growth loss or early stand breakup (Perala, 1977).

Trees with large fire scars may be at risk from wind breakage and decay organisms. Young red pine stands are susceptible to fire injury; however, in pole-sized and larger timber stands, prescribed fires can reduce the risk of wildfire and control understory development. Mature trees are resistant to fire injury because of their thick bark, but sometimes hot fire causes scars that can weaken trees and increase the risk of wind breakage and even cause of death (Benzie, 1977).

MDNR forest management experts reported that (1) stands are most susceptible to damage when planted in mixture with or near jack pine, and (2) there is always the potential threat of fire arising from recreational activities.

Animals

<u>Deer, Elk or Moose</u>

MDNR forest management experts reported that (1) deer (and elk in some locations) are the most destructive animals to impact aspen stands; damage can range from small to total destruction of the stand, (2) when other favored food is in abundance damage to red pine stands by deer is small because deer do not like red pine, but deer will eat red pine when red pine is all that is available such as during budworm outbreaks, (3) the most effective treatment for deer problems is to reduce the herd; this may be accomplished by a longer hunting season or a severe winter kill, (4) planting in areas where deer populations are high is not recommended, (5) deer populations need to be kept in the carrying capacity of the range and (6) no significant damage is seen in stands where deer populations are controlled. Young succulent nursery plantings are quite susceptible. Deer will graze their rows and nip the tops.

Results of the survey show all (100.0%) aspen and red pine stands are subject to attack by deer (Tables 2 and 8). Reduction in volume is 16.0% for aspen and 14.1% for red pine (see Tables 3 and 9).

Porcupine

Porcupines are a localized problem from time to time, but they do not cause any widespread damage to stands. Results of the survey show 100.0% of red pine stands are subject to attack by porcupine causing 4.6% reduction in volume when stands are not treated. Shooting the porcupine is the only effective treatment.

Rabbit

Rabbits damage seedlings by eating terminal shoots or nibbling young bark. Results of the survey show 100.0% of aspen stands are subject to attack by rabbits causing 5.8% reduction in volume when stands are not treated. Shooting rabbits is the most effective treatment. MDNR forest management experts reported no significant damage to stands.

Red Squirrels

Red squirrels often cut cones and conebearing branch tips. They may completely destroy the current and succeeding year's cone crop but damage is usually less in closed stands than in open-grown stands (Benzie, 1977). Squirrel "caches" are a good source of cones for cone collectors. Since most red pine stands are regenerated by planting rather than from natural seeding, injury from this activity is not serious.

Financial Risks

Timber Prices

The change in stumpage prices over time can greatly alter the expected returns from investments in aspen and red pine. Many factors can cause variability in stumpage prices over time. Demand for timber products could vary if population, economic activity, consumer preference or income change significantly.

The supply of timber could be less than expected and push prices higher than projected. This may occur because of factors such as greater diversion of commercial timberlands to other uses, more constraints on timber management because of environmental considerations, nontimber objectives of forest owners, or extraordinary mortality losses. Also, more intensive management could result in a higher supply level that may result in lower stumpage prices (USDA Forest Service Report, 1982).

Despite many uncertainties, the USDA Forest Service reported that it does seem that the Nation is faced with the prospect of a continuing and substantial increases in relative stumpage prices for most timber products. These increases are likely to be largest for softwood sawtimber, the higher quality hardwood timber of preferred species, and the products (mainly lumber and plywood) made from this timber. This outlook is consistent with the trends that have prevailed during most of the twentieth century. It reflects growing economic scarcity of a basic raw material (USDA Forest Service Report, 1982). Price trend data used in this study are in Appendix A, Tables.

Costs

A significant change in production costs over time can also alter the expected returns from investments in aspen and red pine. Many factors could cause variability in costs which may result in changes in costs different from deterministic projections used in this study. Cost data are presented in Appendix A, Tables.

Treatment Costs

Data on treatment costs from the survey are sketchy. FMD experts reported they had little or no knowledge of actual treatment costs, even in cases where treatment is recommended. Often, however, treatment is not recommended, except for high value trees because the cost of treatment is prohibitive. Because few responses were given, results for cost of treatment for insects or diseases are not part of this analysis.

Data Verification

Individual responses to questions in the questionnaire were reviewed by FMD officials to determine if the responses were reasonable. As a result of this review, data given by one respondent was determined to be unrealistic and is not included in the data analysis. It was determined by FMD officials that sensitivity analyses should be performed to test the sensitivity of some individual data values on IRRs. Specific values changed and results of the sensitivity analyses are presented in Chapter V.

Summary

A questionnaire was used to gather expert judgment on the impacts of various pests because few data were available in literature. Results from he analysis of data from the questionnaire show overall expected levels of attack by insects and diseases are much greater for high risk sites than for moderate and low risk sites (Tables 2 and 8). In many instances, probabilities of attack for low risk sites were minimal. Probabilities of attack for animals and weather related factors are not site specific.

For aspen, there is a relatively high probability of attack for bronze leaf, gypsy moth, forest tent caterpillar, deer and rabbit (Table 2). Gypsy moth is the insect most likely to attack all sites. Standard deviations for high risk sites are relatively small when compared to moderate and low risk sites, that is, the responses are more consistent for high risk sites. The percentage probabilities of attack are based on 1 to 7 responses. These percentages are used in discrete probability distributions so that, for example, 92.5% of samples on high risk sites will have bronze leaf disease.

High probabilities of attack for red pine are root collar weevil, saratoga spittlebug, white grubs, deer and porcupine (Table 8). Generally standard deviations are higher for high risk sites than for moderate and low risk sites. The percentage probabilities of attack are based on

1 to 11 responses. These percentages are also used in discrete probability distributions so that, for example, 82.5% of samples on high risk sites will have the Saratoga spittlebug.

The mean percentage reduction in volume and grade (without treatment) is higher for high risk sites than for moderate and low risk sites (Tables 3 and 9). For aspen (Table 3), the most significant percentage reductions in volume is for bronze leaf on high and moderate sites. Reductions for drought and deer is also significant because these reductions is not site specific. Although there is a high probability attack for gypsy moth (100.0% on high, 88.6% on moderate, and 54.0% on low risk sites), reduction in volume is only 30.0% on high sites and 14.4% on moderate sites; but, on low risk sites reduction in volume is relatively insignificant.

For red pine, the most significant percentage reductions in volume (without treatment) for biophysical risks are redheaded pine sawfly, Saratoga spittlebug, and white grubs (Table 9). Drought, flood, and deer are also notable because they are not site specific, however, the probability of flood is only 0.8%. Standard deviations are relatively smaller on low risk sites.

Treatment for pests (Tables 4, 6, 14, 15, 16, 17, and 18) can be viewed as very successful, but little or no experience related to costs is available. No significant volume or grade loss occurs when stands are treated. Reduction in grade for aspen (without treatment) is insignificant (Table 5), although reduction caused by hypoxylon is 26.4% on high risk sites. The most significant reduction in grade (without treatment) for red pine is from poles to sawtimber (Table 10). The redheaded pine sawfly, Saratoga spittlebug, and white grub on high risk sites show relatively high percentages. Reductions in grade (from sawtimber to pulpwood) for redheaded pine sawfly and Saratoga spittlebug are also noteworthy (Table 11). Generally, reductions in grade (without treatment) caused by biophysical risks were insignificant.

Aspen and red pine stands on high risk sites are the most susceptible to attack and volume loss. The consensus of the forest management experts in the survey was that the potential for damage and volume loss due to pests and weather-related factors can be minimized. Deer are considered to be the most important animal to attack aspen or red pine stands.

CHAPTER V

DETERMINISTIC VS. STOCHASTIC IRRs

The internal rate of return (IRR) is the investment criterion used to measure results of the Forest Management Division (FMD) analyses. Using a deterministic investment model, FMD analyzed three investment alternatives for improved aspen and four for red pine. These investment alternatives are for aspen site indices 60, 70 and 80, and red pine site indices 50, 60, 70 and 80.

IRR is also the investment criterion used in this study to measure results of analyses that incorporate risk. The technique used to calculate IRRs on investments that include risks is discussed in Chapter III, Methods. The calculations are complex and involve input values that change many times during an investment simulation. The results of analyses that include risk have a range of IRRs and a probability of occurrence for each IRR within the range.

This Chapter focuses upon results for (1) deterministic and stochastic analyses, (2) other measurement criteria, such as present net value (PNV) and mean volume, and (3) sensitivity analyses/tests for costs, mean volumes after reductions, and excluding the effects of secondary risks.

Deterministic IRRs

Table 20 presents per acre returns for the FMD deterministic analyses for aspen and red pine. Rates of return are presented for aspen, site indices 60, 70, and 80, with 60-year investment period (three 20-year rotations) and for red pine, site indices 50, 60, 70 and 80 with rotation lengths of 70, 60, 70 and 50 years, respectively. Specific values (volume, prices and costs) used by FMD to calculate deterministic IRRs are shown in Appendix A, Tables A1, A2 and A3.

IRRs for aspen are 6.93% for site index 60, 7.98% for site index 70 and 8.66% for site index 80. The IRRs for aspen actually include three 20 year rotations for each analysis. Red pine IRRs are 4.12% for site index 50, 5.06% for site indices 60 and 70, and 6.57% for site index 80.

One important assumption of a deterministic analysis is the calculated financial criterion will occur with 100% probability. Therefore, it is assumed in these analyses that the deterministic IRRs shown above occurs with certainty. IRRs for aspen are higher than IRRs for red pine because of generally shorter rotation lengths, higher volumes, and higher sites for aspen.

Table 20. Deterministic IRRs for Aspen and Red Pine

Site Index	Rotation Length[a]	IRR (%)
Aspen:		
60	60	6.93
70	60	7.98
80	60	8.66
Red Pine:		
50	70	4.12
60	60	5.06
70	70	5.06
80	50	6.57

[a]Rotation length for aspen is actually three 20 year rotations with clearcut harvest at end of each rotation period. The initial stand of aspen is established by planting, subsequent stands are established by natural regeneration.

Source: Forest Management Division Records

Stochastic IRRs

Stochastic analyses were also performed for aspen (site indices 60, 70 and 80) and red pine (site indices 50, 60, 70 and 80). However, for the stochastic analysis, each site index included analyses for three site characteristics; previously identified as high, moderate, and low risk sites. The data from which probability distributions were developed for volume, timber prices and planting costs are presented in Appendix A, Tables A4, through A11. Probability distributions for these variables were used as the basis for calculating stochastic IRRs. In addition, risks were treated independently for each of the 3 aspen rotations. For example, gypsy moth may affect 0-3 stands for each model iteration. Stochastic analysis uses deterministic starting point volume. Reduction is caused by decrease in deterministic volume.

Aspen

Table 21 shows stochastic IRRs for aspen. Results show negative IRRs for all high risk sites. Moderate and low risk sites show positive IRRs. Negative IRRs on high risk sites are expected because of the high probability of attack for many biophysical risks on high sites and the subsequent generally higher reduction in volume when the risks occur. On many sites, particularly high risk sites, sometimes both young and older stands are completely destroyed and must be replanted. When this occurred, stands were replanted on the second or third 20-year cycle.

There are many very negative and incalculable IRRs, generally on high risk sites when many iterations occurred where stands were completely destroyed. These are reported as errors by the software. Therefore, the IRRs given in Table 21 are based on calculations where errors did not occur. If the software had been able to calculate values for all 1,000 iterations, negative IRRs for high risk sites would still occur and show values that are more negative.

Errors also occurred in the spreadsheet calculations for moderate and low risk sites, however, it is believed that because fewer errors occurred mean IRRs were not significantly affected.

Stochastic IRRs for site index 60 are -10.11 for a high risk site, 2.33% for a moderate risk site, and 5.98% for a low risk site. For site index 70, IRRs are -4.05% for a high site, 3.30% for a moderate site and 6.96% for a low risk site. Site index 80 show -1.00% for a high site, 3.63% for a moderate site, and 7.60% for a low risk site. Low risk sites showed lower standard deviations than high and moderate risk sites.

On low risk sites, deterministic IRRs are approximately one percent higher than the stochastic IRRs for all site indices. The range between deterministic and stochastic IRRs is wider for moderate risk sites. This is expected because the effects of pests are greater for moderate sites than for low risk sites.

Stochastic results for this analysis were expected because of the impact of many biophysical risks on volume. As presented in Chapter IV (Tables 2 and 3), there is a high probability of attack and a high percentage reduction in volume for some biophysical risks (e.g., bronze leaf, forest tent and gypsy moth), particularly for high risk sites. It is also important to note that survey results show 21.8% (Tables 2 and 3) of all aspen stands may be lost to deer and rabbit regardless of site index or site characteristic. Moderate and low risk sites show impacts of biophysical risks are less, therefore, IRRs for moderate and low risk sites are higher than IRRs for high risk sites.

Red Pine

Stochastic analyses for red pine show positive IRRs for all site indices and characteristics, but stochastic IRRs are lower than deterministic IRRs (see Table 22). The IRRs for site index 50 ranged from 3.23% on a high risk site to 3.93% on a low risk site. For site index 60, the range is 3.30% on a high risk site to 4.05% on a low risk site. For site index 70, the range is 1.48% on a high site to 4.23% on a low site, and finally, site index 80 shows 2.84% for high site and 5.43% for low risk site. Standard deviations for low risk sites were much lower than standard deviations for high and moderate risk sites.

The average range of difference between deterministic and stochastic IRRs for all low risk sites is about 0.80%. For moderate sites the range is wider, about 1.25%. These results are expected and fairly consistent with probability data for biophysical risks. High probabilities of attack are associated with several biophysical risks (mainly, root collar weevil, Saratoga spittlebug, and white grubs).

Table 21. Mean Stochastic IRRs for Aspen

Site[a] Index	Site	Deterministic IRR (%)[b]	Stochastic IRR (%)[d]	Sd	Probability of Deterministic IRR (%)
60	HRS	--[c]	-10.11	41.1	0.0
60	MRS	6.93	2.33	11.2	6.0
60	LRS	6.93	5.98	1.8	30.3
70	HRS	--	-4.05	28.2	0.0
70	MRS	7.98	3.30	10.1	7.1
70	LRS	7.98	6.96	2.0	30.5
80	HRS	--	-1.00	19.6	0.0
80	MRS	8.66	3.63	11.9	7.6
80	LRS	8.66	7.60	2.1	30.9

[a]Rotation length is 60 years for all site indices.

[b]It is assumed that the deterministic IRR will occur with 100% probability for all site characteristics.

[c] -- FMD investments will be made only on moderate (MRS) and low risk sites (LRS). High risk (HRS) stochastic IRRs are for comparative purposes only. IRR cannot be calculated in some cases.

[d]Errors out of 1,000 iterations (IRRs are based on non-error calculations):
SI-60, HRS 920, MRS 79, and LRS 1
SI-70, HRS 919, MRS 59, and LRS 1
SI-80, HRS 914, MRS 46, and LRS 1

Table 22. Mean Stochastic IRRs for Red Pine

Site[a] Index	Site	Deterministic IRR (%)[b]	Stochastic IRR (%)	Sd	Probability of Deterministic IRR (%)
50	HRS	--[c]	3.23	0.9	20.3
50	MRS	4.12	3.25	1.1	24.4
50	LRS	4.12	3.93	0.5	45.2
60	HRS	--	3.30	0.9	0.6
60	MRS	5.06	3.40	1.0	0.1
60	LRS	5.06	4.05	0.5	0.1
70	HRS	--	1.48	1.7	0.0
70	MRS	5.06	3.71	1.0	0.0
70	LRS	5.06	4.23	0.2	0.0
80	HRS	--	2.84	1.5	0.2
80	MRS	6.57	4.39	1.4	0.9
80	LRS	6.57	5.43	0.6	2.6

[a]Rotation length is 70 years for SI-50 and 70, 60 years for SI-60, and 50 years for SI-80.

[b]It is assumed that the deterministic IRR will occur with 100% probability for all site characteristics.

[c] -- FMD investments will be considered only for moderate (MRS) and low risk sites (LRS). High risk (HRS) stochastic IRRs are for comparative purposes only.

Reduction in volume for Saratoga spittlebug and white grub is also significant on high risk sites, but volume reductions less significant on moderate and low risk sites. Results of the survey show volume loss due to deer and porcupine is 18.7% on all red pine sites.

Probability of Occurrence for IRR

Two additional dimensions of stochastic analyses are (1) a range of IRRs for each investment outcome, and (2) a probability of occurrence associated with achieving IRRs within the range. Appendix B, Figures 4 through 24 present probability distribution curves for aspen and red pine analyses. A probability distribution curve shows a range (minimum and maximum) of rates of return and the probability of achieving each rate of return within the specified range.

Aspen

The probability of achieving a range of IRRs for aspen analyses is shown in Appendix B, Figures 4 through 12. All high and moderate risk sites show a wide range of negative IRRs. However, there is a very narrow range of positive values. Because of the width of the horizontal scale the positive ranges are difficult to discern. The curves, particularly for high risk sites, simply show that the probability of achieving positive IRRs is near zero.

Probability distribution curves for moderate sites have a generally wider range of positive IRRs. Low risk sites also show both positive and negative ranges of IRRs, but the negative range is relatively narrow. The positive range of IRRs for low sites did not vary significantly (0.0% to approximately 12%). The probability of achieving deterministic IRRs (6.93%, 7.98% and 8.66%) is 0.0% for site indices 60, 70 and 80 high risk sites. For moderate risk sites, the probability of achieving deterministic IRRs is approximately 7.0% for all three site indices. Low risk sites show probabilities of approximately 30% for all site indices.

Red Pine

The probability of achieving the deterministic IRR (4.12%) on red pine site index 50 (high risk site) is approximately 20%, 25% on a moderate risk site, and 45% on a low risk site. For site indices 60, 70 and 80 the probability of achieving the deterministic IRRs (5.06 for SI-60 and 70, and 6.57% for SI-80) is near zero for all three site indices and characteristics.

Other Measurement Criteria

In addition to IRR, present net value (PNV) and mean volume (with and without treatment) for each investment alternative provide additional insights regarding the investment options. Present net value is the discounted revenues minus discounted costs. Mean volume is the expected volume less reductions for risk for each investment alternative.

Present Net Value

Present net value for aspen and red pine is shown in Table 23. PNVs are calculated using 4% rate of interest because the MDNR uses this rate as their base rate of interest. Aspen analyses showed positive PNVs for low risk sites only, $104.46 for site index 60, $175.43 for site index 70, and $228.65 for site index 80. PNVs for moderate risk sites are negative because the stochastic IRRs for moderate risk sites are less than the rate of interest (4%). On high risk sites, negative PNVs are expected because rates of return are negative.

Red pine analyses showed positive PNVs for site indices 60, 70, and 80 low risk sites and site index 80, moderate risk site. The remaining sites show negative PNVs. Negative PNVs are attributed to the base interest rate (4%) which is greater than most mean stochastic IRRs for red pine. PNVs can become positive for the remaining red pine sites and all moderate risk aspen sites by using a lower rate of interest.

Table 23. Present Net Value for Aspen and Red Pine, 1982 Dollars

Site Index	Site Characteristic	Present Net Value[a]	Standard Deviation
Aspen:			
60	High Risk	-346.88	53.9
60	Moderate Risk	- 61.18	123.8
60	Low Risk	104.46	105.0
70	High Risk	-344.89	60.2
70	Moderate Risk	- 23.61	144.3
70	Low Risk	175.43	128.8
80	High Risk	-343.40	65.0
80	Moderate Risk	- 4.56	159.9
80	Low Risk	228.65	146.7
Red Pine:			
50	High Risk	-116.68	54.3
50	Moderate Risk	-113.25	50.4
50	Low Risk	- 77.21	33.0
60	High Risk	- 56.96	85.2
60	Moderate Risk	- 40.42	80.8
60	Low Risk	13.14	53.3
70	High Risk	-139.80	94.5
70	Moderate Risk	- 15.67	63.3
70	Low Risk	32.22	33.6
80	High Risk	- 59.47	129.3
80	Moderate Risk	71.57	135.1
80	Low Risk	180.16	87.8

[a]Discount rate is 4%.

Mean Volume (Without Treatment)

Mean volumes for aspen without treatment are shown in Table 24. Volume varied by site index and site characteristic, but the most significant difference in volume occurs between site characteristics (mainly, high and moderate or high and low sites). For example, on aspen high risk sites the average volume ranged from 1.87 to 2.51 cords/acre over a 60 year period. On moderate risk sites the range is 35.03 to 49.22 cords/per acre. The average volume for low risk sites ranged from 65.42 to 92.66 cords/acre. The low volume for high risk sites supports FMD policy of avoiding high risk sites as potential planting sites.

