Optimal Rotation of *Eucalyptus camaldulensis* Plantations In Thailand Based on Financial Return and Risk [1]

by
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Abstract
Simulation models were developed to estimate optimal, risk-adjusted rotations for *Eucalyptus camaldulensis* pulpwood plantations in Thailand. Sources of variation in the simulation model were costs, yields, and prices. Monte Carlo simulation was used to estimate expected land expectation values (LEVs) for a range of rotation ages and planting densities. Investors' risk tolerance levels were incorporated to determine the optimal risk-adjusted rotation. Results indicated that the optimal rotation length did not vary with risk tolerance levels except that extremely risk-averse investors would not invest in eucalyptus pulpwood plantations in Thailand.

INTRODUCTION
Eucalyptus plantations are an alternative investment for private investors in Thailand. However, many investors are reluctant to invest in eucalyptus plantations because they are not familiar with this kind of investment and need better information. Establishment, management, and harvesting costs are subject to considerable variation, as are yields and product prices. In addition, investors must select among several planting densities and rotation lengths, which also affect financial outcomes. Thus, eucalyptus plantations are relatively risky investments. Deterministic methods may not be appropriate to estimate returns from eucalyptus plantations for investors. The purpose of the study is to analyze investments in eucalyptus plantations using stochastic methods to model risk.

Background
The method most commonly used in forestry investment analysis is the deterministic discounted cash flow method, which is based on the assumption of complete knowledge and certainty of future events. However, these assumptions rarely hold. The deterministic discounted cash flow method does not provide an adequate solution when major risks (variation of costs, product prices, revenues, etc.) exist (Anderson et al. 1985). Risk has been incorporated in investment analysis and there have been many examples of its application in forestry. Common techniques include adjusting the discount rate by adding a premium, or calculating rates of return based on a range of values for key variables (Engelhard and Anderson 1983). The disadvantage of these techniques is the difficulty of determining the appropriate premiums with respect to different risk factors and the attitude of the investor toward risk. In addition, these methods can only adjust the average return on the investment and can only be easily used when outcome probabilities are simply expressed (Smith 1988). Another common technique is sensitivity analysis, which is "an orderly or systematic process of varying key assumptions, and evaluating their importance on financial criteria and decisions" (Bullard and Straka 1998). Schweitzer (1970) applied sensitivity analysis to study the impact of estimation error on evaluation of timber production opportunities. However, these techniques do not incorporate probability distributions for input values and do not provide probability distributions for outcomes.

Techniques incorporating probability distributions for variables not known with certainty have been applied in forestry investment analysis. Schweitzer (1968) developed a computer program that allowed the user to specify a probability distribution for the inputs of the model in the assessment of a forestry investment. Thompson and Haynes (1971) combined linear programming with a subjective probability distribution for land and/or timber availability in a decision model that minimized wood procurement costs over an industrial firm's planning period.

The Hertz method is another risk analysis technique (Hertz 1964). As a means of introducing variation into the analysis, this method uses probability distributions for variables that affect the rate of return. A computerized Monte Carlo simulation is used to draw samples for several stochastic variables. Then, statistic parameters are estimated and the output probability distributions are built. Engelhard and Anderson (1983) listed the following advantages

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of the Hertz method: 1) it utilizes all the quantitative information available; 2) it displays all possible outcomes; 3) it can be used in the decision making process to accept or reject a particular proposition, and also to choose among alternative propositions. Hassler and Sinclair (1982) used the Hertz method to evaluate the financial outcome of a prospective logging operation. The probability distribution of key components of revenue and cost were represented by a beta probability distribution. Anderson et al. (1985) applied the Hertz method to loblolly pine plantations threatened by bark beetles. Mean and standard deviations of the internal rate of return (IRR) of each scenario were computed. Taylor and Fortson (1991) developed a stochastic simulation model based on the Hertz method to estimate the impacts of planting density and rotation age on the return and risk of unthinned loblolly pine plantations. Expected LEV was estimated for each site, density, and rotation age combination. Sources of risk were stumpage prices, survival, and yield. Optimal planting density and rotation length combinations can be identified for various degrees of risk aversion to tailor these capital budgeting decisions to individual investors.