There is a direct relationship between low volume and lower IRRs. On each high risk site mean volume is less than 3 cords/acre or only a fraction of the starting point/base volume; consequently, IRRs for low risk sites are negative. Moderate and low risk sites show a similar relationship, but IRRs are positive. Mean volumes for low risk sites, although higher for both high and moderate sites, are approximately 33% less than the deterministic or starting point volumes. This is expected since pests may damage or destroy entire stands of aspen. An almost 100% increase in volume is achieved from moderate to low risk site.

On red pine high risk sites mean volumes ranged from 12.72 to 15.54 MBF/acre (see Table 25). For moderate and low risk sites the ranges are 21.55 to 31.21 and 28.77 to 39.38 MBF/acre, respectively. There is also a direct relationship between lower volume and lower IRRs for red pine, but on high risk sites mean volumes are about 36% of starting point volume. On low risk sites mean volume is 80% of starting point volume. Mean volumes for low risk sites, although higher for both high and moderate sites, are approximately 20% less than the starting point volumes.

Mean Volume (With Treatment)

Mean volumes for aspen with treatment are shown in Table 26. Treatments are for bronze leaf, hypoxylon, shoot blight, gypsy moth, forest tent and poplar borer. Volume on high risk sites increases significantly when stands are treated. For example, on high risk sites mean volume is 66% of starting point volume with treatment, but only about 2% without treatment. This means that treatment is very effective. Data are available for treatment on high risk sites.

Mean volumes for red pine are also shown in Table 27. Treatments are for jack pine budworm, root collar weevils, redheaded pine sawfly, Saratoga spittlebug and white grubs. For high risk sites, mean volume without treatment is 36% of starting point volume, but 70% of starting point volume when stands are treated. Treatment is also very effective for red pine.

Table 24. Mean Volume for Aspen Over 60 Years (Without Treatment)

Site Index	Site Characteristic	Starting Point Volume (Cords)	Mean Volume (Cords)	Standard Deviation
60	High Risk	96.00	1.87	5.2
60	Moderate Risk	96.00	35.03	16.8
60	Low Risk	96.00	65.42	14.9
70	High Risk	120.00	2.15	6.3
70	Moderate Risk	120.00	42.80	20.9
70	Low Risk	120.00	80.57	18.4
80	High Risk	138.00	2.51	7.3
80	Moderate Risk	138.00	49.22	24.0
80	Low Risk	138.00	92.66	21.1

Table 25. Mean Volume for Red Pine (Without Treatment)

Site Index	Site Characteristic	Starting Point Volume[a] (MBF)	Mean Volume (MBF)	Standard Deviation
50	High Risk	35.95	12.72	7.2
50	Moderate Risk	35.95	21.55	7.9
50	Low Risk	35.95	28.91	5.2
60	High Risk	36.48	13.61	7.3
60	Moderate Risk	36.48	22.10	8.1
60	Low Risk	36.48	28.77	5.6
70	High Risk	46.43	15.52	12.0
70	Moderate Risk	46.43	31.21	7.8
70	Low Risk	46.43	39.38	4.0
80	High Risk	40.16	15.54	8.0
80	Moderate Risk	40.16	24.40	8.8
80	Low Risk	40.16	31.87	6.1

[a]Volumes are based on thinnings and clearcuts. Rotation ages for site indices 50, 60, 70 and 80 are _70_, _60_, _70_ and _50_ years respectively.

Table 26. Mean Volume for Aspen Over 60 Years (With Treatment)

Site Index	Site Characteristic	Starting Point Volume (Cords)	Mean Volume (Cords)	Standard Deviation
60	High Risk	96.00	63.54	11.5
70	High Risk	120.00	79.42	14.3
80	High Risk	138.00	91.34	16.5

Table 27. Mean Volume for Red Pine (With Treatment)

Site Index	Site Characteristic	Starting Point Volume[a] (MBF)	Mean Volume (MBF)	Standard Deviation
50	High Risk	35.95	25.38	5.8
60	High Risk	36.48	26.10	6.0
70	High Risk	46.43	35.35	4.1
80	High Risk	40.16	28.78	6.6

[a]Volumes are based on thinnings and clearcuts. Rotation ages for site indices 50, 60, 70 and 80 are 70, 60, 70 and 50 years respectively.

Sensitivity Analyses

It was noted in Chapter V that individual responses to questions in the questionnaire were reviewed by FMD officials to determine if the responses were reasonable. FMD officials determined that sensitivity analyses should be performed to test the sensitivity of some individual data values on IRRs. Sensitivity analyses were performed to determine the impact of changing the probability of occurrence for several biophysical risks and changing the reduction in volume for one risk. Specific changes and values used in the sensitivity analysis are summarized in Table 28. The sensitivity analysis focused on changes in:

(1) the mean probability of attack (MPOA) for drought (aspen),

(2) the MPOA for jack pine budworm, redheaded pine sawfly and drought (red pine), and

(2) mean percentage reduction in yield/volume (MPRY) for flooding (red pine).

The FMD recommended sensitivity analyses will be referred to as "changes in risk factors."

Other sensitivity analyses were performed to provide greater insight regarding the returns. These analyses are listed below and involve:

(1) using mean prices/trends and costs -- to determine the effect of having biophysical variability,

(2) mean volumes after reductions -- to determine the effect of having price/cost variability, and

(3) no/without secondary impacts included -- to determine if secondary impacts make a difference in the study.

Table 28. FMD Sensitivity Analyses for Aspen and Red Pine

Risk	Site	Description	Old (%)	New (%)
Aspen:				
Drought	HRS	% of stands attacked	21.7	100.0
	MRS	% of stands attacked	21.7	100.0
	LRS	% of stands attacked	21.7	100.0
Red Pine:				
J.P. Budworm	HRS	% of stands attacked	53.8	75.0
R.P. Sawfly	HRS	% of stands attacked	53.8	75.0
	MRS	% of stands attacked	22.8	25.0
	LRS	% of stands attacked	3.8	5.0
Drought	HRS	% of stands attacked	39.3	100.0
	MRS	% of stands attacked	39.3	100.0
	LRS	% of stands attacked	39.3	100.0
Flooding	HRS	% reduction in volume	16.7	80.0
	MRS	% reduction in volume	16.7	80.0
	LRS	% reduction in volume	16.7	80.0

Biophysical Risks

Aspen

Results of the biophysical risk sensitivity analysis for aspen are given in Table 29. Changing the probability of occurrence for drought from 21.8% to 100% caused significant changes in the IRRs for all aspen site indices and characteristics. IRRs on all moderate risk sites changed from positive to negative values. IRRs for low risk sites remained positive, but, were reduced significantly, for example, from 7.60% to 4.99% on site index 80. The results of this sensitivity analysis are not surprising since starting point volume is reduced by 33.3% for all sites when drought occurs.

The effects of this sensitivity simulation were significant. IRRs on moderate risk sites were reduced from an average 3.09% to -0.42%. For low risk sites the reduction was from 6.85% to 4.46%. Therefore, IRRs for aspen are very sensitive to drought. When IRRs for moderate and low risk sites are combined, the difference between base and sensitivity IRR is 3.05%.

Red Pine

The results of the biophysical risk sensitivity analysis for red pine are given in Table 30. Results for this sensitivity analysis are similar to aspen since IRRs are also lower than the base stochastic results. It should be noted however, that IRRs for moderate site were lower than IRR for high sites for indices 50 and 60. This occurred when first or second thinnings did not occur because of attacks by pests, therefore, thinning costs were not incurred on high sites. On moderate sites very small volumes were harvested, but when compared to harvesting costs, revenue from sale exceeded costs (The US Forest Service may call this phenomena a below cost timber sale). This scenario caused IRRs for moderate sites to decrease relative to high sites. Although the range of difference is smaller for red pine, there is a significant reduction in IRRs for most site indices and characteristics.

The effects of the biophysical risk sensitivity analysis for red pine was less significant when compared to aspen. IRR for moderate sites were reduced from an average 3.68% to 2.71% and for low sites the average was 4.41% to 3.95%. When we combine both moderate and low sites, the average difference is from 4.04% to 3.33%. Therefore, the biophysical risk sensitivity analysis caused the IRR for red pine to decrease on average by 0.71.

Without Secondary Impacts

Aspen

Results of the sensitivity analysis for aspen excluding secondary impacts are given in Table 29. The elimination of secondary impacts produced interesting, but, expected results. IRRs for high risk sites are still negative, except for site index 80. IRRs for moderate and low risk sites are positive and fall between base stochastic IRRs and deterministic IRRs (i.e., greater than stochastic, less than deterministic). This means that inclusion of secondary biophysical risks affects volume and rates of return. On average, the IRR increased from 4.97% to 5.86% for moderate and low risk sites, an increase of 0.89%.

Red Pine

Results of the sensitivity analysis for red pine are given in Table 30. The IRRs are higher than base stochastic IRRs. The higher IRRs for high risk sites occurred because of the strong linkage between the occurrence of primary biophysical risks and some secondary risks. The occurrence of many primary biophysical risks are linked to secondary risks (mainly, bark beetle and armillaria). In many instances these linkages are strong (Table 19, Chapter IV), causing armillaria and bark beetle to occur with high probability for high and moderate sites.
Probabilities of occurrence for these pests are fairly insignificant on low risk sites.

Table 29. Sensitivity Analysis for Aspen (Biophysical Risks)

Site Index	Stochastic		Change in Risk Factors		No Secondary Impacts	
	IRR[a] (%)	Sd	IRR[b] (%)	Sd	IRR[c] (%)	Sd
60-HRS	-10.11	41.1	-39.13	71.0	-4.40	27.4
MRS	2.33	11.2	-4.76	27.1	3.83	6.5
LRS	5.98	1.8	3.02	8.4	6.59	1.8
70-HRS	-4.05	28.2	-14.14	40.7	-1.81	21.5
MRS	3.30	10.1	-3.85	24.5	5.04	2.7
LRS	6.96	2.0	4.36	2.3	7.61	1.9
80-HRS	-1.00	19.6	-7.38	27.8	0.19	14.3
MRS	3.63	11.9	-3.96	26.4	5.61	2.8
LRS	7.60	2.1	4.99	2.4	8.25	2.0

[a]Errors out of 1,000 iterations:
SI-60, HRS 920, MRS 79, and LRS 1
SI-70, HRS 919, MRS 59, and LRS 1
SI-80, HRS 914, MRS 46, and LRS 1

[b]Errors out of 1,000 iterations:
SI-60, HRS 961, MRS 442, and LRS 17
SI-70, HRS 964, MRS 393, and LRS 14
SI-80, HRS 960, MRS 364, and LRS 14

[c]Errors out of 1,000 iterations:
SI-60, HRS 870, MRS 32, and LRS 0
SI-70, HRS 856, MRS 24, and LRS 0
SI-80, HRS 846, MRS 21, and LRS 0

Table 30. Sensitivity Analysis for Red Pine (Biophysical Risks)

Site Index	Stochastic		Change in Risk Factors		No Secondary Impacts	
	IRR (%)	Sd	IRR (%)	Sd	IRR (%)	Sd
50-HRS	3.23	0.9	3.00	0.7	3.98	0.3
MRS	3.25	1.1	2.30	1.0	4.03	0.3
LRS	3.93	0.5	3.53	0.5	4.18	0.3
60-HRS	3.30	0.9	3.00	0.7	4.69	0.3
MRS	3.40	1.0	2.48	1.0	4.38	0.3
LRS	4.05	0.5	3.52	0.2	4.39	0.3
70-HRS	1.48	1.7	0.76	1.4	4.23	0.2
MRS	3.71	1.0	3.07	1.4	4.23	0.3
LRS	4.23	0.2	4.01	0.1	4.34	0.3
80-HRS	2.84	1.5	2.35	1.0	5.57	0.3
MRS	4.39	1.4	3.01	0.4	5.67	0.3
LRS	5.43	0.6	4.75	0.3	5.81	0.3

When the impacts of secondary pests are removed, the probabilities of occurrence for secondary pests (occurring as primary pests) are reduced causing less reduction in volume. The impact of this scenario is most relevant for high and moderate risk sites, since low risk sites have much lower probabilities of occurrence and lower reductions in volume. Consider, for example, a 100% probability of occurrence for both armillaria and bark beetle on a high or low risk site. The maximum combined volume loss on the high site is 20.8% of the stand; on the low risk site the combined volume loss is 0.5%. Therefore, removing secondary impacts has less effect on IRRs for low risk sites than for high risk sites.

Mean Prices/Trend/Costs

Aspen

Mean prices and costs for this sensitivity analysis are actually the starting point prices and costs. Results for aspen are given in Table 31. The results show lower IRRs for both moderate and low risk sites when compared to the stochastic (base) sensitivity analysis. Lower IRRs for this analysis are attributed to the generally higher trend for aspen prices (Appendix Tables A4, A5, and A6).

IRRs for moderate risk sites showed more variability than IRRs for low risk sites. Standard deviations for low risk sites were also lower than standard deviations for moderate risk sites as well as the base stochastic analysis. The higher standard deviations for moderate risk sites occurred because of some very negative IRRs. The results of this sensitivity analysis shows that price caused less variability on the results than biophysical risks.

Red Pine

Table 32 presents results of the red pine sensitivity analysis. Unlike aspen, the IRRs for red pine are basically the same as the base stochastic IRRs. Standard deviations are also nearly identical to the base stochastic, reflecting the same general level of variability in results. Results reflect a generally flat average price trend for red pine products (see Appendix Tables A4, A5, and A6). The average decline in IRR for moderate and low risk sites is from 4.04% for stochastic analysis to 4.00% for this sensitivity analysis. Therefore, the effects of prices and costs were minimal.

Prices and costs for aspen and red pine were used to form a triangular probability distribution. The price trend or annual price increase has a normal distribution that is skewed to the right.

Mean Volume

Results of using mean volumes in the sensitivity analysis for aspen produced higher IRRs for moderate and low risk sites. The effects of a higher price trend are evident since IRRs for this analysis are greater than stochastic IRRs. Standard deviations for this sensitivity analysis were significantly lower than standard deviations for the stochastic analysis.

IRRs for all red pine site characteristics were lower than base stochastic IRRs. Rates of return for this sensitivity are lower than deterministic IRRs mainly to the effects of a generally lower trend for price and costs. Standard deviations were slightly lower for mean volume results when compared to stochastic results.

Table 31. Sensitivity Analysis for Aspen (Financial Risks)

Site Index	Stochastic		Mean Price/ Trend & Cost		Mean Volume	
	IRR[a] (%)	Sd	IRR[b] (%)	Sd	IRR[c] (%)	Sd
60-HRS	-10.11	41.1	-1.70	2.0	-43.49	33.0
MRS	2.33	11.2	1.17	16.7	3.54	1.0
LRS	5.98	1.8	5.38	1.3	6.23	1.0
70-HRS	-4.05	28.2	-0.69	2.0	-35.81	29.6
MRS	3.30	10.1	3.17	7.0	4.39	1.1
LRS	6.96	2.0	6.37	1.4	7.17	1.2
80-HRS	-1.00	19.6	-0.15	2.0	-28.8	26.1
MRS	3.63	11.9	3.29	10.0	4.98	1.1
LRS	7.60	2.1	7.00	1.5	7.81	1.3

[a]Errors out of 1,000 iterations:
SI-60, HRS 920, MRS 79, and LRS 1
SI-70, HRS 919, MRS 59, and LRS 1
SI-80, HRS 914, MRS 46, and LRS 1

[b]Errors out of 1,000 iterations:
SI-60, HRS 961, MRS 442, and LRS 17
SI-70, HRS 964, MRS 393, and LRS 14
SI-80, HRS 960, MRS 364, and LRS 14

[c]Errors out of 1,000 iterations:
SI-60, HRS 870, MRS 32, and LRS 0
SI-70, HRS 856, MRS 24, and LRS 0
SI-80, HRS 846, MRS 21, and LRS 0

Table 32. Sensitivity Analysis for Red Pine (Financial Risks)

Site Index	Stochastic		Mean Price/ Trend & Cost		Mean Volume	
	IRR (%)	Sd	IRR (%)	Sd	IRR (%)	Sd
50-HRS	3.23	0.9	3.20	0.8	2.09	0.4
MRS	3.25	1.1	3.19	1.1	2.59	0.2
LRS	3.93	0.5	3.88	0.4	2.98	0.2
60-HRS	3.30	0.9	3.20	0.8	2.64	0.4
MRS	3.40	1.0	3.36	1.1	3.04	0.3
LRS	4.05	0.5	4.01	0.5	3.48	0.2
70-HRS	1.48	1.7	1.54	1.8	0.43	0.1
MRS	3.71	1.0	3.67	1.0	1.99	0.1
LRS	4.23	0.2	4.21	0.2	2.19	0.1
80-HRS	2.84	1.5	2.83	1.5	1.66	0.5
MRS	4.39	1.4	4.36	1.4	3.74	0.6
LRS	5.43	0.6	5.34	0.6	4.75	0.7

Summary

This chapter focused on (1) results of FMD deterministic analyses, (2) stochastic analysis that included risk for biophysical and financial risks, and (3) sensitivity analyses. Deterministic IRRs are assumed to occur with 100% probability. Deterministic rates of return for aspen are higher because of generally shorter rotation lengths, higher volume, and higher sites for aspen.

Stochastic IRRs for aspen averaged 1.00% less than deterministic IRRs for low risk sites. Stochastic IRRs for aspen on moderate risk sites were about half the deterministic IRRs. High risk aspen sites produced negative returns. IRRs for all red pine sites are positive, but are also lower than deterministic IRRs. The highest red pine IRRs occurred on low risk sites, where the difference between stochastic and deterministic IRRs averaged less than 1.0%. Results of the stochastic analysis show rates of return for both aspen and red pine that were lower than deterministic rates of return.

The probability of achieving deterministic IRRs, or higher, is zero percent for all high risk aspen sites. For moderate risk sites the probability is approximately 7% for each site. The probability of achieving deterministic rates of return on low risk sites averages 30% on each low risk site.

The probability of achieving deterministic IRRs for red pine is near zero for site indices 60, 70, and 80. For site index 60 the probabilities are 20, 24, and 45% on high, moderate, and low risk sites, respectively.

Present net values were calculated using a 4% discount rate. PNVs for aspen were negative for high and moderate risk sites. PNVs for red pine were negative for all red pine sites except low risk sites and site index 80 moderate risk site. The PNVs were negative because the base stochastic IRRs, although positive, were less than the 4% discount rate used in this study.

Mean volume for aspen (without treatment) averaged less than 2% of starting point or base volume for high risk sites. For moderate sites mean volume averaged 35%. For low risk sites mean volume is 66% of the starting point volume. For red pine, mean volume averaged 36% of starting point volume for high risk sites, 60% for moderate risk sites, and 80% for low risk sites. The overall difference between starting point volume and mean volume is reflected in the IRRs for the three site characteristics. For example, mean volume for aspen high risk sites is only 2% of starting point volume, therefore, IRRs are negative because of the low volumes. Mean volumes on high risk sites when stands are treated increased significantly.

The sensitivity analysis for aspen biophysical risks decreased IRRs significantly for all sites and site characteristics. Changing the probability of drought to 100% reduced initial volume by more than 33% for all sites and site characteristics. This scenario accounts for the dramatic decrease in rates of return.

The sensitivity analysis for red pine also reduced IRRs, but the reductions were less than reductions for aspen. The sensitivity analysis for elimination of secondary risks increased IRRs for both aspen and red pine. However, IRRs for this sensitivity analysis were above the base stochastic IRRs but below deterministic IRRs. The most profound increase in IRRs occurred on red pine high risk sites because of the strong linkages between primary pests and some secondary pests. These linkages were not as strong for aspen.

The sensitivity analysis for mean prices/trends and costs reduced IRRs below base stochastic IRRs for aspen. However, IRRs for red pine remained about the same. The decrease for aspen was caused by the marginally higher price trend for aspen.

The use of mean volume in the sensitivity analysis for aspen increased IRRs dramatically over base stochastic IRRs for all aspen sites and site characteristics. Positive IRRs for aspen occurred on high risk sites and IRRs for all sites exceeded deterministic IRRs. Mean volumes also increased IRRs for red pine, but the increase is less dramatic. Overall, the sensitivity analysis results were very sensitive to DNR suggestions and secondary pests. The sources of variability were related more to biophysical risks than price risks.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The objectives of this study are (1) to identify biophysical risks associated with growing improved aspen and red pine, and (2) to estimate rates of return for aspen and red pine after the inclusion of risk in the analyses of selected investments in aspen and red pine on state-owned forest lands in Michigan.