METHODS

Establishment, management, and other costs, yields, and pulpwood prices were treated as stochastic variables. Establishment costs consist of site surveying, site preparation, staking, seedlings, and planting. Management costs consist of replanting, and weed and fire control. Other costs are harvesting, transportation, and land rent. Yield probability distributions for 2x2 and 3x3 meter planting densities were derived from Pohjonen and Pukkala (1994) and Monte Carlo simulation runs. The discount rate used in the analysis was 5.6 %- the current rate on Thai government bonds adjusted for inflation. Triangular probability distributions were developed for costs and pulpwood prices by expert interviews. An expert in eucalyptus plantation management was asked to provide minimum, most likely, and maximum values for costs and prices (Mr. Montee Phothai, pers. comm. June 2001).

The first step in the analysis was to evaluate the financial returns offered by eucalyptus plantations. Expected LEVs were calculated for a number of management scenarios. Management scenarios differed by planting density and/or rotation length. Two planting densities, 2x2 and 3x3 meters, were considered. Rotation lengths ranged from 3 to 14 years. Combinations of these densities and rotation ages represent the most commonly used management scenarios in Thailand. Expected LEVs were derived using Monte Carlo simulation. Values for each of the stochastic variables were selected from the appropriate distributions. Each simulation consisted of 2,000 iterations. Means and standard deviations for the LEVs were computed.

Expected LEVs do not, however, provide much information about the relative financial risk associated with each scenario. To illustrate the financial risk associated with each management scenario, the coefficient of variation and the probability that a non-positive LEV will result were computed.

To evaluate which variables cause the greatest variation in LEV, Spearman's Rank Order Correlation Coefficient ρ, which is a non-parametric statistic that measures the correlation between two variables, was determined for each stochastic variable and LEV. The input variable with the highest ρ value is responsible for the greatest portion of the variation in LEV (Vose 2000). This method is superior to standard sensitivity analysis, which allows one variable of interest to vary while holding other potentially stochastic variables constant and may result in unrealistic input combinations (Koller 2000).

Finally, to investigate the impact of investor risk aversion on the acceptability of eucalyptus plantations as an investment, utilities for each scenario were computed for various degrees of investor risk aversion. Utility incorporates the expected financial return, the financial risk, and the degree of investor risk aversion. The following utility equation derived by Taylor and Fortson (1991) was used in this analysis:

Utility = (Return * Alpha)–Risk * (1–Alpha) (3)

where:

Alpha = degree of risk aversion
Return = expected LEV
Risk = standard deviation of LEV

Alpha values of 0.00, 0.25, 0.50, 0.75, and 1.00 were used to represent the risk tolerance levels of investors. An alpha value equal to 0 represents an investor with no tolerance for risk. An alpha value equal to 1 represents a risk-neutral investor. The expected LEV and associated standard deviation from 15 simulations were used to calculate expected utility for each management scenario. The optimal risk-adjusted rotation and planting density for each risk tolerance level is the one with the highest expected utility.

RESULTS

Eucalyptus plantations generate a positive expected LEV after three years for both planting densities (Table 1). Expected LEVs for 2x2 planting densities were greater than those for 3x3 planting densities for all rotation ages except years three and four. For both planting densities, expected LEV reached a maximum at year nine.

The probability that expected LEV is less than or equal to zero decreased rapidly from year 3 through year 6, and reached trivial levels in year seven for both planting densities. Probabilities of LEVs less than or equal to zero were greater for 2x2 planting densities than for 3x3 planting densities throughout the non-trivial range. At year 9, the rotation age that maximizes financial return, the probability of a non-positive LEV was less than 1% for both planting densities. Similarly, coefficients of variation decreased rapidly through year 6 for both planting densities and level off thereafter. Although coefficients of variation were greater for 2x2 planting densities for the shorter rotations, they were essentially equal to the 3x3 planting densities for all rotation ages greater than 6.