Many risks, including insects, diseases, animals and other natural factors, are identified as having a potential impact on the growth and yield of aspen and red pine. A review of the literature was completed to identify and assess the effects of biophysical risks that may impact stands. Additionally, the Delphi technique was used to help determine the significant risks believed to affect aspen and red pine stands. A questionnaire was administered to forest management experts in Michigan to obtain their professional judgements on the potential impacts of biophysical risks.

Internal rates of return that include risk are calculated using a stochastic investment model and compared with rates of return calculated by FMD using a deterministic investment model. The stochastic investment model uses

Monte Carlo simulation to calculate rates of return. Rates of Returns are calculated based on three risk site characteristics (high, moderate and low), and with three investment alternatives for aspen and four investment alternatives for red pine. Using a stochastic investment model, rates of return were calculated for each investment alternative. Results for each investment alternative included a range of rates of return and a probability of occurrence for each rate of return. Finally, sensitivity analyses were performed to add more context to the study.

Results of the survey questionnaire show many biophysical risks are not expected to have a significant impact on growth and yield of aspen and red pine stands in Michigan. FMD experts believe the potential for damage to stands by some risks can be greatly reduced or eliminated with proper site selection; that is, by avoiding sites classified as high risk. Risks that attack stands and cause reductions in volume were highlighted in this study.

For those risks that are believed to attack stands planted on high, moderate, and low risk sites, results of the survey questionnaire show varying levels of damage. Sites defined as high risk are likely to sustain substantially more damage by insects and diseases than moderate or low risk sites. Overall, low risk sites are likely to sustain substantially less damage by insect or disease attacks. The general level of damage to stands by insects and diseases on high risk sites is greater for aspen high risk sites than for red pine high risk sites.

Several pests were identified as having a high probability of attack associated with them and the potential for reduction in volume. For aspen, bronze leaf disease, hypoxylon canker, gypsy moth, forest tent caterpillar, and deer are the most significant. For red pine, armillaria, jack pine budworm, red headed pine sawfly, Saratoga spittlebug, white grubs, and deer are the most important.

Results of the survey showed a high probability of attack by deer. It was disclosed through personal conversations with DNR forest management experts that they consider deer to be the most destructive threat to newly planted aspen or red pine stands in Michigan. It was their opinion that efforts must be made to control the deer population in the state before serious consideration is given to making investments in aspen and red pine planting.

Reduction in volume due to attacks by insects and diseases is greater for high risk sites than for moderate or low risk sites. Reduction in volume due to an attack is less for moderate and low risk sites. Results from the survey questionnaire also showed high probabilities of occurrence between primary biophysical risks and some secondary risks. This means that some insects or diseases are more likely to attack a stand after it is attacked by some other insect, disease or weather-related factor. For example, armillaria, bark beetle, jack pine budworm, and redheaded pine sawfly will follow drought at about 60% probability in red pine stands. DNR forest management experts concluded that insects, diseases and weather-related factors generally have not caused major damage to stands in Michigan. They also concluded that planting aspen and red pine on sites classified as moderate and low risk minimizes the chance of insect or disease attacks. Simulation results indicate that red pine plantations are less affected than aspen plantations, and that low risk sites are least affected.

Results of this study showed deterministic, or desired, rates of return are higher than most stochastic rates of return. The desired IRR for all aspen investments averaged 7.86%; stochastic IRRs for aspen averaged 3.09% on moderate risk sites and 6.85% on low risk sites. The probability of achieving the deterministic IRR of 7.86% or higher for aspen investments is 0% on moderate risk sites and 27% on low risk sites. This means that 100% of the time, lower IRRs would be achieved on moderate risk sites; 73% of the time, lower IRRs would be realized on low risk sites.

The deterministic IRRs for red pine sites averaged 5.20%. Stochastic IRRs averaged 3.69% for moderate risk sites and 4.41% for low risk sites. The probability of achieving the desired rate of return for red pine investments averaged 6% for moderate risk sites and 12% for low risk sites. Therefore, 94% of the time, lower IRRs would be realized on moderate risk sites; 88% of the time, lower IRRs would be realized on low risk sites.

The probability of achieving most likely rates of return that are lower than the desired IRRs is caused by the likelihood that biophysical risks will attack stands causing a reduction in volume. The effects of an attack lower rates of return. The results of sensitivity analyses support this conclusion.

Two other measurement criteria were calculated for this study, present net value (PNV) and mean volume (with and without treatment). PNVs were calculated using a 4% discount rate. Results showed positive PNVs for aspen low risk sites and red pine site indices 60 and 70 low risk sites and SI 80 low and moderate risk sites. These sites had rates of return greater than 4.00%. Mean volume was lowest on high risk sites, higher on moderate risk sites, and highest on low risk sites. This variation in volume between high, moderate, and low risk sites is linked to the effects of insects and diseases on stands (see Tables 3 and 9). For example, higher levels of attack mean lower total volumes; lower levels of attack mean higher volumes. The conclusions were reflected in mean volumes for all aspen and red pine site indices and site characteristics.

Three primary reasons for conducting sensitivity analyses for this study have been given. First, to determine the effect of having biophysical variability; secondly, to determine the effect of having price/cost variability versus volume variability; and finally, to determine if secondary impacts make a difference in the study.

The effects of biophysical variability is established when we examine IRRs for both aspen and red pine. For example, when the probability of drought for aspen is increased to 100%, the IRRs for moderate and low risk sites are decreased by more than 2.0 percentage points. The biophysical sensitivity analysis for red pine showed similar results; IRRs decreased by an average of more than 1.0 percentage point for moderate and low risk sites.

The effects of secondary impacts were more evident for red pine than for aspen, particularly for high risk red pine sites. The increase in IRRs for aspen and red pine were greater for moderate sites than for low sites. For red pine, the most dramatic increase in IRRs occurred on high risk sites. The dramatic increase in IRRs for red pine on high risk sites indicates a strong linkage between primary and secondary risks. The data linkages between primary and secondary risks for aspen and red pine were presented in Tables 7 and 19.

What are the effects of having price/cost variability in this study? The effects of price/cost variability are more evident for aspen than for red pine. IRRs for moderate and low risk aspen sites decreased by an average 0.41 percentage points below base stochastic average. The decrease in IRRs indicate the effects of price/cost on the analysis. There is a slight upward price trend for aspen.

For red pine the effects of using mean prices/costs in the analysis had little impact on rates of return. IRRs remained virtually unchanged for all red pine sites. Standard deviations for aspen IRRs were significantly higher than for red pine IRRs.

The sensitivity analysis for mean volume clearly illustrates the impacts of biophysical risks as well as impacts of price/cost variability. When mean volumes are used, IRRs for all aspen sites (including high risk) increase by more than 1.0 percentage point over the deterministic IRRs. The increase in rates of return over the deterministic results is caused by a generally higher price trend for aspen. The same analysis for red pine produced higher IRRs also. However, IRRs were lower than deterministic IRRs but, higher than stochastic IRRs. The difference between the deterministic IRRs for red pine and the IRRs calculated for this sensitivity analysis is caused by a generally flat trend for prices.

Results of the sensitivity analysis for price/trend/cost variability revealed that prices and costs are relatively unimportant. Thomson (1989) reached a similar conclusion in an analysis of a tree improvement study. Mills (1980), however, concluded that physical risk is not a significant investment risk and that the majority of risks associated with forest investments stem from financial fluctuations in the value of land and stumpage. Lothner et al. (1986) found that product price uncertainty is the major cause of uncertainty surrounding the financial returns from short-rotation hybrid poplar investments. The results for biophysical variability revealed that biophysical risks are important and can cause significant reductions in expected rates of return in a risk analysis.

The implications of the results given above are many. The investments for this analysis covered only part of the FMD investment portfolio. Whether stochastic rates of return are at a level for consideration for inclusion in the FMD portfolio is unknown. However, when investments are examined by species, site index, and site characteristic, conclusions can be inferred.

At present the return on investments in long-term, tax-free government bonds average between 6.5 and 7.5%. The current rate of inflation is between 4 and 5% per year. Conservatively, this means that the true real rate of return is between 1.5 and 3.5% per year. Based on this rate for bonds, investments yielding at least 3.5% per year should be considered. This means that the following investments should be considered for inclusion in the FMD portfolio:

(1) aspen site index 60 and 70 (low risk sites),

(2) aspen site index 80 (moderate and low risk sites),

(3) red pine site indices 50 and 60 (low risk sites),

(4) red pine site index 70 and 80 (moderate and low risk sites).

Investments on other aspen and red pine sites may be worthy of consideration when the make-up of the FMD investment portfolio is known.

Further Studies and Recommendations

There is a need for additional research on risks associated with investments in forestry. Probabilities of attack for risks and reductions in volume were difficult to estimate for forest management experts. One important area of research would be long-term studies to determine impacts of insects and diseases on the overall volume losses in specific timber stands. In short, validation studies are needed.

Analyses of investments in forestry that include risk require historical data on the various cost and income variables. They provide the basis for making projections. These data are critical in performing stochastic as well as deterministic analyses. A complete stochastic analysis of this study was not performed because of a lack of data on some of the variables in the model (i.e., harvesting and/or thinning costs, management costs, and treatment costs). Therefore, the author believes that there are several steps the Forest Management Division can take to enhance studies dealing with risk in investment analysis. Recommendations that may aid FMD in future research efforts to incorporate risk in forest investment analyses include:

(1) Improving the FMD record keeping system would provide researchers and managers with valuable historical data on the various input variables such as planting, site preparation, thinning/harvesting, and other treatment costs. Historical records on costs and prices are essential when performing risk analyses.

(2) There is a need to give some attention to controlling the State's deer population. FMD forest management experts at the forest level were vociferous about the deer problem on state forest lands. They reported an expanding deer population that has the potential to completely destroy newly planted aspen or red pine stands. These experts believe that the deer population must be reduced significantly before investments are made in planting aspen or red pine stands.

(3) FMD needs to determine acceptable rates of return for their investment portfolio.

Risks associated with investments in forestry are real and should be included in analyses of forest investments. Future analysis by FMD may include species other than aspen and red pine. Consideration for timing of pests are important and should be incorporated along with data on treatment costs.

It is hoped that this study has provided some additional insights into the area of inclusion of risk in timber investments. The Delphi approach used in this study was our attempt to obtain data on effects of biophysical risks by tapping into a rich, but namely under-utilized resource base. The author believes that whenever possible researchers should harness the knowledge of personnel who have over long periods of time gained valuable knowledge and experience about forests and forest systems. The predictions of forest management experts versus expert systems may constitute an additional area for future research.

Based on the results of this study, the author recommends that future efforts by FMD to incorporate risk into timber investments should focus on biophysical risks. Financial risks, at least timber prices and planting costs, appear to be relatively unimportant in this study.

APPENDICES

APPENDIX A

DATA TABLES

Table A1. Average Expected Yield for Aspen on State Forest

Site Index	Rotation Length[a]	Harvest Year	Pulpwood Cords/Acre
60	60	20	32.0
60	60	40	32.0
60	60	60	32.0
70	60	20	40.0
70	60	40	40.0
70	60	60	40.0
80	60	20	46.0
80	60	40	46.0
80	60	60	46.0

[a]Rotation length is actually three 20-year rotations with clearcut harvest at end of each rotation period.

Source: Forest Management Division Records

Table A2. Average Expected Yield for Red Pine on State Forests

Site Index	Rotation Length	Harvest Year	Pulpwood MBF/ Acre[a]	Sawtimber MBF/Acre	Poles MBF/Acre	Total MBF/ Acre
50	70	40	6.84	0.40	--	7.24
		50	8.04	--[b]	--	8.04
		60	0.15	3.37	--	3.52
		70	0.93	3.25	12.98	17.16
60	60	30	6.10	0.32	--	6.42
		40	6.20	--	--	6.20
		50	0.14	4.15	--	4.29
		60	0.93	3.65	15.00	19.58
70	70	30	7.07	--	--	7.07
		40	7.11	--	--	7.11
		50	0.16	5.03	--	5.19
		60	0.18	0.89	3.57	4.64
		70	1.06	4.36	17.00	22.42
80	50	20	5.16	0.16	--	5.32
		30	5.93	--	--	5.93
		40	0.13	5.65	--	5.78
		50	0.88	4.47	17.87	23.22

[a] = conversion factor is 2 cords = 1 MBF

[b] = no data/yield

Source: Forest Management Division Records

Table A3. Aspen and Red Pine Prices and Costs Used in FMD Analyses

	Aspen	Red Pine
Prices:[a]		
Pulpwood ($/Cord)	10.00	--
Pulpwood ($/MBF)	--[b]	14.00
Sawtimber ($/MBF)	--	70.00
Poles ($/MBF)	--	130.00
Costs ($/Acre)[a]		
Planting	97.90	125.00
Site Preparation	--	50.00
Environmental Protection	1.00	--
Management Fee	2.50	2.50
Harvesting (1st)	8.50	10.00
Harvesting (All Others)	10.00	13.00

[a] = 1986 Dollars

[b] -- = no data

Source: Forest Management Division Records

Table A4. Average Rate of Real Price Increase for Aspen and Red Pine

	Percent/Year	Standard Deviation	Years
Aspen:			
Pulpwood	1.25	0.24	1954-89
Red Pine:			
Pulpwood	0.62	0.20	1972-89
Sawtimber	2.40	0.24	1965-89
Poles	1.24	0.16	1984-89

Source: Forest Economics Research Unit, North Central Forest Experiment Station

Table A5. Normalized Prices for Triangular Distribution, Aspen and Red Pine

	Average Low Price	Sd	Starting Point Price[a]	Average High Price	Sd
Aspen:	$/AC		$/AC		$/AC
Pulpwood	2.83	1.23	10.00	22.96	8.79
Red Pine:					
Pulpwood	4.06	0.84	14.00	25.75	1.69
Sawtimber	31.86	12.95	70.00	130.16	32.28
Poles	109.13	11.37	130.00	145.22	10.78

[a] Starting point price from FMD deterministic analyses.

Source: Forest Economics Research Unit, North Central Forest Experiment Station

Table A6. Normalized Planting Costs for Triangular Distribution, Aspen and Red Pine

	Low Cost	Starting Point Cost	High Cost
Aspen[a]	79.02	97.90	116.77
Red Pine	100.90	125.00	149.10

[a] High and low cost estimates are derived from variability in actual planting cost data for red pine.

Source: Forest Management Division Records

Table A7. Aspen Prices - Pulpwood, 1972-1989 ($ Per Cord)

YEAR	NOMINAL[a] LOW	NOMINAL[a] MEAN	NOMINAL[a] HIGH	MEAN LOW	MEAN $10.00	MEAN HIGH	NOMINAL AVERAGE	REAL AVERAGE	LOG REAL
1954	0.51	2.19	3.07	2.33	4.566	14.02	1.92	6.75	1.91
1955	0.63	1.82	2.50	3.44	5.510	13.77	1.65	5.62	1.73
1956	0.75	1.91	2.75	3.94	5.249	14.44	1.80	6.05	1.80
1957	0.98	1.88	2.75	5.19	5.319	14.63	1.87	6.17	1.82
1958	0.88	1.79	2.20	4.90	5.602	12.32	1.62	5.26	1.66
1959	0.90	1.84	2.40	4.89	5.435	13.04	1.71	5.47	1.70
1960	0.69	1.82	2.30	3.76	5.495	12.64	1.60	5.05	1.62
1961	0.50	1.82	3.00	2.75	5.495	16.48	1.77	5.61	1.72
1962	0.55	1.81	5.50	3.05	5.540	30.47	2.62	8.26	2.11
1963	0.50	1.81	2.55	2.76	5.525	14.09	1.62	5.13	1.63
1964	0.50	1.82	2.63	2.75	5.510	14.46	1.65	5.21	1.65
1965	0.50	1.77	2.75	2.83	5.666	15.58	1.67	5.18	1.64
1966	0.50	1.67	4.04	3.00	6.006	24.23	2.07	6.21	1.83
1967	0.25	1.72	5.31	1.45	5.814	30.87	2.43	7.27	1.98
1968	1.00	2.00	4.82	5.00	5.000	24.10	2.61	7.62	2.03
1969	0.38	1.77	4.23	2.12	5.650	23.87	2.12	5.96	1.79
1970	0.38	1.66	4.47	2.30	6.012	26.85	2.17	5.88	1.77
1971	0.50	1.84	6.11	2.72	5.45	33.30	2.82	7.39	2.00
1972	0.38	1.89	4.60	1.99	5.305	24.40	2.29	5.75	1.75
1973	0.63	1.81	5.68	3.45	5.525	31.40	2.71	6.01	1.79
1974	0.88	2.13	6.77	4.11	4.695	31.76	3.26	6.09	1.81
1975	1.20	2.36	3.60	5.10	4.246	15.29	2.39	4.08	1.41
1976	0.46	2.99	8.75	1.54	3.344	29.26	4.07	6.66	1.90
1977	0.50	3.15	11.13	1.59	3.175	35.33	4.93	7.59	2.03
1978	0.38	3.08	12.96	1.22	3.247	42.06	5.47	7.83	2.06
1980	0.38	5.05	22.62	0.74	1.982	44.84	9.35	10.41	2.34
1981	0.23	5.52	35.60	0.41	1.812		13.78	14.06	2.64
1982	0.80	4.99	16.50	1.61	2.005	33.08	7.43	7.43	2.01
1983	1.48	5.25	15.90	2.82	1.907	30.32	7.54	7.45	2.01
1984	2.01	6.84	12.93	2.94	1.463	18.92	7.26	7.00	1.95
1985	1.87	7.43	16.41	2.51	1.346	22.09	8.57	8.30	2.12
1986	1.43	8.74	15.61	1.63	1.145	17.87	8.59	8.57	2.15
1987	2.03	8.14	15.34	2.50	1.229	18.85	8.50	8.27	2.11
1988	1.83	9.00	16.93	2.03	1.111	18.80	9.25	8.66	2.16
1989	3.49	9.63	16.71	3.62	1.038	17.35	9.94	8.86	2.18
Average Price =				2.83	10.00	22.96			
STD =				1.23		8.79			
Values < > 3 Std Removed				-0.85		49.34			
Rate of real price increase in percent/year							1.251		

[a]Low and High represent the lowest and highest prices. Mean price is the arithmetic mean of all prices.

Source: Forest Economics Research Unit, North Central Forest Experiment Station

Table A8. Red Pine Prices - Pulpwood, 1954-1989 ($ Per Cord)

YEAR	NOMINAL[a] LOW	NOMINAL[a] MEAN	NOMINAL[a] HIGH	MEAN LOW	MEAN $14.00	MEAN HIGH	NOMINAL AVERAGE	REAL AVERAGE	LOG REAL
1972	2.20	3.97	5.51	7.76	3.526	19.41	3.89	9.78	2.28
1973	1.85	3.59	6.47	7.21	3.900	25.22	3.97	8.82	2.18
1974	1.50	3.95	7.43	5.32	3.544	26.33	4.29	8.02	2.08
1975	1.78	4.79	8.12	5.19	2.926	23.76	4.89	8.38	2.13
1976	1.50	9.35	15.00	2.25	1.497	22.46	8.62	14.10	2.65
1977	1.50	7.42	15.25	2.83	1.887	28.77	8.06	12.41	2.52
1978	1.50	5.58	13.42	3.76	2.509	33.67	6.83	9.78	2.28
1980	1.52	10.55	36.39	2.01	1.328		16.15	17.98	2.89
1981	1.62	10.96	22.28	2.06	1.278	28.47	11.62	11.85	2.47
1982	2.21	11.90	21.06	2.59	1.176	24.77	11.72	11.72	2.46
1983	3.87	11.41	19.68	4.75	1.227	24.14	11.65	11.50	2.44
1984	2.83	8.81	14.50	4.49	1.590	23.06	8.71	8.40	2.13
1985	2.53	11.45	18.61	3.09	1.223	22.75	10.86	10.52	2.35
1986	3.58	10.32	22.50	4.85	1.357	30.52	12.13	12.11	2.49
1987	3.15	9.04	16.67	4.88	1.549	25.81	9.62	9.36	2.24
1988	1.83	10.73	21.48	2.38	1.305	28.04	11.34	10.61	2.36
1989	3.06	12.14	21.50	3.53	1.153	24.79	12.23	10.90	2.39
Average Price =				4.06	$14.00	25.75			
STD =				1.68		3.39			
				41.30		13.15			
Values < > 3 Std Removed				-0.97		35.91			

Rate of real price increase in percent/year 0.618

[a]Low and High represent the lowest and highest prices. Mean price is the arithmetic mean of all prices.