The sensitivity analysis conducted using Spearman's Rank Order Correlation Coefficients ρ indicated that pulpwood price had the greatest influence on the variation of LEV ($\rho > 0.9$). The second most influential variable was log transportation costs ($\rho < -0.23$). The third and fourth most influential factors were land rent and stand volume.

For low risk tolerance levels, ($\propto = 0$ and 0.25), the expected utility of each rotation age was negative for both planting densities. These investors would not invest in *Eucalyptus camaldulensis* plantations. For high-risk tolerance, ($\propto = 0.5$, 0.75, and 1.0) expected utility was positive for all rotations ages greater than four and reached a maximum at year nine for both planting densities (Figures 1,2, and 3). Utility increased as risk tolerance increased for all management scenarios with positive utility levels.

CONCLUSIONS AND DISCUSSION

This study demonstrated that *Eucalyptus camaldulensis* plantations in Thailand are acceptable investments over a range of risk-aversion levels. Ignoring risk, 2x2 meter planting densities on nine-year rotations represented the optimal management scenario considered in this study. This scenario maximized the expected financial returns for investors. Within a four-year range around the optimal rotation age, the risk associated with the investment differed only slightly by planting density and rotation age. Investors with extremely low risk tolerance are unlikely to invest in Eucalyptus plantations in Thailand. Once a minimum threshold of risk tolerance is passed, however, the degree of risk tolerance has no impact on the optimal risk-adjusted rotation in this study. This result may be due to the nature of the risks incorporated into the study. None of the stochastic variables considered had probability distributions that were functions of rotation length or planting density. Sources of risk, such as fire or disease, whose probabilities of occurrence during a rotation increase as the length of the rotation increases, may well affect the optimal, risk-adjusted, rotation age. In addition, different discount rates could have an impact on the results. Further studies including other uncertainty variables and different discount rates should be conducted. However, we feel that our results are applicable to many situations and provide valuable information for investors and Extension Service foresters in Thailand.

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Table 1. Expected LEVs, coefficients of variation, and probabilities that expected LEV ≤ 0 for *Eucalyptus camaldulensis* plantations in Thailand.

Years	**Expected LEV (Dollar/ha)**		**Coefficient of variation**		**Probability LEV < 0**	
	2x2	**3x3**	**2x2**	**3x3**	**2x2**	**3x3**
3	-1,331.70	-623.98	-0.58	-1.11	95.60	80.10
4	344.32	669.71	2.77	1.27	37.00	22.50
5	1,529.67	1,482.84	0.72	0.65	8.50	5.90
6	2,248.11	2,050.00	0.54	0.51	2.30	1.70
7	2,687.72	2,395.49	0.46	0.45	0.60	0.70
8	2,891.15	2,602.20	0.43	0.42	0.40	0.20
9	2,963.16	2,725.67	0.42	0.40	0.20	0.20
10	2,939.51	2,697.30	0.41	0.40	0.20	0.20
11	2,809.95	2,634.65	0.42	0.40	0.30	0.10
12	2,661.69	2,536.65	0.42	0.41	0.30	0.10
13	2,497.07	2,416.02	0.43	0.41	0.60	0.20
14	2,258.89	2,226.76	0.45	0.43	0.60	0.30