Source: Forest Economics Researh Unit, North Central Forest Experiment Station

Table A9. Red Pine Prices - Sawtimber, 1965-1989 (MBFI) International Rule

	-------NOMINAL[a]------			MEAN		MEAN	NOMINAL	REAL	LOG
YEAR	LOW	MEAN	HIGH	LOW	$70.00	HIGH	AVERAGE	AVERAGE	REAL
1965	6.00	9.04	15.00	46.46	7.743	116.15	10.01	31.00	3.43
1966	6.50	8.88	15.00	51.24	7.883	118.24	10.13	30.41	3.41
1967	7.00	11.40	15.00	42.98	6.140	92.11	11.13	33.33	3.51
1968	8.00	9.43	15.00	59.38	7.423	111.35	10.81	31.61	3.45
1969	4.00	9.82	40.00	28.51	7.128		17.94	50.39	3.92
1970	5.00	10.49	15.00	33.37	6.673	100.10	10.16	27.54	3.32
1971	6.00	10.94	17.00	38.39	6.399	108.78	11.31	29.69	3.39
1972	8.00	10.54	13.00	53.13	6.641	86.34	10.51	26.42	3.27
1973	6.00	10.93	28.00	38.43	6.404	179.32	14.98	33.28	3.51
1974	4.00	17.40	43.00	16.09	4.023	172.99	21.47	40.12	3.69
1975	9.41	30.08	43.00	21.90	2.327	100.07	27.50	47.08	3.85
1976	8.00	19.73	47.14	28.38	3.548	167.25	24.96	40.85	3.71
1977	10.00	19.52	45.00	35.86	3.586	161.37	24.84	38.27	3.64
1978	10.00	26.33	45.00	26.59	2.659	119.64	27.11	38.78	3.66
1980	1.40	26.91	60.00	3.64	2.601	156.08	29.44	32.78	3.49
1981	2.88	32.66	101.00	6.17	2.143	216.47	45.51	46.44	3.84
1982	14.20	35.73	75.00	27.82	1.959	146.94	41.64	41.64	3.73
1983	12.00	31.58	65.00	26.60	2.217	144.08	36.19	35.73	3.58
1984	20.00	41.06	73.00	34.10	1.705	124.45	44.69	43.09	3.76
1985	21.00	43.89	88.22	33.49	1.595	140.70	51.04	49.45	3.90
1986	24.00	53.19	90.00	31.58	1.316	118.44	55.73	55.62	4.02
1987	21.70	57.67	90.00	26.34	1.214	109.24	56.46	54.92	4.01
1988	21.70	62.79	90.00	24.19	1.115	100.33	58.16	54.41	4.00
1989	30.00	69.86	103.00	30.06	1.002	103.21	67.62	60.27	4.10
Average Price =				31.86	$70.00	130.16			
STD =				12.95		32.28			0.18
				40.65		24.80			
Values < > 3 Std Removed				-6.99		227.01			
Rate of real price increase in percent/year									2.403

[a]Low and High represent the lowest and highest prices. Mean price is the arithmetic mean of all prices.

Source: Forest Economics Research Unit, North Central Forest Experiment Station

Table A10. Red Pine Prices - Poles, 1984-1989 (Cords)

	NOMINAL[a]								
YEAR	LOW	MEAN	HIGH	MEAN LOW	130.00	MEAN HIGH	NOMINAL AVERAGE	REAL AVERAGE	LOG REAL
1984	91.00	113.89	123.00	103.87	1.141	140.40	109.30	105.40	4.66
1985	80.00	95.55	120.37	108.84	1.361	163.77	98.64	95.58	4.56
1986	132.73	133.36	134.54	129.39	0.975	131.15	133.54	133.28	4.89
1987	83.91	96.71	114.44	112.79	1.344	153.83	98.35	95.67	4.56
1988	78.27	93.54	104.03	108.77	1.390	144.58	91.95	86.01	4.45
1989	111.89	159.65	169.00	91.11	0.814	137.61	146.85	130.88	4.87
Average				109.13	130.00	145.22			
S. Deviation				11.37		10.78			
Low price % of Avg				83.49					
Values < > 3 Std Removed				75.01		177.58			
High price % of Avg						150.07			
STD % of avg				10.42		7.42			

Rate of real price increase percent/year	1.242

[a]Low and High represent the lowest and highest prices. Mean price is the arithmetic mean of all prices.

Source: Forest Economics Research Unit, North Central Forest Experiment Station

Table A11. Red Pine Planting Costs, 1984 - 1990

Hand Planting				Machine Planting				
Year	Acres	Nominal $	Real 1982 $	Year	Acres	Nominal $	Real 1982 $	Log Real
				85	91	58.33	56.52	
				83	1238	67.20	66.34	
				85	10	70.40	68.22	
				87	468	73.38	71.38	
				85	72	76.44	74.07	
				86	642	79.02	78.86	
				85	263	80.69	78.19	
				85	121	81.00	78.49	
				85	54	85.35	82.71	
				85	70	88.00	85.27	
				85	78	88.00	85.27	
				85	20	88.00	85.27	
88	55	41.09	38.44	85	74	88.00	85.27	
84	41	44.23	42.65	85	20	88.00	85.27	
86	40	51.35	51.25	85	40	88.00	85.27	
89	43	61.88	55.15	85	6	88.00	85.27	
84	57	69.04	66.57	85	26	88.00	85.27	
84	69	70.51	67.99	85	7	88.00	85.27	
87	117	71.07	69.13	85	24	89.83	87.05	
85	18	75.78	73.43	85	10	91.60	88.76	
84	110	78.02	75.24	86	92	101.48	101.28	
85	329	80.50	78.00	85	20	103.20	100.00	
85	347	83.68	81.09	85	33	106.18	102.89	
85	28	84.93	82.30	85	9	113.89	110.36	
86	53	86.21	86.04	85	11	114.64	111.08	
85	84	94.77	91.83	82	90	116.00	116.00	
85	7	101.71	98.56	88	793	121.03	113.22	
86	96	107.00	106.79	87	270	126.50	123.05	
87	71	110.45	107.44	86	197	127.00	126.75	
85	18	111.00	107.56	84	95	129.00	124.40	
85	18	111.00	107.56	86	20	133.90	133.63	
87	25	133.10	129.47	89	23	140.00	124.78	
89	229	133.44	118.93	86	85	141.84	141.55	
86	70	136.00	135.73	85	8	143.88	139.41	
84	158	193.00	186.11	87	95	176.95	172.13	
90	27	225.99	194.48	89	31	181.97	162.18	

Average	85.05	Average	96.07
S. Deviation	26.20	S. Deviation	22.01
Low price % of Avg	45.71	Low price % of Avg	58.83
Values < > 3 Std Removed	6.45	Values Greater Removed	162.10
High price % of Avg	159.58	High price % of Avg	145.12
STD % of avg	30.81	STD % of avg	22.91
	24.10		6.33

Table A11, Continued

	Hand	Mach	---Nominal---		---Real---		--Log Real--		P. P.
Year	Acres	Acres	Hand	Machine	Hand	Machine	Hand	Machine	Index
1982		90		116.00		116.00		4.754	100.00
1983		1238		67.20		66.34		4.195	101.30
1984	435	95	90.96	129.00	87.71	124.40	4.474	4.823	103.70
1985	849	1067	92.92	91.02	90.04	88.20	4.500	4.480	103.20
1986	270	1036	92.39	116.65	92.20	116.41	4.524	4.757	100.20
1987	213	833	104.87	125.61	102.02	122.19	4.625	4.806	102.80
1988	55	793	41.09	121.03	38.44	113.22	3.649	4.729	106.90
1989	43	31	61.88	181.97	55.15	162.18	4.010	5.089	112.20
1990	272	54	97.66	160.99	84.04	138.54	4.431	4.931	116.20

Source: Forest Management Division Records.

Table A12. Approximate Stages When Risks May Occur in Aspen and Red Pine Stands

Risk	Stages of Possible Attack
Aspen	
Bronze Leaf Disease	Sapling
Shoot Blight	Sapling
Gypsy Moth	All
Forest Tent Caterpillar	All (10-12 year cycles)
Poplar Borer	Sapling
Deer, Elk & Moose	1st 4 or 5 years
Rabbit	Seedlings
Red Pine	
Armillaria	All (New stands mainly)
Diplodia	Saplings
Bark Beetle	All
Jack Pine Budworm	All (10 year cycles)
Root Collar Weevil	All (10 year cycles)
Redheaded Pine Sawfly	Sapling (10 year cycles)
Saratoga Spittlebug	Seedlings and saplings 10 year cycles)
White Grubs	Seedlings (up to age 3-5)
Deer	Seedlings
Porcupine	Poles & up (older larger trees)
Drought	All
Flooding	All
Frost	Site related (seedlings & saplings)
Lightning	Poles

Source: Forest Management Division Records

APPENDIX B

PROBABILITY DISTRIBUTION CURVES

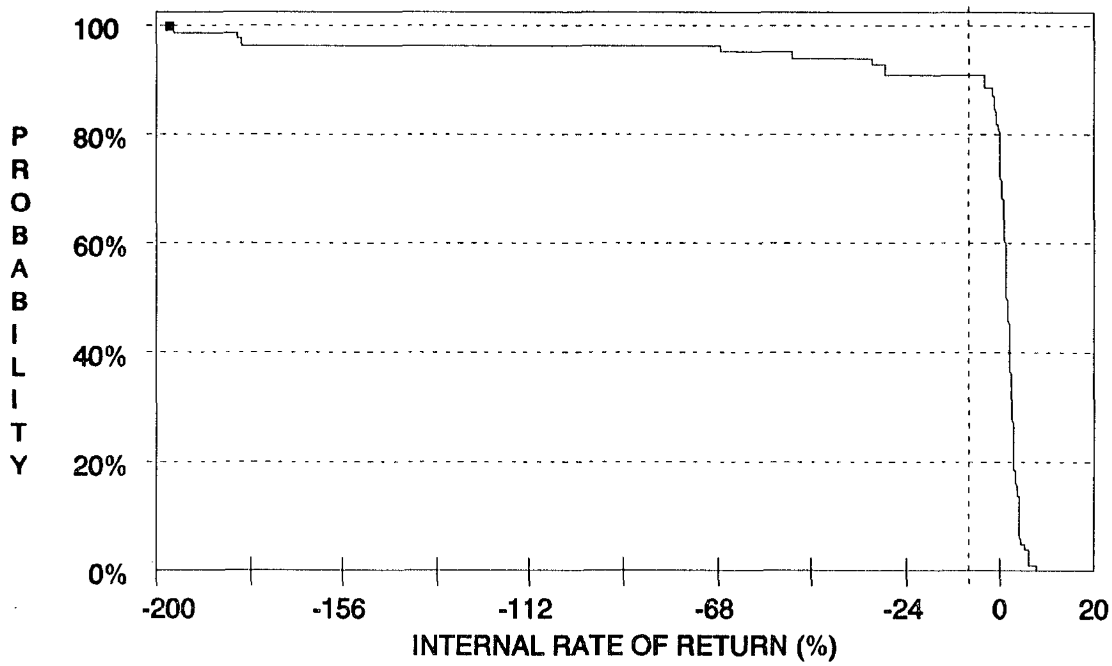

Figure 4. Inverted Cumulative Probability Distribution Curve for Aspen, Site Index 60, High Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

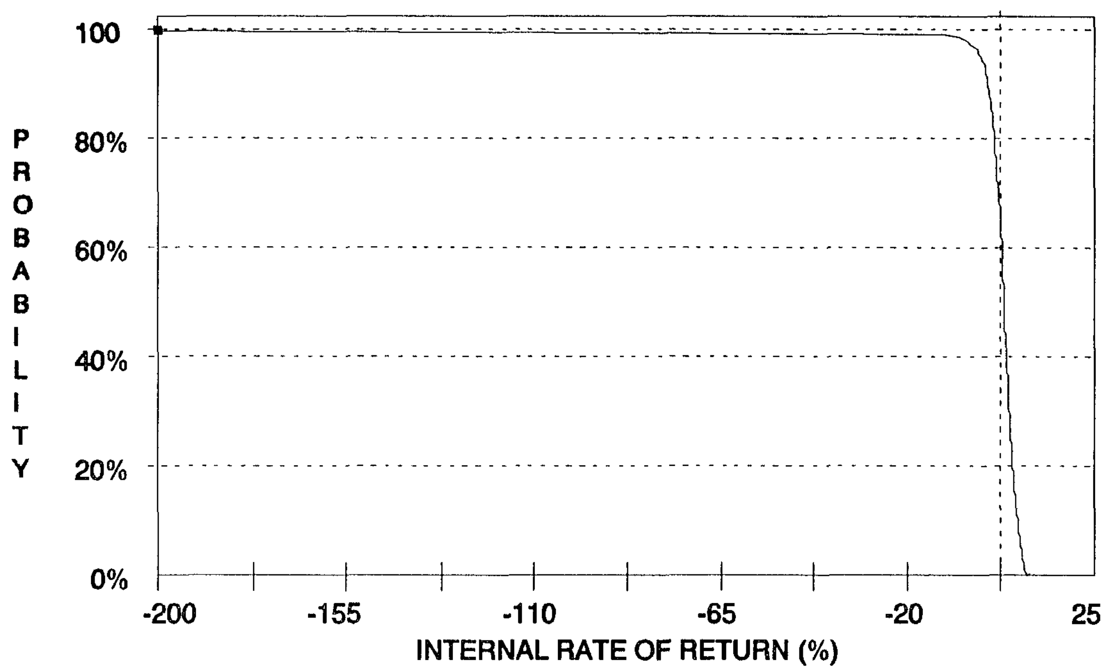

Figure 5. Inverted Cumulative Probability Distribution Curve for Aspen, Site Index 60, Moderate Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

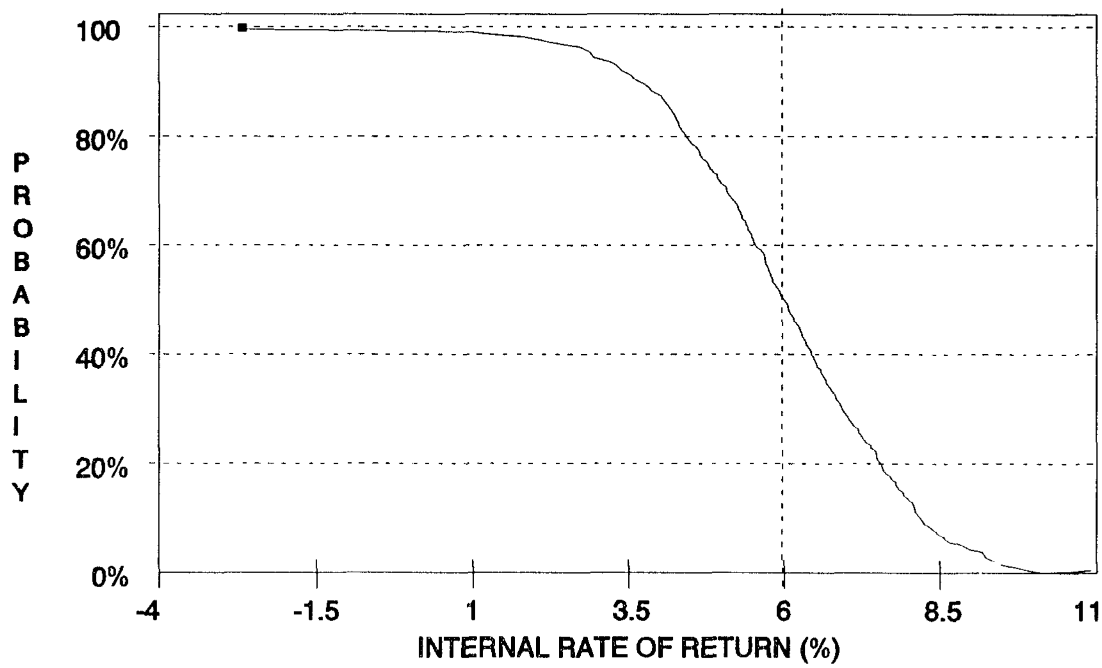

Figure 6. Inverted Cumulative Probability Distribution Curve for Aspen, Site Index 60, Low Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

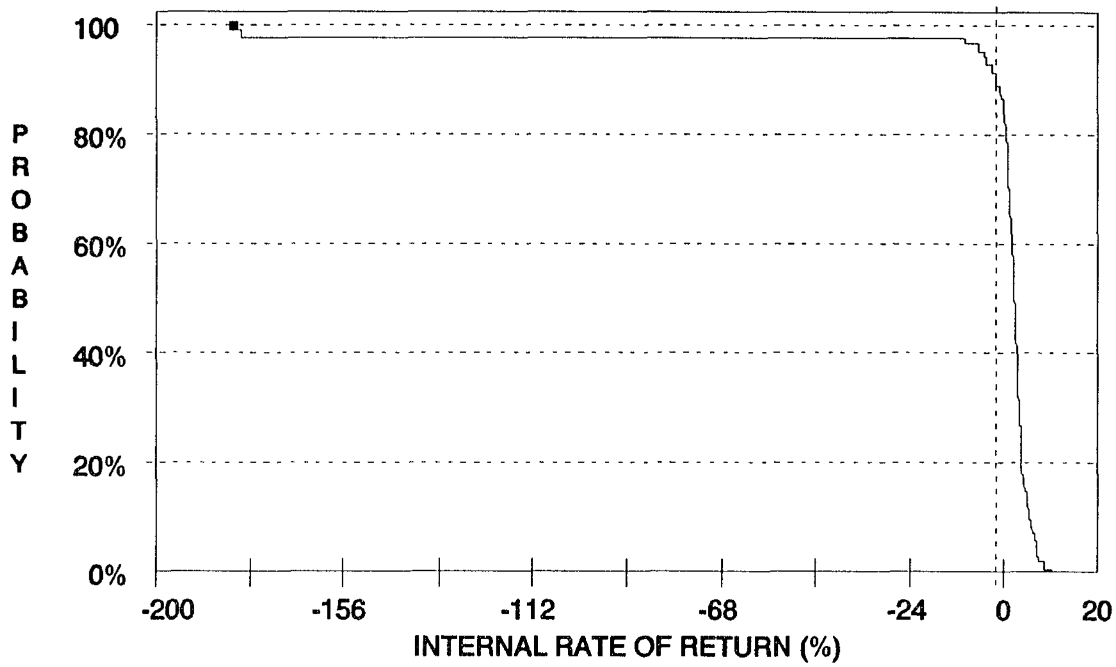

Figure 7. Inverted Cumulative Probability Distribution Curve for Aspen, Site Index 70, High Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

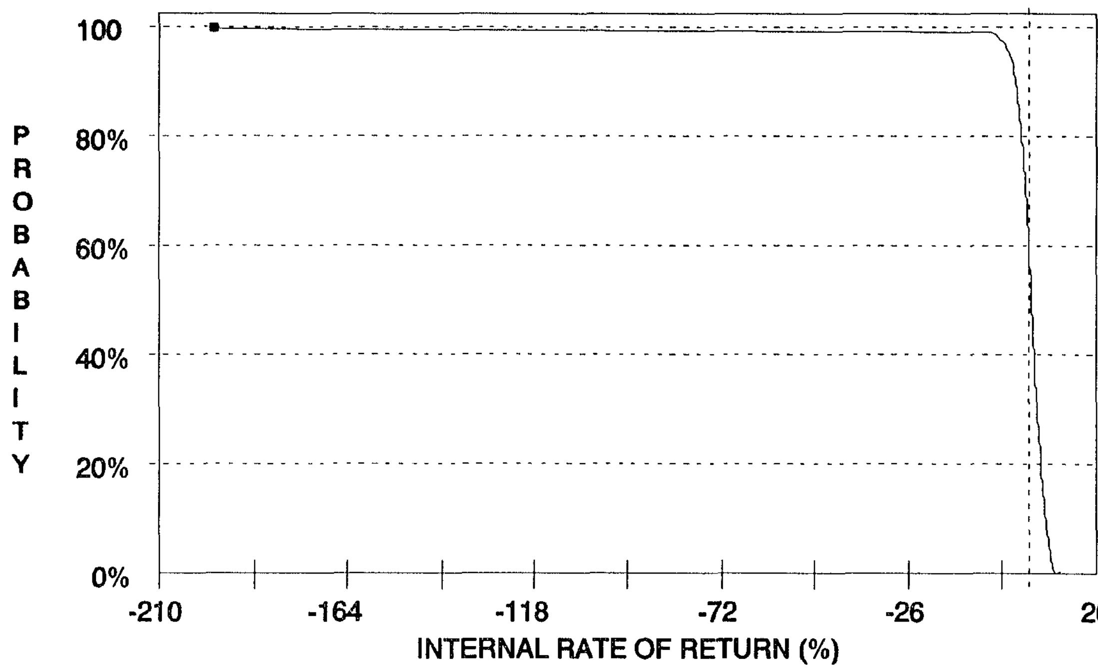

Figure 8. Inverted Cumulative Probability Distribution Curve for Aspen, Site Index 70, Moderate Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

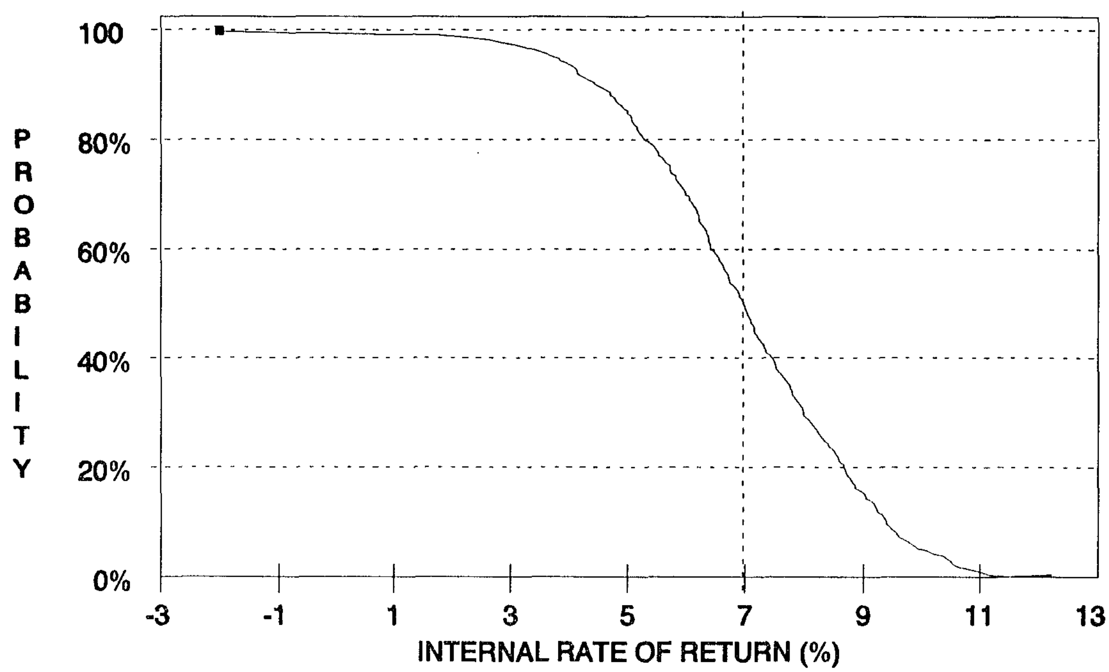

Figure 9. Inverted Cumulative Probability Distribution Curve for Aspen, Site Index 70, Low Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

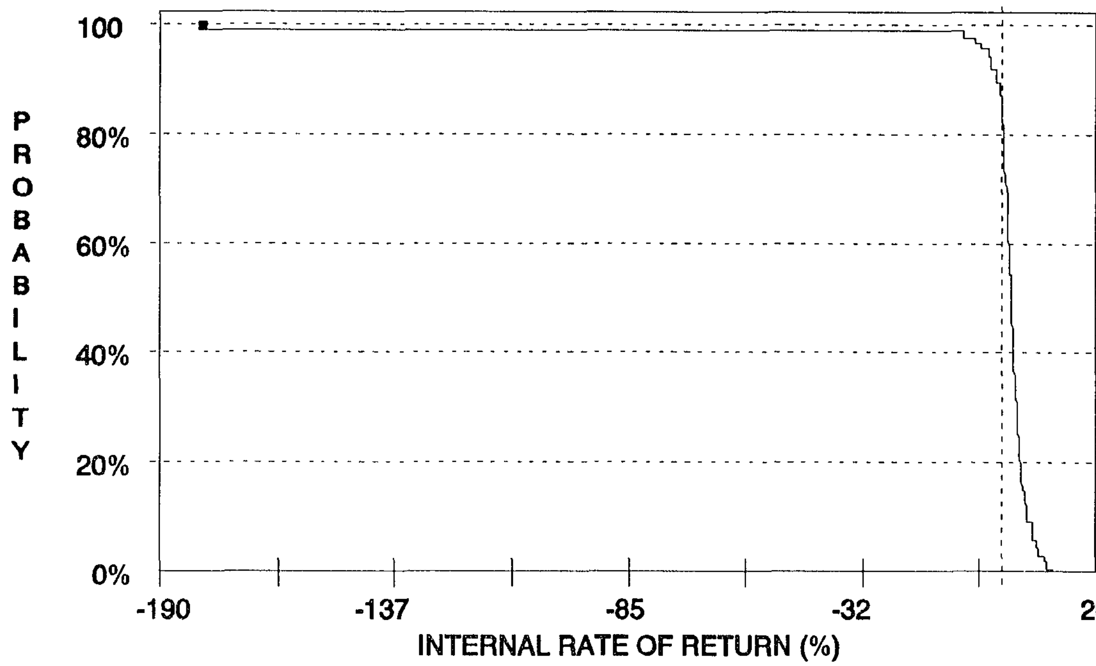

Figure 10. Inverted Cumulative Probability Distribution Curve for Aspen, Site Index 80, High Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

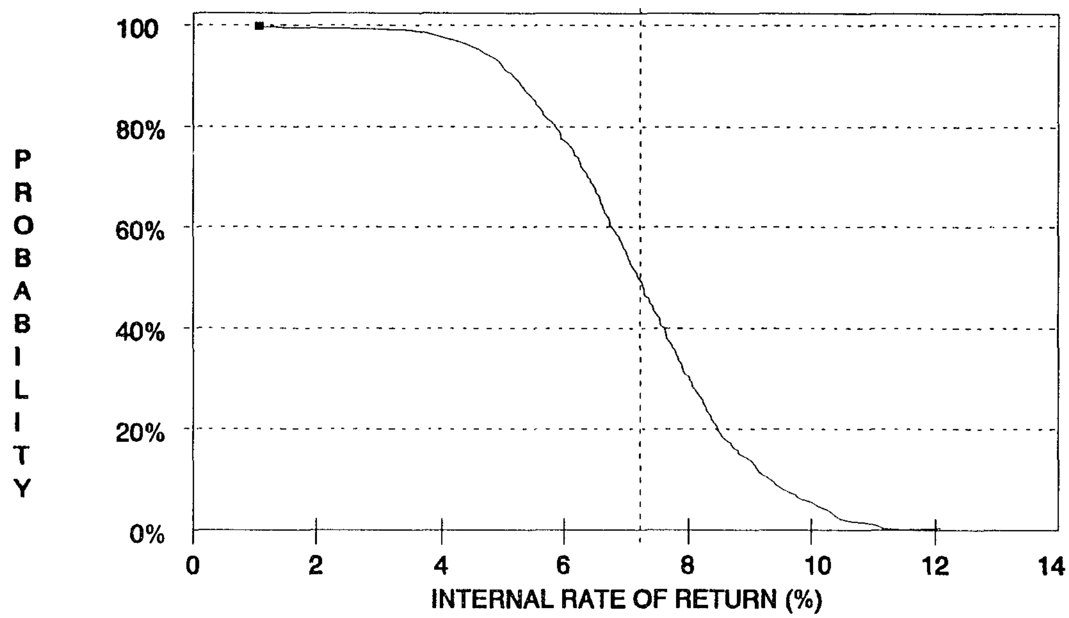

Figure 11. Inverted Cumulative Probability Distribution Curve for Aspen, Site Index 80, Moderate Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

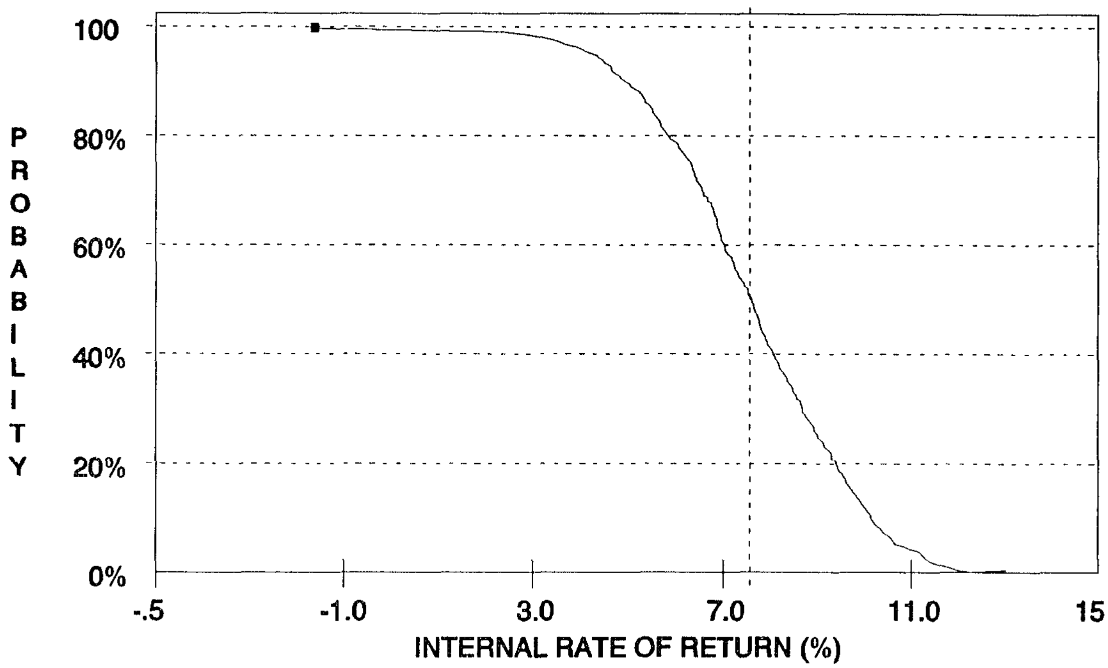

Figure 12. Inverted Cumulative Probability Distribution Curve for Aspen, Site Index 80, Low Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

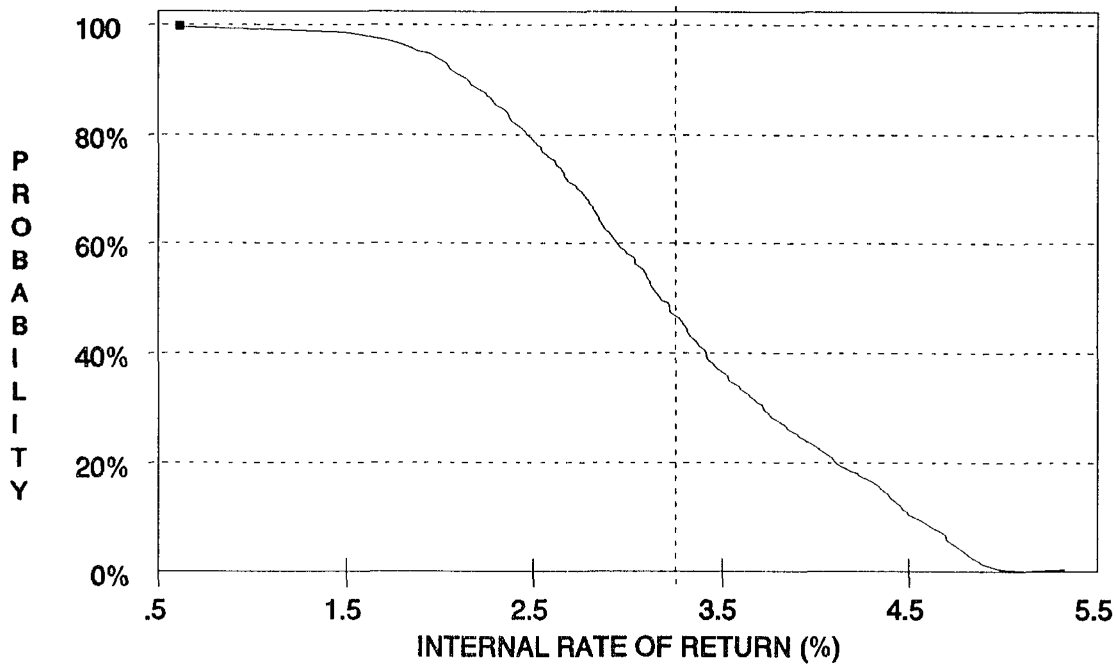

Figure 13. Inverted Cumulative Probability Distribution Curve for Red Pine, Site Index 50, High Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

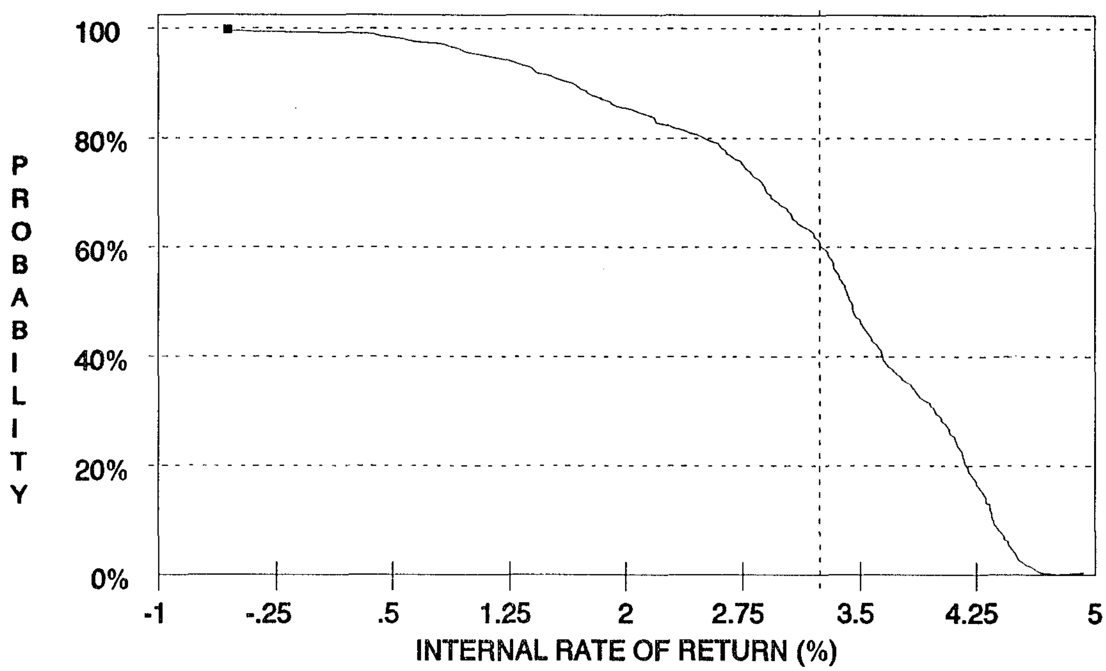

Figure 14. Inverted Cumulative Probability Distribution Curve for Red Pine, Site Index 50, Moderate Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

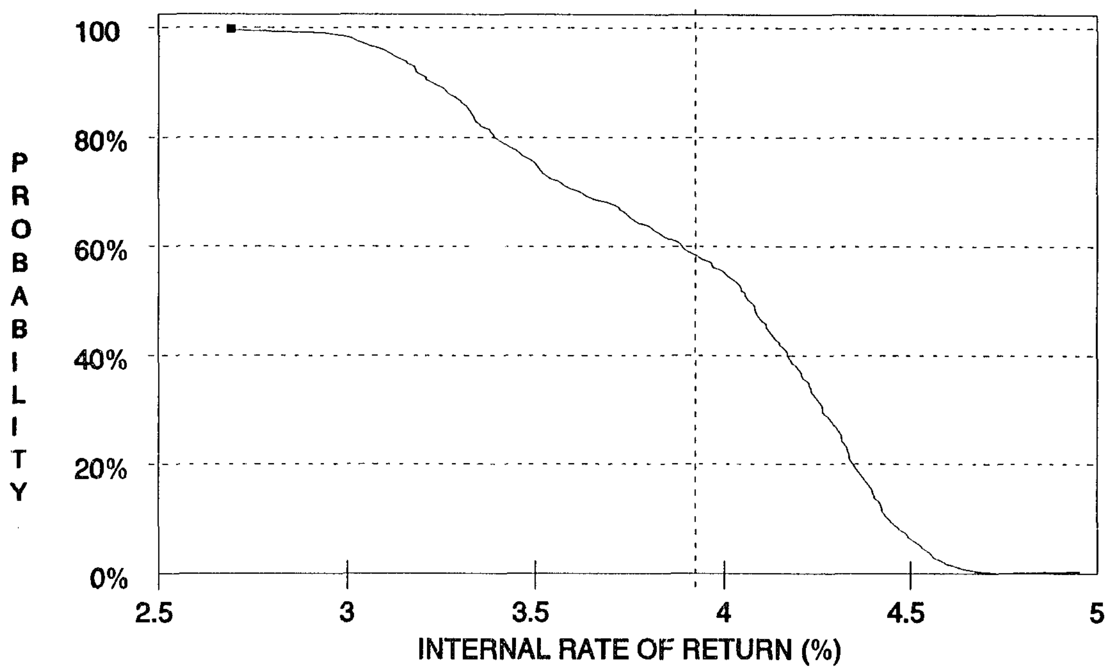

Figure 15. Inverted Cumulative Probability Distribution Curve for Red Pine, Site Index 50, Low Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

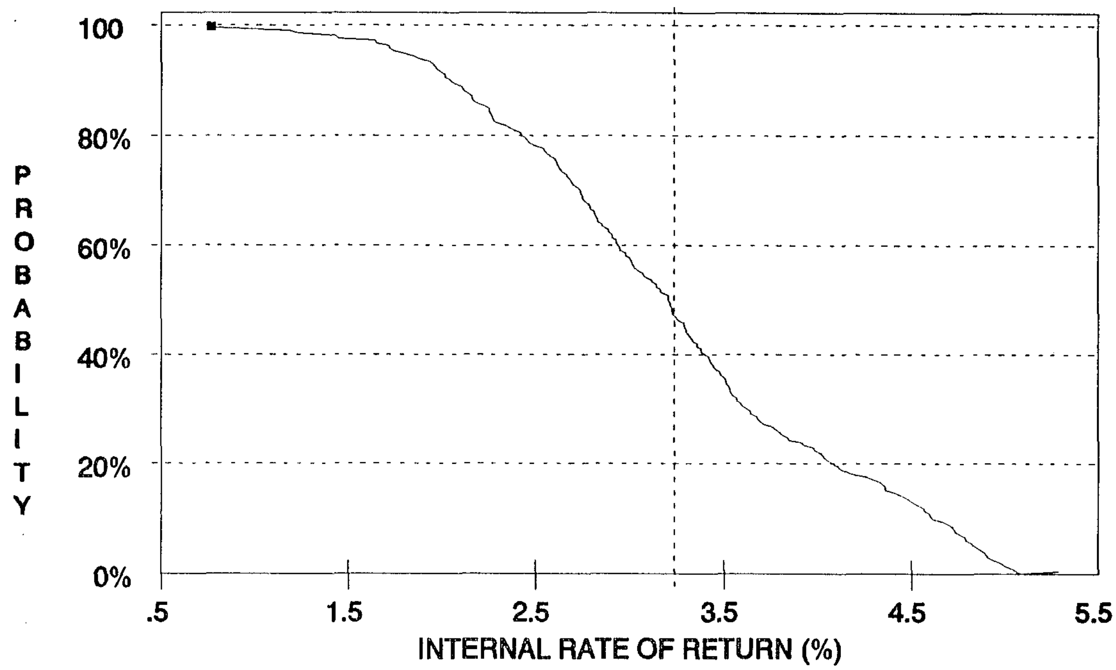

Figure 16. Inverted Cumulative Probability Distribution Curve for Red Pine, Site Index 60, High Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