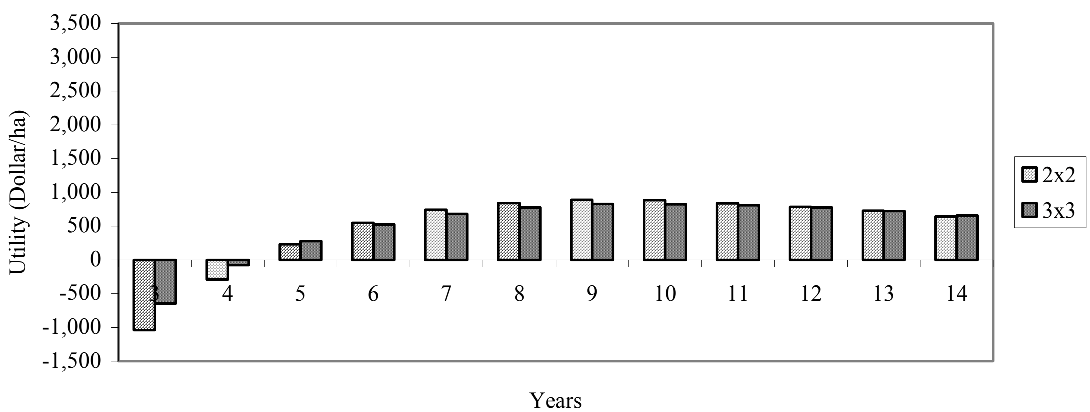

Figure 1. Expected utility for investors whose risk aversion level equals 0.5.

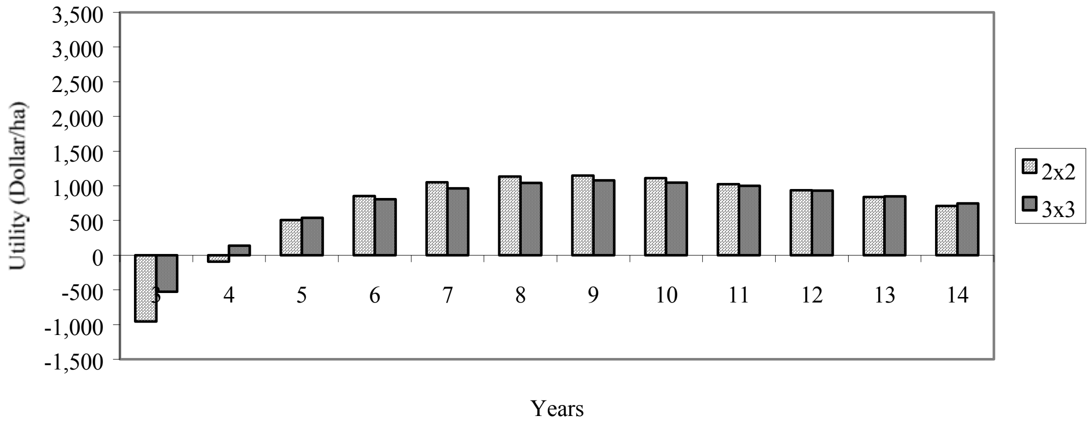

Figure 2. Expected utility for investors whose risk aversion level equals 0.75.

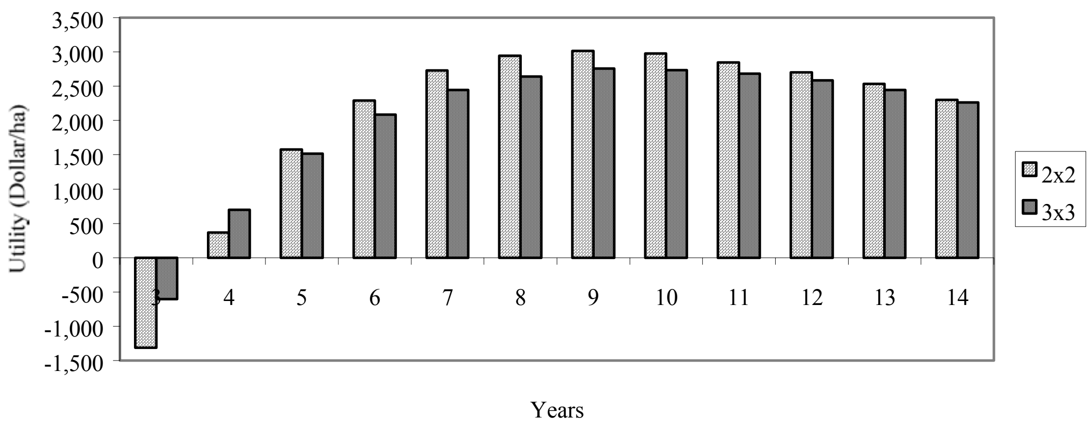

Figure 3. Expected utility for investors whose risk aversion level equals 1.