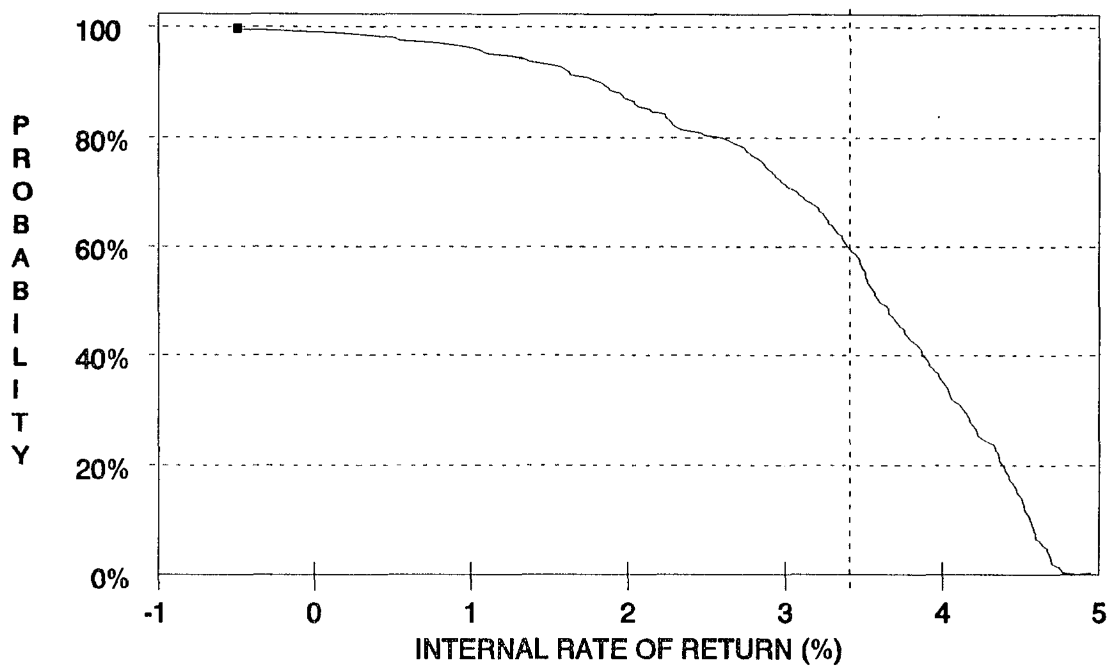

Figure 17. Inverted Cumulative Probability Distribution Curve for Red Pine, Site Index 60, Moderate Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

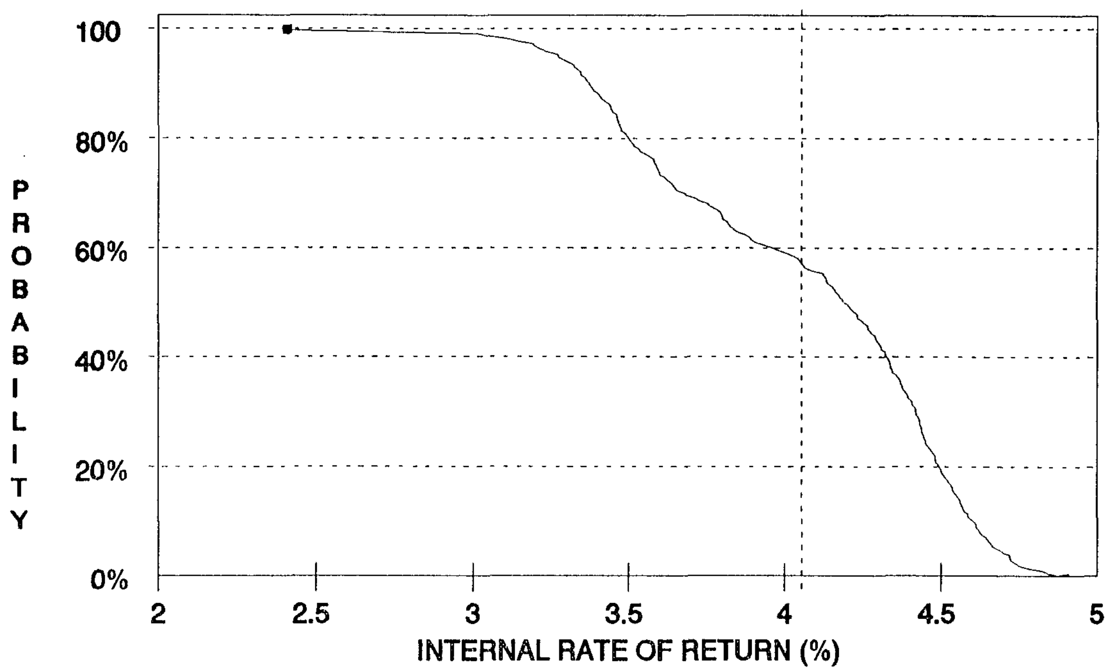

Figure 18. Inverted Cumulative Probability Distribution Curve for Red Pine, Site Index 60, Low Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

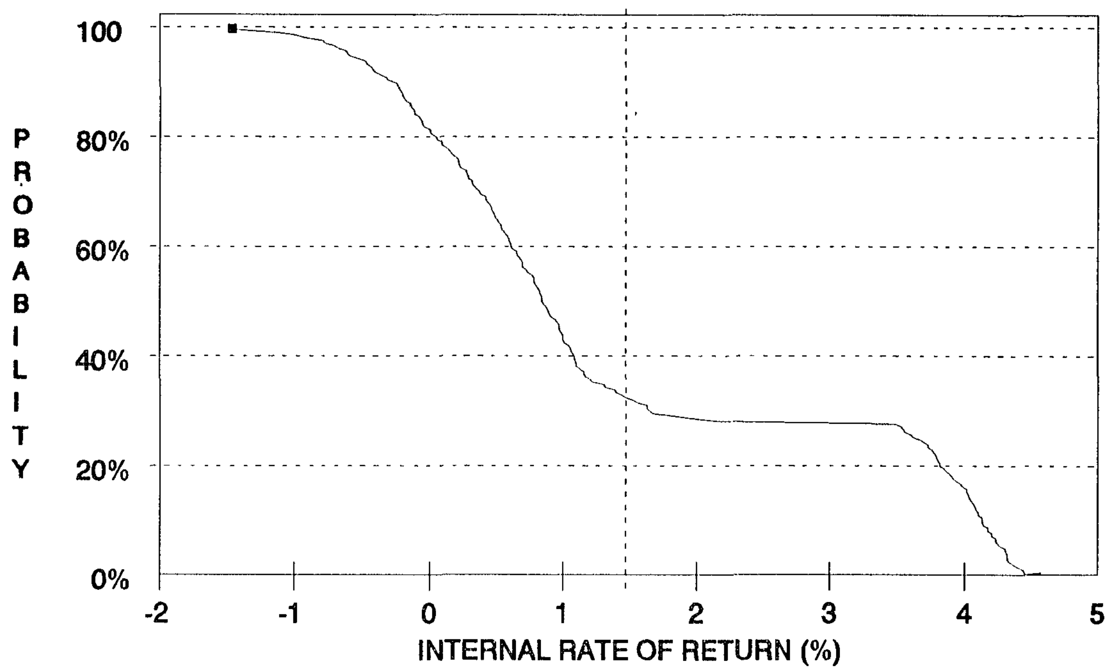

Figure 19. Inverted Cumulative Probability Distribution Curve for Red Pine, Site Index 70, High Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

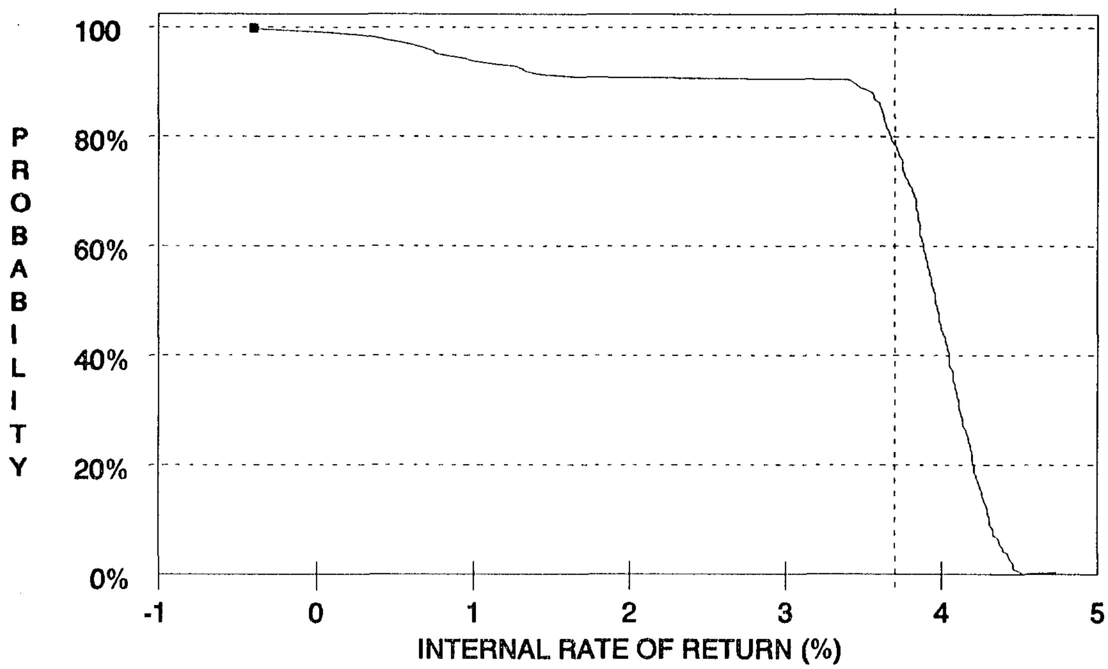

Figure 20. Inverted Cumulative Probability Distribution Curve for Red Pine, Site Index 70, Moderate Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

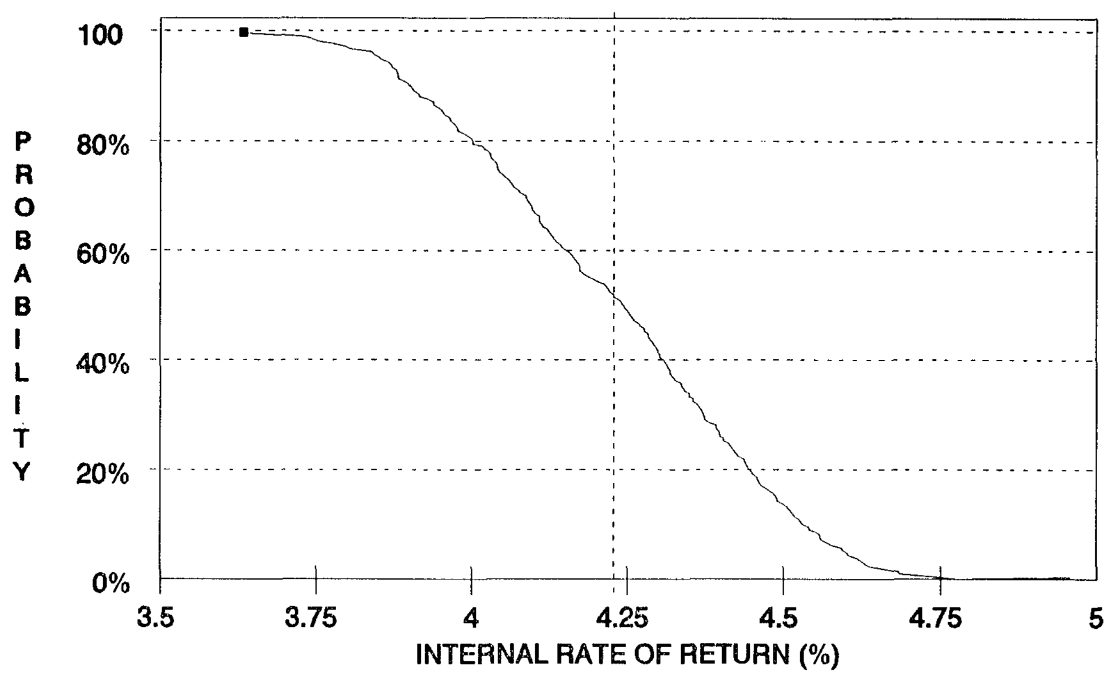

Figure 21. Inverted Cumulative Probability Distribution Curve for Red Pine, Site Index 70, Low Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

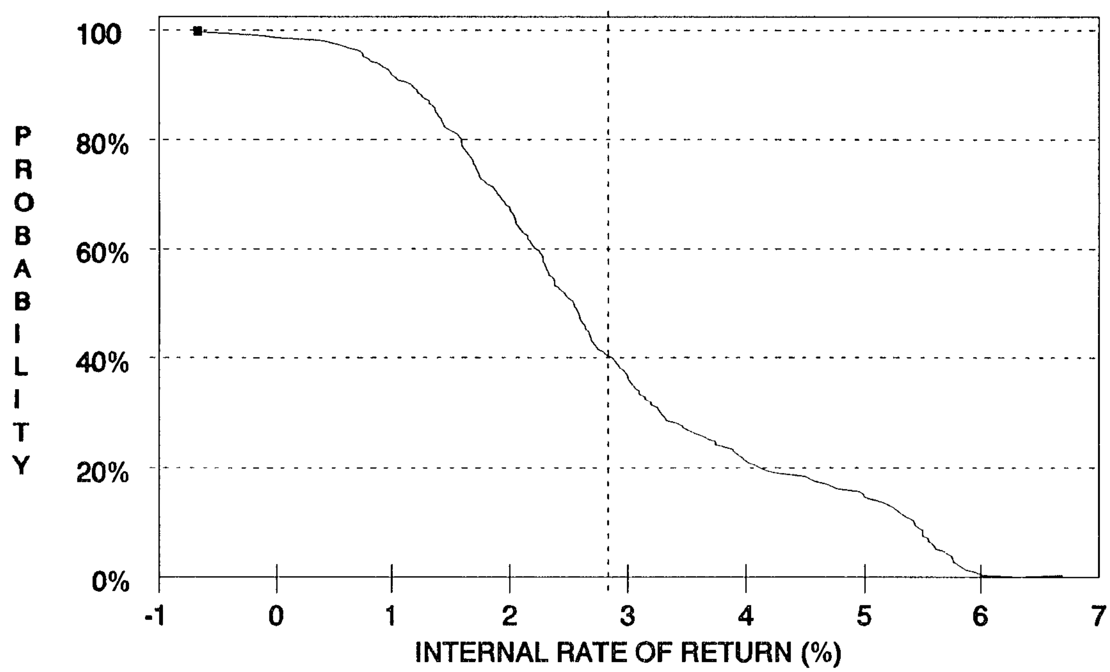

Figure 22. Inverted Cumulative Probability Distribution Curve for Red Pine, Site Index 80, High Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

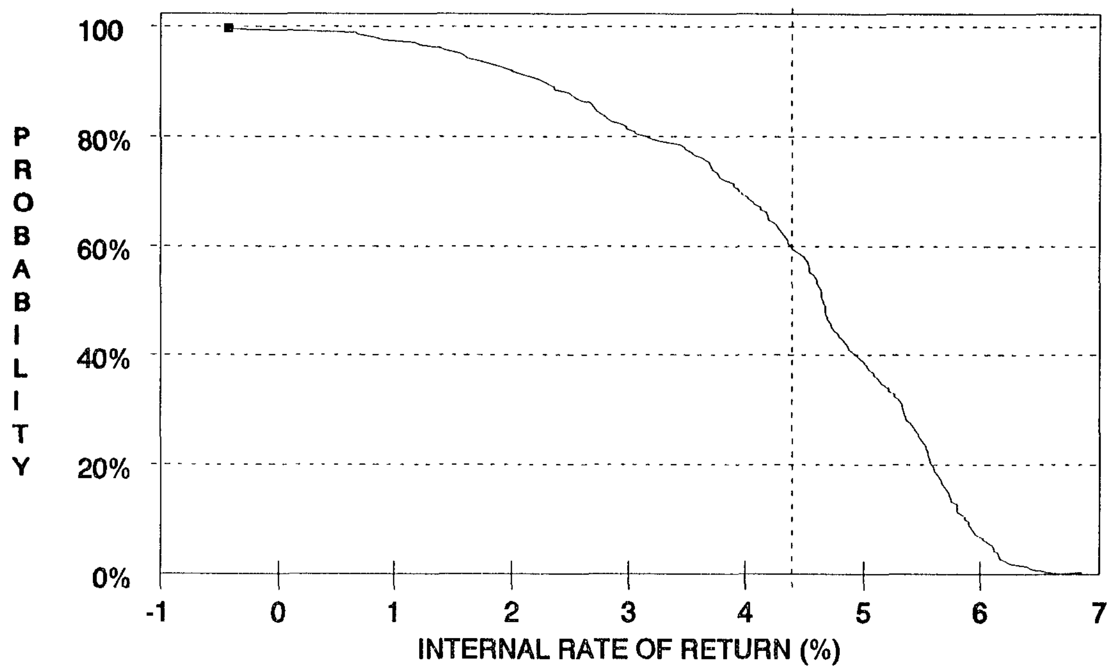

Figure 23. Inverted Cumulative Probability Distribution Curve for Red Pine, Site Index 80, Moderate Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

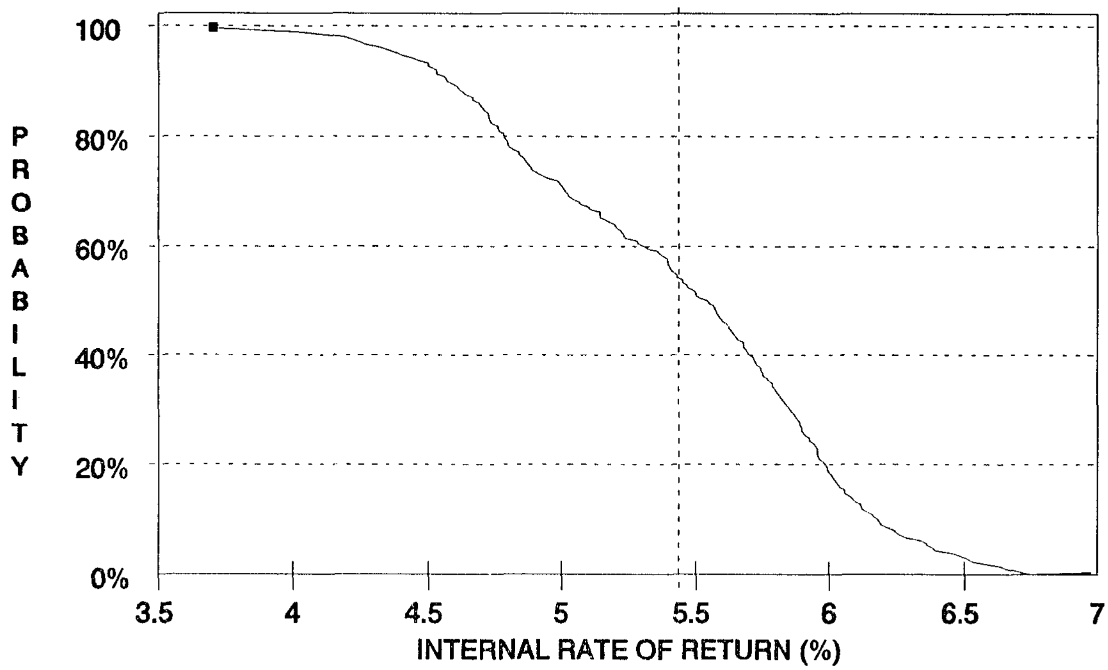

Figure 24. Inverted Cumulative Probability Distribution Curve for Red Pine, Site Index 80, Low Risk Site.

Note: Vertical dashed line is the Expected Value of IRR.

APPENDIX C

RISK IDENTIFICATION SUMMARY

POTENTIAL BIOPHYSICAL RISKS of ASPEN AND RED PINE

Below is the summary of a November 17, 1989, meeting with William Botti, Frank Sapio, Robert Heyde and Ronald Murray of the MDNR Forest Management Division, and Dr. Larry Leefers of Michigan State University. The purpose of this meeting was to identify biophysical risks that may impact growth and yield of aspen and red pine in Michigan.

Tables C1 through C8 summarizes the comments given by the experts about biophysical risks that may impact growth and yield of aspen and red pine.

Table C1. Diseases that May Attack Aspen

Diseases	**Expected Loss**	**Comments**
Bronze Leaf	DNK	Extent of damage not yet determined.
Shepard's crook	None	No impact
Hypoxylon canker	None	No impact
Heart rot	None	Old age problem in aspen
Shoot blight	None	Not a particularly serious problem

DNK - Panel members do not know.

Table C2. Insects That May Attack Aspen Stands

Insects	**Expected Loss**	**Comments**
Agrilus horni	None	No impact
Aspen leaf rollers	None	No impact
Gypsy moth	DNK	Potential problem; may cause repeated defoliation; hybrid aspen may be resistance because of leathery leaves.
Forest caterpillar	DNK	May cause repeated defoliation.
Large aspen tortix	None	Not a problem
Poplar borer	DNK	Big problem

DNK - Panel members do not know.

Table C3. Animals That May Attack Aspen Stands

Animals	Expected Loss	Comments
Deer	DNK	Potential for damage, but extent of damage unknown; can minimize damage by planting in 20 acre blocks, fencing or other barriers and avoiding areas with large population of deer; can risk rate stand for control.
Elk, Moose & Rabbit	DNK	Same as for deer

DNK - Panel members do not know.

Table C4. Weather Related Risks of Aspen

Weather Factors	Expected Loss	Comments
Drought	DNK	Site prep with herbicide can prevent mortality caused by lack of moisture; once stand is established, drought is not a problem unless competition from grass; planting seedlings below root collar helps with drought problem.
Flooding	None	Avoid planting in flood plain
Frost	DNK	Good site selection can prevent most damage
Hail	None	No impact
Ice	None	No impact
Lightning	None	No impact
Snow breakage	None	No impact
Sunscall	None	No impact
Wind	None	No impact
Fire	None	Not a problem in aspen stands

DNK - Panel members do not know.

Table C5. Diseases That May Attack Red Pine Stands

Diseases	Expected Loss	Comments
Annosus root rot	None	No impact
Armillaria	1-30%	Affect stands up to age 30; whole tree mortality; if no birch or oak, stand loss is 1-2% if oak or birch is present, loss 15-30%.
Diplodia	0-1%	No impact
Needle blight	None	No impact
Shoot blight	None	No impact
Scleroderris	1-5%	Site & weather related; probability of occurrence low if proper site is selected; occasional spots in red pine; stay away from pockets; mortality occurs in seedlings only.

Table C6. Insects That May Attack Red Pine Stands

Diseases	Expected Loss	Comments
Bark beetles	1-20%	Causes include improper harvesting, drought, low site indices; consider drought cycle that occurs every 10 years; damaged trees are salvageable; scattered losses; data is available from Sapio.
European pine moth	None	Declining problem
Gypsy moth	None	No impact
Jack pine budworm	0-5%	Occurs in 10 year cycles; can be eliminated with good site selection; SI 50 or greater for red pine.
Pine webworm	None	No impact
Root collar weevils	0-5%	Not a problem in the UP; if risk rated, loss is minimal.
Saratoga spittlebug	DNK	Can be managed if sweet fir is treated; risk rate site.
Redheaded sawfly	1-2%	Monitor/treat; could lose 50%, even with monitoring; more on low or stressed sites.
Pine shoot borer	0-1%	Problematic in stands 30 years or greater; no problem in UP recovers after a period of time; in LP, height growth affected, no diameter loss, but not a big problem; 1% may be growth loss in terms of height, not diameter; a declining problem.
Tussock moth	None	No impact
White grub	10-15%	10-15% mortality in 1-2 year old trees; whole tree mortality; difficulty to quantify; if planting follows pine, no problem; widespread in UP; lowering of production and mortality.

DNK - Panel members do not know.

Table C7. Animals That May Attack Red Pine

Animal	Expected Loss	Comments
Deer	0-40%	Problem in some areas; red pine can't be planted in UP where you have 70 deer per sq mile; increase size of planting; can risk rate stand to control; a geographical problem; mainly small seedlings are affected.
Hare	None	No impact
Mice	None	No impact
Porcupine	1-2%	Kill tops of product already there; few stands are affected; detection is a problem; mainly small trees are damaged.
Red squirrels	None	Beneficial impacts
Moose	None	No impact
ORV's	None	No impact

Table C8. Weather Related Risks of Red Pine

Weather	**Expected Loss**	**Comments**
Drought	DNK	Similar impact as bark beetle; check mortality figures; some yield tables have factored in mortality.
Flooding	None	Potential big problem
Frost	None	Potential big problem
Hail	None	No impact
Ice	None	No impact
Lightning	DNK	Relationship between bark beetle; difficult to quantify
Snow breakage	Slight	Problem in eastern UP with breakage; not sure of growth impacts; affects seedlings primarily.
Wind	DNK	A factor if stand is over thinned.
Fire	DNK	Proper site selection will decrease risk, more a problem of location.

DNK - Respondents do not know

Table C9. Biophysical Risks Identified as Significant by Panel Members for Aspen and Red Pine

Aspen	Red Pine
Bronze Leaf Disease	Armillaria
Shoot Blight	Diplodia
Gypsy Moth	Bark Beetle (Ips pini)
Forest Tent Caterpillar	Jack Pine Budworm
Poplar Borer	Pine Root Collar Weevils
Porcupine	Redheaded Pine Sawfly
Deer, Elk or Moose	Saratoga Spittlebug
Rabbit	White Grubs
Drought	Porcupine
Flooding	Deer, Elk or Moose
Frost	Rabbit
Lightning	Drought
	Flooding
	Frost
	Lightning

APPENDIX D

QUESTIONNAIRE

ASSESSING RISKS FOR INVESTMENTS IN IMPROVED ASPEN AND RED PINE TYPES IN THE PROPOSED MICHIGAN FOREST DEVELOPMENT FUND

JOB TITLE______________________________ **LOCATION**___________________________

We are doing a study to assess the inclusion of risk for investments in improved aspen and red pine on State forest lands in Michigan. As part of this study, we are conducting a survey of forest management experts in Michigan who have extensive knowledge of the effects of insects, diseases, animals, and other natural factors on improved aspen and red pine stands. We value your extensive knowledge, experience, and judgement; they are crucial to the success of our study. Your assistance in helping us assess these investment risks is appreciated.

The conceptual framework for the study is to compare the results of an analysis of several management regimes by the Forest Management Division using a deterministic model (fixed costs, prices and yields) with results when risks are included in the analysis (i.e., costs, prices, and yields vary due to risks). Our survey instrument is several pages in length, and it is divided into 2 sections. Section I seeks data for red pine on: 1) the effects of insects, diseases, animals, and other natural factors; 2) possible treatments to reduce losses; and 3) treatment costs. Section II seeks similar information for improved aspen. If there are questions, contact Ron Murray (517 373-1275, Michigan Department of Natural Resources) or Carter Catlin (303 498-1760, Land Management Planning - Ft. Collins, CO.).

PURPOSE: The objective of the study is to assess the impact various risks have on the outcome of investments in improved aspen and red pine. Our questionnaire is designed to obtain data to help us determine the impact insects, diseases, animals, and other natural factors have on growth and yield.

GENERAL INFORMATION: Pests and weather injury problems believed to have a significant impact on the growth and yield of aspen and red pine are listed in the attached questionnaire. This list is based on an informal survey of pest specialists in Michigan who are familiar with those problems. Risks that are not likely to significantly affect growth and yield are listed in Appendix A. If you feel any of these were excluded improperly, they can be inserted at appropriate locations in the questionnaire.

With this survey data, we hope to answer several types of questions, such as: 1.) What is the chance of occurrence for each risk? 2.) What is the reduction in growth and yield if the stand is attacked by a specific risk? 3.) If the stand is monitored and treated to reduce the injury, what is the approximate overall reduction in growth and yield in the stand? 4.) If the stand is not treated to reduce the injury, what is the overall reduction in growth and yield in the stand? 5.) What age is the injury most likely to occur? 6.) When the stand requires treatment, what are the treatment costs for each treatment and how many treatments are required?

It would be appreciated if you would provide as much information as possible, but leave blank any section you do not feel you can complete with confidence. Your response should be drawn from in-house sources or actual experiences. We prefer your best estimates based on your experience and knowledge of the risk as it relates to aspen or red pine stands. If, for example, in your judgement the likelihood of an attack by a given pest is very low, your response should reflect a very low chance of occurrence. Your response should be based on your experience as to what you have seen over the years in stands.

A brief description of the management regimes for red pine and aspen is included at the beginning of Section I and II of the questionnaire. More detail descriptions of the regimes assumed are available from the Forest Development Fund Five Year Plan.

In developing the questionnaire, it is acknowledged that a) some risks are more likely to occur in one region of the state vs. another region; b) the occurence of some risks may depend upon specific site characteristics; and c) there are interdependencies and interrelationships between some risks. When formulating a response, however, keep in mind the specific goals, scenarios, qualifications, and management strategies for each species.

The questionnaire contain questions concerning 3 levels of site risks. Generally, these sites are identified as:

High Risk - site where known risk(s) are present in abundance and not treated
Moderate Risk - site where some of the known risk(s) are present
Low Risk - site where known risk(s) are absence

The questionnaire also request information on treatment costs for the various risks. These costs are categorized as:

Maximum - treatment for the most severe infestation
Average - treatment for the average attack level
Minimum - treatment for the less severe attack

Direct Costs - include labor/wage payments, materials, supplies, equipment use, and overhead.

The source of the costs reported are:

Mostly actual data |__| Mostly estimates |__| Other Source____________________

These costs are for the following year(s) ______________________________

DATA FROM YOUR COMPLETED QUESTIONNAIRE WILL BE KEPT CONFIDENTIAL AND USED ONLY TO HELP DERIVE A PROBABILITY OF OCCURRENCE FOR THE IDENTIFIED RISKS.

SECTION I - MANAGEMENT REGIME for RED PINE PLANTING

Goal: To establish red pine on sites that are:
1. currently non-stocked but would support good red pine growth and
2. reforestation of stands capable of producing good red pine following the harvest of red pine, jack pine, or hardwoods.

Qualification for Red Pine Site:
1. site index for red pine 50 or greater
2. site must be at least 10 contiguous acres in size
3. management objective must be red pine
4. have no history of past attempts to plant red pine that have failed for reasons that cannot be fully explained or are likely to be repeated if the current attempt is made.

Management:
Seedlings grown in the State nursery will be planted on a 6x8 foot spacing (908 trees/acre) in most cases. Variations in stock source may be necessary occasionally if nursery production cannot meet the demand due to unforeseen circumstances. Spacing may vary somewhat, if deemed appropriate, but the number of trees per acre planted should remain between 900 and 1,000 trees per acre. Planting stock will be 2-0 or 3-0 stock from a known Michigan seed source.

Stands will be managed for pulpwood, poles and sawtimber. The planned thinning regimes and rotations are listed below.

	Site Index				Residual
	50	**60**	**70**	**80**	**Basal Area**
First Thinning @ Year	40	30	30	20	90
Second Thinning	50	40	40	30	100
Third Thinning	60	50	50	40	110
Fourth Thinning			60	50	120
Final Harvest	70	60	70	60	0

Planting sites will be risk rated. High risk sites will be avoided to the degree possible, that is, sites that are determined to be highly susceptible to possible attack by diseases, insects, animals and weather related impacts.

Given the goal, qualifications, and management strategy for red pine as shown above, please answer the questions that follow for each risk based on your knowledge, experience, and judgement.

ARMILLARIA ROOT ROT (Shoestring) **Red Pine**

1. Consider 300 recently planted stands on 100 high, 100 moderate & 100 low risk sites at your location. During the rotation of these stands, what number would you expect to see an attack by **ARMILLARIA?**

High Risk site - multiple stress factors present or abundant presence of one stress factor	
Moderate risk site - stress factors present, e.g. cutover hardwoods	
Low risk site - few obvious stress factors present	

2. In a typical stand that is attacked, what would you predict as an overall percentage reduction in total stand volume or growth over the rotation?

High risk site	%
Moderate risk site	%
Low risk site	%

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of an attack?

	Poles to	Sawtimber to		Pulp to
	Saw	Pulp	Cull	Cull
High risk site				%
Moderate risk site				%
Low risk site				%

COMMENTS:

DIPLODIA SHOOT BLIGHT AND CANKER **Red Pine**

1. Consider 300 recently planted stands on 100 high, 100 moderate & 100 low risk sites at your location. During the rotation of these stands, what number would you expect to see an attack by DIPLODIA?

High Risk site - multiple stress factors present or abundant presence of one stress factor	
Moderate risk site - stress factors present, e.g. snow damage	
Low risk site - no entry points present, stands not stressed	

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

High risk site	%
Moderate risk site	%
Low risk site	%

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of an attack?

	Poles to	**Sawtimber to**		**Pulp to**
	Saw	**Pulp**	**Cull**	**Cull**
High risk site				%
Moderate risk site				%
Low risk site				%

COMMENTS: ____

BARK BEETLE - Pine Engraver Beetle (Ips pini) **Red Pine**

1. Consider 300 recently planted stands on 100 high, 100 moderate & 100 low risk sites at your location. During the rotation of these stands, what number would you expect to see an attack by the ENGRAVER BEETLE (assume normal annual rainfall)?

High Risk site - abundant presence of injured, dead, or dying trees	
Moderate risk site - injured, dead, or dying trees present	
Low risk site - few injured, dead, or dying trees present	

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

High risk site	%
Moderate risk site	%
Low risk site	%

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of an attack?

	Poles to	Sawtimber to		Pulp to
	Saw	Pulp	Cull	Cull
High risk site				%
Moderate risk site				%
Low risk site				%

COMMENTS:

1. Consider 300 recently planted stands on 100 high, 100 moderate & 100 low risk sites at your location. During the rotation of these stands, what number would you expect to see an attack by JACK PINE BUDWORM?

High Risk site - abundant presence of older, taller jack pine near stand	
Moderate risk site - a few older, taller jack pine adjacent	
Low risk site - no older, taller jack pine near stand	

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Without Treatment	With Treatment
High risk site		%
Moderate risk site	%	\\\\\\\\\\\\\\\\\\\
Low risk site	%	\\\\\\\\\\\\\\\\\\\

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of this attack?

	Without Treatment				With Treatment			
	Poles to	Saw to		Pulp to	Poles to	Saw to		Pulp to
	Saw	Pulp	Cull	Cull	Saw	Pulp	Cull	Cull
High site								
Moderate site				%	\\\\\	\\\\	\\\\	\\\\
Low site				%	\\\\\	\\\\	\\\\	\\\\

4. Possible treatments to reduce losses are identified below. If treated, which of these or other treatments would you recommend?

Treatments	Treatment Applied		Cost Per Treatment ($/Ac) (Direct Costs Only)		
	Age(s)	Number	Maximum	Average	Minimum
Bacillus thuringinesis (Dipel, Thuricide)					
Carbaryl (Sevin)					

COMMENTS:____

PINE ROOT COLLAR WEEVILS **Red Pine**

1. Consider 300 recently planted stands on 100 high, 100 moderate & 100 low risk sites. During the rotation of these stands, what number would you expect to see an attack by PINE ROOT COLLAR WEEVILS?

High site - infestation source less than 1/2 mile from stand	
Moderate site - infestation source 1/2 mile from stand	
Low risk site - infestation source more than 1/2 mile from stand	

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Without Treatment	With Treatment
High risk site		%
Moderate risk site	%	\\\\\\\\\\\\\\\\
Low risk site	%	\\\\\\\\\\\\\\\\

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of this attack?

	Without Treatment				With Treatment			
	Poles to	Saw to		Pulp to	Poles to	Saw to		Pulp to
	Saw	Pulp	Cull	Cull	Saw	Pulp	Cull	Cull
High site								
Moderate site				%	\\\\\	\\\\	\\\\	\\\\
Low site				%	\\\\\	\\\\	\\\\	\\\\

4. What treatments would you recommend to reduce losses?

Treatments	Treatment Applied		Cost Per Treatment ($/Ac) (Direct Costs Only)		
	Age(s)	Number	Maximum	Average	Minimum

COMMENTS: ____

____

____

1. Consider 300 recently planted stands on 100 high, 100 moderate & 100 low risk sites. During the rotation of these stands, what number would you expect to see an attack by attack by the REDHEADED PINE SAWFLY?

High site - abundant competition, soil moisture very low	%
Moderate site - some competing bushy vegetation soil moisture low	%
Low site - little competing vegetation, soil moisture good	%

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Without Treatment	With Treatment
High risk site		%
Moderate risk site	%	\\\\\\\\\\\\\\\\\\
Low risk site	%	\\\\\\\\\\\\\\\\\\

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of this attack?

	Without Treatment				With Treatment			
	Poles to	Saw to		Pulp to	Poles to	Saw to		Pulp to
	Saw	Pulp	Cull	Cull	Saw	Pulp	Cull	Cull
High site								
Moderate site				%	\\\\\	\\\\	\\\\	\\\\
Low site				%	\\\\\	\\\\	\\\\	\\\\

4. Possible treatments to reduce losses are identified below. If treated, which of these or other treatments would you recommend?

Treatments	Treatment Applied		Cost Per Treatment ($/Ac) (Direct Costs Only)		
	Age(s)	Number	Maximum	Average	Minimum
Carbaryl (Sevin)					
Malathion (Cythion)					
Insectidal Soap					

COMMENTS: ____________________

SARATOGA SPITTLEBUG **Red Pine**

1. Consider 300 recently planted stands on 100 high, 100 moderate & 100 low risk sites at your location. During the rotation of these stands, what number would you expect to see an attack by the SARATOGA SPITTLEBUG?

High risk site - sweetfern density or other low, woody vegetation greater than 30% of groundcover	%
Moderate risk site - sweetfern density or other low, woody vegetation 16 - 30% of groundcover	%
Low risk site - sweetfern density or other low, woody vegetation 0 - 15% of groundcover	%

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Without Treatment	With Treatment
High risk site		%
Moderate risk site	%	\\\\\\\\\\\\\\\\
Low risk site	%	\\\\\\\\\\\\\\\\

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of this attack?

	Without Treatment				With Treatment			
	Poles to	Saw to		Pulp to	Poles to	Saw to		Pulp to
	Saw	Pulp	Cull	Cull	Saw	Pulp	Cull	Cull
High site								
Moderate site				%	\\\\\	\\\\	\\\\	\\\\
Low site				%	\\\\\	\\\\	\\\\	\\\\

4. One possible treatment to reduce losses is given below. What other treatment(s) would you recommend?

Treatments	Treatment Applied		Cost Per Treatment ($/Ac) (Direct Costs Only)		
	Age(s)	Number	Maximum	Average	Minimum
Malathion (Cythion)					

COMMENTS: ____________________

1. Consider 300 recently planted stands on 100 high, 100 moderate & 100 low risk sites. During the rotation of these stands, what number would you expect to see an attack by WHITE GRUBS?

High risk site - high grub population, site not treated	
Moderate risk site - grub present near threshold numbers, untreated site	
Low risk site - no obvious indicator of grubs or site treated	

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Without Treatment	With Treatment
High risk site		%
Moderate risk site	%	\\\\\\\\\\\\\\\\
Low risk site	%	\\\\\\\\\\\\\\\\

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of this attack?

	Without Treatment				With Treatment			
	Poles to	Saw to		Pulp to	Poles to	Saw to		Pulp to
	Saw	Pulp	Cull	Cull	Saw	Pulp	Cull	Cull
High site								
Moderate site				%	\\\\\	\\\\	\\\\	\\\\
Low site				%	\\\\\	\\\\	\\\\	\\\\

4. One possible treatment to reduce losses is given below. What other treatment(s) would you recommend?

Treatments	Treatment Applied		Cost Per Treatment ($/Ac) (Direct Costs Only)		
	Age(s)	Number	Maximum	Average	Minimum
Dursban					

COMMENTS: ____________________

1. Consider 100 recently planted red pine stands at your location. During the rotation of these stands, what number would you expect to see a significant impact by DEER causing:

Less than 20% mortality and/or top kill	
More than 20% mortality and/or top kill	

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Without Treatment	With Treatment
Less than 20% mortality and/or top kill		%
More than 20% mortality and/or top kill		%

3. Possible treatments to reduce losses are identified below. Which of these or other treatments would you recommend?

	Treatment Applied		Cost Per Treatment ($/Ac) (Direct Costs Only)		
Treatments	Age(s)	Number	Maximum	Average	Minimum
Bone Tar Oil					
Capsaicin					
Fencing		\\\\\\			

COMMENTS: ____

PORCUPINE **Red Pine**

1. Consider 100 recently planted red pine stands at your location. During the rotation of these stands, what number would you expect to see a significant impact by PORCUPINE causing:

Less than 20% mortality and/or top kill	
More than 20% mortality and/or top kill	

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Without Treatment	With Treatment
Less than 20% mortality and/or top kill		%
More than 20% mortality and/or top kill		%

3. One possible treatment to reduce losses is given below. What other treatment(s) would you recommend?

Treatments	**Treatment Applied**		**Cost Per Treatment ($/Ac) (Direct Costs Only)**		
	Age(s)	**Number**	**Maximum**	**Average**	**Minimum**
Shooting	\\\\\\\\	\\\\\\			

COMMENTS: ____

1. Consider 100 recently planted red pine stands at your location. What would you estimate as the likelihood that these stands will incur damages during the rotation as a result of drought, flooding, frost and lightning? In a typical stand that is injured, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Likelihood of Occurrence	Reduction in Merchantable Volume
Drought	%	%
Flood	%	%
Frost	%	%
Lightning	%	%

COMMENTS: ______________________________

OTHER (SPECIFY) (See Appendix for List)

1. Consider 300 recently planted stands on 100 high, 100 moderate & 100 low risk sites at your location. During the rotation of these stands, what number would you expect to see an attack by ______________________________?

High risk site -	
Moderate risk site -	
Low risk site -	

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

High risk site	%
Moderate risk site	%
Low risk site	%

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of this attack?

	Without Treatment				**With Treatment**			
	Poles to	**Saw to**		**Pulp to**	**Poles to**	**Saw to**		**Pulp to**
	Saw	**Pulp**	**Cull**	**Cull**	**Saw**	**Pulp**	**Cull**	**Cull**
High site								
Moderate site				%	\\\\\	\\\\	\\\\	\\\\
Low site				%	\\\\\	\\\\	\\\\	\\\\

4. Possible treatments to reduce losses are identified below. Which of these or other treatments would you recommend?

Treatments	**Treatment Applied**		**Cost Per Treatment ($/Ac) (Direct Costs Only)**		
	Age(s)	**Number**	**Maximum**	**Average**	**Minimum**

COMMENTS:____

____

SECTION II - MANAGEMENT REGIME for IMPROVED ASPEN PLANTING

Goal:

To convert good quality northern hardwood sites which currently support sprout origin red maple or other relatively low value hardwoods to Improved Aspen.

Qualifications for Aspen Site:

1. Management objective must be Improved Aspen and/or treatment specified must be site conversion

2. Site index must be 50 or greater or northern hardwoods

3. Stand species composition, structure, quality, or other factors must preclude management for high quality hardwood products.

Management Strategy:

Seedlings grown in the State nursery will be planted on a spacing as recommended at the time of planting to establish 500 trees/acre. Variations in stock source may be necessary occasionally if nursery production cannot meet the demand due to unforeseen circumstances. Planting spacing may vary somewhat, if deemed appropriate, but the number of trees per acre planted should remain between 450 and 550 trees per acre. Planting stock will be Plug-1 or container stock from a known seed source and recommended by the Division.

Planting may be accomplished by a Division/Department crew or by contract. Decisions to machine vs. hand plant will be made based on the number, size, and distribution of planting sites as well as the topography and other physical characteristics of the planting site. Relative costs involved will be a major factor in this decision.

In instances where other ground vegetation is dense enough that it will interfere with establishment or growth of Improved Aspen regeneration, selective herbicide treatment, tiling, or furrowing to reduce that competition is needed.

Pest monitoring and control should be scheduled for major aspen pests known to occur throughout the life of the regime. Stands will be managed for pulpwood. The planned rotations are listed below.

	Site Index		
	60	70	80
Final Harvest @ Year	20	20	20
Final Harvest	40	40	40
Final Harvest	60	60	60

Given the goal, qualifications, and management strategy for aspen shown above, please answer the questions that follow based on your knowledge, experience, and judgement.

BRONZE LEAF DISEASE **Aspen**

1. Consider 300 recently planted stands on 100 high, 100 moderate & 100 low risk sites at your location. During the rotation of these stands, what number would you expect to see an attack by BRONZE LEAF DISEASE?

High risk site - stand located next to infested hardwoods	
Moderate risk site - stand located near infested hardwoods	
Low risk site - stand located away from infested hardwoods	

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Without Treatment	With Treatment
High risk site		%
Moderate risk site	%	\\\\\\\\\\\\\\\\
Low risk site	%	\\\\\\\\\\\\\\\\

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of this attack?

	Without Treatment Pulp to Cull	With Treatment Pulp to Cull
High risk site		%
Moderate risk site	%	\\\\\\\\\\\\\\\\
Low risk site	%	\\\\\\\\\\\\\\\\

4. Possible treatments to reduce losses are identified below. Which of these or other treatments would you recommend?

Treatments	Treatment Applied		Cost Per Treatment ($/Ac) (Direct Costs Only)		
	Age(s)	Number	Maximum	Average	Minimum

COMMENTS: ____________________

____

SHOOT BLIGHT **Aspen**

1. Consider 100 recently planted stands at your location. During the rotation of these stands, what number would you expect to see an attack by SHOOT BLIGHT?

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Without Treatment	With Treatment
		%

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of this attack?

	Without Treatment Pulp to Cull	With Treatment Pulp to Cull
		%

4. Possible treatments to reduce losses are identified below. Which of these or other treatments would you recommend?

Treatments	Treatment Applied		Cost Per Treatment ($/Ac) (Direct Costs Only)		
	Age(s)	Number	Maximum	Average	Minimum

COMMENTS:

GYPSY MOTH **Aspen**

1. Consider 300 recently planted stands on 100 high, 100 moderate & 100 low risk sites at your location. During the rotation of these stands, what number would you expect to see an attack by the GYPSY MOTH?

High risk site - stands located next to other infested hardwoods, especially black or white oaks	
Moderate risk site - stands located near other infested hardwoods, especially black or white oaks	
Low risk site - stands located away from other infested hardwoods, especially black or white oaks	

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Without Treatment	**With Treatment**
High risk site		%
Moderate risk site		%
Low risk site		%

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of this attack?

	Without Treatment Pulp to Cull	**With Treatment Pulp to Cull**
High risk site		%
Moderate risk site		%
Low risk site		%

4. Possible treatments to reduce losses are identified below. Which of these or other treatments would you recommend?

Treatments	**Treatment Applied**		**Cost Per Treatment ($/Ac) (Direct Costs Only)**		
	Age(s)	**Number**	**Maximum**	**Average**	**Minimum**
Bacillus thuringinesis (Dipel, Thuricide)					
Dimilin (Diflubenzvion)					

COMMENTS:____

FOREST TENT CATERPILLAR **Aspen**

1. Consider 100 recently planted stands at your location. During the rotation of these stands, what number would you expect to see an attack by the FOREST TENT CATERPILLAR?

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Without Treatment	With Treatment

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of this attack?

	Without Treatment Pulp to Cull	With Treatment Pulp to Cull

4. Possible treatments to reduce losses are identified below. Which of these or other treatments would you recommend?

Treatments	Treatment Applied		Cost Per Treatment ($/Ac) (Direct Costs Only)		
	Age(s)	Number	Maximum	Average	Minimum
BT					
Dimilin					

COMMENTS: ______________________________

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____

____

POPLAR BORER **Aspen**

1. Consider 100 recently planted stands at your location. During the rotation of these stands, what number would you expect to see an attack by the POPLAR BORER?

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Without Treatment	With Treatment

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of this attack?

	Without Treatment Pulp to Cull	With Treatment Pulp to Cull

4. Possible treatments to reduce losses are identified below. Which of these or other treatments would you recommend?

Treatments	Treatment Applied		Cost Per Treatment ($/Ac) (Direct Costs Only)		
	Age(s)	Number	Maximum	Average	Minimum

COMMENTS:

1. Consider 100 recently planted aspen stands at your location. During the rotation of these stands, what percent would you expect to see injury to plants by DEER, ELK or MOOSE resulting in:

Less than 20% mortality and/or top kill	
More than 20% mortality and/or top kill	

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Without Treatment	**With Treatment**
Less than 20% mortality and/or top kill		%
More than 20% mortality and/or top kill		%

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of this attack?

Treatments	**Treatment Applied**		**Cost Per Treatment ($/Ac) (Direct Costs Only)**		
	Age(s)	**Number**	**Maximum**	**Average**	**Minimum**
Bone Tar Oil					
Capsaicin					
Fencing					

COMMENTS:

RABBIT **Aspen**

1. Consider 100 recently planted aspen stands at your location. During the rotation of these stands, what percent would you expect to see injury to plants by RABBIT causing:

Less than 20% mortality and/or top kill	
More than 20% mortality and/or top kill	

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Without Treatment	With Treatment
Less than 20% mortality		%
More than 20% mortality		%

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of this attack?

Treatments	Treatment Applied		Cost Per Treatment ($/Ac) (Direct Costs Only)		
	Age(s)	Number	Maximum	Average	Minimum
Capsacicin (Hot Sauce Repellant)					
Thiram (Arasan 42-S					
Shooting					

COMMENTS: ______________________________

1. Consider 100 recently planted aspen stands at your location. What would you estimate as the likelihood that these stands will incur damages during the rotation as a result of drought and frost? In a typical stand that is injured, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Likelihood of Occurrence	Reduction in Merchantable Volume
Drought	%	%
Frost	%	%

COMMENTS: ____________________

OTHER (Specify) Hypoxylon (See Appendix A for List)

1. Consider 300 recently planted stands on 100 high, 100 moderate & 100 low risk sites at your location. During the rotation of these stands, what number would you expect to see an attack by ________________________?

High risk site -	
Moderate risk site -	
Low risk site -	

2. In a typical stand that is attacked, what would you predict as an overall resulting percentage reduction in total stand volume or growth over the rotation?

	Without Treatment	**With Treatment**
High risk site		%
Moderate risk site		%
Low risk site		%

3. Of what grows, what would you predict as an overall resulting percentage volume reduction in grade as a result of this attack?

	Without Treatment Pulp to Cull	**With Treatment** Pulp to Cull
High risk site		%
Moderate risk site		%
Low risk site		%

4. Possible treatments to reduce losses are identified below. Which of these or other treatments would you recommend?

Treatments	**Treatment Applied**		**Cost Per Treatment ($/Ac) (Direct Costs Only)**		
	Age(s)	**Number**	**Maximum**	**Average**	**Minimum**

COMMENTS: ____

____

Listed below are the biophysical risks we have already identified as potential threats to read pine stands. Assume that a stand is attacked by each risk sometime during the rotation of the stand:

a.) What other risk(s) would you expect to occur as a result of an attack by the risks listed below?

b.) What would you estimate as the probability that this risk will attack?

	------Risk(s) That Are Likely To Occur------					
	Risk 1	Probab ility	Risk-2	Probab ility	Risk-3	Prob
1. Armillaria						
2. Diplodia						
3. Bark Beetle						
4. J.P. Budworm						
5. P.R.C. Weevil						
6. Pine Sawfly						
7. S. Spittlebug						
8. White Grubs						
9. Deer						
10. Porcupine						
11. Drought						
12. Flooding						
13. Frost						
14. Lightning						

COMMENTS: ______________________________

Listed below are the biophysical risks we have already identified as potential threats to aspen stands. Assume that a stand is attacked by each risk sometime during the rotation of the stand:

a.) What other risk(s) would you expect to occur as a result of an attack by the risks listed below?

b.) What would you estimate as the probability that this risk will attack?

	------Risk(s) That Are Likely To Occur------					
	Risk 1	Probability	Risk-2	Probability	Risk-3	Prob
1. B. Leaf						
2. S. Blight						
3. Gypsy Moth						
4. F. Caterpillar						
5. Poplar Borer						
6. Deer, Elk, etc.						
7. Rabbit						
8. Drought						
9. Frost						
10. Hypoxylon						

COMMENTS:

APPENDIX A

RED PINE

Diseases:
Annosus root rot
Needle blight
Red pine shoot blight
Scleroderris canker
Red pine shoot borer

Insects:
European pine moth
Gypsy moth
Pine webworm

Animals:
Hare
Mice
Red squirrels
Moose
ORVs

Weather:
Ice
Snow breakage
Wind
Hail

Fire

ASPEN

Diseases:
Shepard's crook
Hypoxylon canker
Heart rot

Insects:
Agrillia hornai
Aspen leaf rollers
Large aspen tortrix

Weather:
Flooding
Frost
Hail
Ice
Lightning
Snow Breakage
Sunscall
Wind

Fire

APPENDIX E

QUESTIONNAIRE RESPONDENTS COMMENTS

SUMMARY OF COMMENTS ON BIOPHYSICAL RISKS ASPEN AND RED PINE

ASPEN

Bronze Leaf Disease. Usually a problem in hybrids with big tooth aspen parents.

Shoot Blight. Not considered a problem in the LP. Common in young stands.

Gypsy Moth. Cyclical pest that occurs in 10 year cycles for 3 years. If grown for bolts, stands may degrade to pulp in some cases.

Forest Tent Caterpillar. Cyclical pest that occurs every 10 years for 2 years. Unrelated to any environmental factor. Do not kill stands. 10 year attack cycle.

Poplar Borer. No comments given by respondents.

Hypoxylon Canker. No treatment; not cost effective. No known treatment. No known treatment. Site related.

Not considered a major problem in the UP.

Recommends harvesting of affected trees.

Thinks hypoxylon loves improved aspen.

Deer, Elk or Moose. Second rotation will be less severe because of sprouts versus seedlings. There will be more sprouts and they are more likely to survive deer browsing.

Do not plant where deer is a problem, they will wipe it out. No significant damage where deer population is held in check. Do not kill all competing vegetation because this gives deer more food for browsing.

No treatment recommended.

Control of deer population can reduce damage significantly. In many areas, only weed species remain. Certain stands will be completely destroyed. Haven't had much experience with improved aspen but knows that site selection is important.

Reduce deer population.

Thinks deer will attack no matter what you do so herd reduction is essential.

Deer are a problem in planted hybrids.

RED PINE

Armillaria. Most reduction will occur from poles to saw and to pulp. This disease will not kill trees immediately. Damaged trees will grow slower perhaps. Most damage will occur on high risk sites only.

Usually attacks a tree here and there.

Not considered a problem in the UP.

Some armillaria will occur in almost all stands and it appears to be encouraged by a long drought as we are now experiencing.

Little reduction in grade from armillaria. a butt rot - only case I've seen it affect the 1st log is in beech. Usually tree wind blows or dies if progresses into 1st log.

Diplodia. Occur in cycles, most high risk stands are affected.

Regional in nature; do not think it is a problem in Michigan and it do not appear to be a problem, however, others may have a different opinion, e.g. Bud Hart.

Function of weather conditions, influenced by weather or moisture in young stands. Mature stand close to an inoculant may cause some problems.

Not a problem in the UP.

Have not seen it in our plantations (UP).

Not a problem in Region I.

Bark Beetle (Ips pini). Seldom have low risk site, there is always some marginal risk factors present. A secondary pest that usually comes after some other insect or disease. Usually do not appear by themselves. The removal of injured trees in thinning may enhance growth of remaining trees, thereby reducing overall losses. Nature of poles are such that reductions will be from poles to saw or cull.

Usually occur in drought situations.

Difficult to distinguish between armillaria and bark beetle damage. Harvesting during drought could bring on bark beetles.

Some beetles will be there.

Not a problem in the UP.

Only a problem in natural cutover stands in UP.

Occurs in periods of extreme extended drought and can be controlled by silvicultural means. Insignificant volume reductions.

Jack Pine Budworm. Few stands escape infection. The insect attack the more vigorous trees, therefore, poles are affected because of reduced diameter. Top kill is a problem; do not need to treat moderate or low risk sites. Very old and very young stands are most critical in terms of treatment; kill young trees, but reduce growth and quality in old trees. Also invite bark beetles.

Not considered a serious problem. Treatments are never, never recommended. The FDF will not allow: 1.) stands to be planted close to jack pine and 2.) effect on interior of stand is negligible.

Timing of harvest may have impact on volume loss, eg if budworm attack and stand is ready for harvest, no volume loss will occur, however if stand is not ready volume loss is significant.

Damage usually caused by stand overrotation, i.e. stands not harvested when needed.

Treat only high risk site next to pole stand. Probably won't be economically to treat.

Not a problem in the UP.

Very limited losses in managed stands in UP.

<u>Pine Root Collar Weevils</u>. Losses usually occurs around edges; very expensive to treat and usually don't treat in forestry situation; treat only valuable Christmas trees.

Treatment is not recommended unless free inmate labor is used. Treatment consist of clearing basal branches, raking dust away from tree.

Disease attack from edge of stand.

Problem caused by scots pine. Grade not significantly affected; treatments are costly.

Problem in newly planted stands, 0-15 years old. In older stands, it will appear as a secondary pest, e. g. following a drought. Primarily the effect is reduced mortality in young stands. Not cost effective to treat.

Not considered a major problem in the UP.

Not a problem in the UP.

<u>Redheaded Pine Sawfly</u>. This insect occurs in pockets. Treat when it occurs; occur in 10 year cycles.

Even if competition is eliminated, this critter may a problem in the UP.

No relationship between competition and the appearance of this pest. Impact will be on stands less than 15 years old.

Not considered a major problem in the UP. Haven't seen much of it.

Your risk factors have no relationship to redheaded pine sawfly attacks. High risk sites are historic mixed pine hardwood sites.

<u>Saratoga Spittlebug</u>. Cyclical pest that occur in 10 year cycles; outbreak last 10-12 years. Form is affected in injured trees, thus reductions are from poles to saw.

Treatment usually occur at 2-5 and 12-15. May require 1 or 2 treatments each injury. Pretreatment cost ($60/acre, 1989 data) to remove alternative hosts before planting. This treatment will add approximately $30 to site prep costs.

Use roundup to kill alternative host.

Recommends treatment of site for sweetfern and/or avoid high risk site.

Not considered a major problem in the UP.

Not a problem in the UP.

White Grubs. Mainly a problem in the UP.

Do not plant old fields or grassy sites. Bob Heyde best source for information.

Loss usually occur after planting; if loss is severe, replanting should take place.

Treat when planted. High risk sites are grass opening and we don't plant these except for wildlife considerations.

Deer, Elk or Moose. Location important here, if deer population is high expect high impact, if deer population is low impact is low. Treatments usually occur on private lands and used mainly on high value trees/lands, e.g. Christmas trees. No treatments used by MDNR.

No treatment recommended.

Location specific. Treatments include weather because, a severe winter will reduce the herd. Usually winters in the UP will reduce deer herds, but weather in the LP do not usually decrease deer populations.

Deer don't like red pine unless it's all that available.

Haven't seen much deer impact on red pine. Treatments are ineffective.

Location specific, deer can completely destroy stands in certain location. Have had several stands where deer completely destroyed stands and have had complete failure in stands also in the UP.

Deer is a major problem in the UP; recommends reducing deer population.

This injury is increasing. No known treatment. No killing as of yet, just top kill and growth reduction.

ASPEN AND RED PINE

Porcupine. No concentrated effort to shoot. Shooting only effective treatment known.

Localized problem from time to time, but not considered significant.

Not considered a significant problem.

Minor pest, no significant impact.

Porcupine population has been reduced by the fisher (a critter that loves to eat porcupines).

No cost incurred because shooting could be done during other activities.

Rabbit. With proper site prep, rabbits should not be a problem.

Attacks tend to be cyclical in nature.

Not a problem in LP.

Not a problem in LP.

Haven't seen impact of rabbit.

Drought, Flooding, Frost and Lightning. The occurrence of these risks usually leads to other biological risks, e.g. insects and diseases. Volume reductions are usually attributed to occurrence of the other biological risks.

Frost is a major problem in some areas, however we do not plant in frost pockets. Areas of occurrence have been identified and are being avoided as potential planting sites (LP).

Location important.

Drought usually causes mortality.

Drought is a problem; has had a drought 3 out of the last 5 years (Baraga area of UP).

Drought is a problem but numbers are difficult to attribute damage to it. The greatest effect is planting survival.

More of a problem in establishing a stand. May require replanting if severe drought in early years.

Stands most susceptible during the first 2 years. May occur 1 or 2 times over the rotation.

Not considered a problem.

Other Comments. Stands planted near jack pine are susceptible to fire.

Snow damage is a problem in UP.

Potential threat of fire from recreational activities.

APPENDIX F

LIST of CONTACT PERSONS

CONTACT PERSONS

	Years of Experience[a]
Bill Botti Program Leader, Timber Management Michigan Department of Natural Resources Box 30028 Lansing, MI 48909	25
Dan Farnsworth Timber Management Specialist Department of Natural Resources 309 West McMillan Newberry, MI 49868	22
Donald Hennig Timber Management Specialist Pere Marquette State Forest Cadillac District Office 8015 Mackinaw Trail Cadillac, MI 49601	20
Robert Heyd Regional Pest Specialist Region I Headquarters Department of Natural Resources 1990 U.S. 41 South Marquette, MI 49855	18
William J. Mahalik State Silviculturist Forest Management Division Region II Headquarters P.O. Box 128 Roscommon, MI 48653	28
Roger Mech Forest Pest Specialist Forest Management Division Region II Headquarters P.O. Box 128 Roscommon, MI 48653	1
Ronald Murray Forest Management Analyst Michigan Department of Natural Resources Box 30028 Lansing, MI 48909	30

Paul Pierce 23
Timber Management Specialist
Copper County State Forest
Box 440
Baraga, MI 49908

Frank Sapio 9
Program Leader, Forest Pest Management
Michigan Department of Natural Resources
Box 30028
Lansing, MI 48909

Bill Tarr 31
Timber Management Specialist
Box 939
Mio, MI

Gary Wycoff 25
North Central Experiment Station
C 1861 Highway 169 East
Grand Rapids, MN 55744

Mike Zuidema 24
Timber Management Specialists
Department of Natural Resources
P.O. Box 495
Escanaba, MI 49829

[a]As of August 1990.

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