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OPTIMAL ROTATION OF *EUCALYPTUS CAMALDULENSIS* PLANTATIONS IN THAILAND BASED ON FINANCIAL RETURN AND RISK

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บทคัดย่อ

แบบจำลองได้รับการพัฒนาขึ้นมาเพื่อใช้ในการประเมินการปรับความเสี่ยงที่เหมาะสมในการกำหนดรอบตัดฟันของสวนป่าไม้ยูคาลิปตัส คามาลดูเลนซิสในประเทศไทย ความผันแปรที่ใช้ในแบบจำลองได้แก่ ต้นทุน ผลผลิต และราคา การประมาณค่าของที่ดิน (LEV) และค่าความเบี่ยงเบนมาตรฐานของค่าของที่ดินต่ออายุรอบตัดฟัน และระยะปลูกใช้ Monte Carlo Simulation ระดับความเสี่ยงของผู้ลงทุนได้ถูกนำเข้ามาใช้ในการประเมินการปรับความเสี่ยงที่ความเหมาะสมของรอบตัดฟันด้วย ผลการศึกษาพบว่า รอบตัดฟันที่เหมาะสมจะอยู่ระหว่าง 8-9 ปี ขึ้นอยู่กับอัตราส่วนลดที่ใช้ และไม่ได้ผันแปรกับระดับความเสี่ยง

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) and standard deviation of LEVs for a range of rotation ages and planting spacings. Investors' risk tolerance levels were incorporated to determine the optimal risk-adjusted rotation. Results indicated that the optimal rotation length was at year 8 or 9 depending on discount rate used and did not vary with risk tolerance levels.

INTRODUCTION

Eucalyptus plantations are a risky investment for private investors in Thailand. 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 spacings and rotation lengths, which also affect financial outcomes. The purpose of the study is to estimate optimal, risk-adjusted rotations for *Eucalyptus camaldulensis* pulpwood plantations in Thailand 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

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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 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 preparation, 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 spacings were derived from Pohjonen and Pukkala (1994) and Monte Carlo simulation runs. The discount rate used in the analysis were 5.6%- the current rate on Thai government bonds adjusted for inflation, 7.6, 9.6, and 11.6%. 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 estimate the financial returns and associated variation for *Eucalyptus* plantations when costs, yields, and product prices were allowed to vary using the Hertz method. Expected LEVs were calculated for a number of management scenarios. Management scenarios differed by planting spacing and/or rotation length. Two planting spacings, 2x2- and 3x3-meters, were considered. Rotation lengths ranged from 3 to 14 years. Expected LEVs were derived using Monte Carlo simulation. Each simulation consisted of 2,000 iterations. Means and standard deviations for the LEVs were computed.

The second step was to investigate the impact of investor risk aversion on the optimal planting spacing and rotations for *Eucalyptus* plantations. 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)
where:

Alpha = degree of risk aversion

Return = expected LEV

Risk = standard deviation of LEV

Alpha values of 0, 0.25, 0.50, 0.75, and 1 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 spacing for each risk tolerance level is the one with the highest expected utility.

RESULTS AND CONCLUSIONS

Eucalyptus plantations generate a positive expected LEV after year 3 or 4 for both planting spacings depending on discount rate used (Table 1). Expected LEVs for 2x2-meter planting spacings were greater than those for 3x3-meter planting spacings for all rotation ages. For both planting spacings, expected LEV reached a maximum at year eight or nine depending on discount rate used. Standard deviations of LEV for 2x2-meter planting spacing were greater than 3x3-meter planting spacing for all ages (Tables 2).

For low risk tolerance levels, ($\propto$ = 0 and 0.25), the expected utility of each rotation age was negative for both planting spacings. These investors would not invest in *Eucalyptus* plantations. For high-risk tolerance, ($\propto$ = 0.5, 0.75, and 1.0) expected utility was positive for all rotations ages greater than 4 or 5 years and reached a maximum at year 8 or 9 for both planting spacings depending on discount rate used (Figures 1, 2, 3 and 4). Expected utilities for 2x2-meter planting spacing were greater than for 3x3-meter planting spacing for almost every rotation age using 5.6 and 7.6% discount rates. On the other hand, expected utilities for 3x3-meter planting spacing trend to be greater than for 2x2-meter planting spacing for almost every

Table 1. Expected LEVs for *Eucalyptus* plantations on 2x2-meter and 3x3-meter planting spacing by discount rate

Rotation ages (yrs)	Discount rate (%)							
	5.6		7.6		9.6		11.6	
	Spacing (meter)							
	2x2	3x3	2x2	3x3	2x2	3x3	2x2	3x3
3	-1,332	-624	-1,104	-550	-970	-506	-882	-477
4	344	670	88	364	-60	188	-155	74
5	1,530	1,483	909	921	551	597	319	387
6	2,248	2,050	1,387	1,294	890	858	570	577
7	2,688	2,395	1,660	1,504	1,070	993	690	665
8	2,891	2,602	1,765	1,615	1,120	1,051	708	690
9	2,963	2,726	1,777	1,666	1,102	1,063	673	680
10	2,940	2,697	1,724	1,613	1,037	999	602	612
11	2,810	2,635	1,602	1,538	922	921	496	535
12	2,662	2,537	1,469	1,440	802	827	388	447
13	2,497	2,416	1,327	1,329	678	727	279	356
14	2,259	2,227	1,141	1,176	526	599	152	248

Notes: The maximum expected LEV for each discount rate and planting spacing (column) is indicated by a shaded cell

Table 2. Standard deviation for *Eucalyptus* plantations on 2x2-meter and 3x3-meter planting spacing by discount rate

Rotation Ages (yrs)	Discount rate (%)							
	5.6		7.6		9.6		11.6	
	Spacing (meter)							
	2x2	3x3	2x2	3x3	2x2	3x3	2x2	3x3
3	767	690	558	501	436	391	356	319
4	955	851	685	611	529	471	427	380
5	1,104	958	784	680	598	519	477	414
6	1,203	1,042	845	732	638	552	503	436
7	1,231	1,075	855	747	639	558	499	435
8	1,251	1,100	860	756	635	559	491	432
9	1,243	1,101	845	749	618	547	472	418
10	1,214	1,079	816	726	590	525	446	397
11	1,174	1,049	781	698	558	499	417	373
12	1,118	1,038	736	683	520	483	384	357
13	1,085	996	706	648	493	453	361	332
14	1,020	959	656	617	453	427	328	309

rotation age using higher discount rates. Utility increased as risk tolerance increased for all management scenarios with positive utility levels.

This study demonstrated that *Eucalyptus camaldulensis* plantations in Thailand are accep - table investments over a range of risk-aversion levels. Ignoring risk, the optimal rotation length was at year 8 or 9 depending on discount rate used for each planting spacing. 2x2-meter planting spacing on eight- or 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 spacing and rotation age.

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. However, the degree of risk tolerance combined with discount rates had an impact on the optimal planting spacing of eucalyptus plantations. It seems that the higher the alternative rate of return, the more preferable the 3x3-meter planting spacing rather than the 2x2-meter planting spacing for low risk-tolerance levels. This may because the 3x3-meter planting spacing was less risky than the 2x2-meter planting spacing.

DISCUSSION

These results do not provide the final verdict on planting spacing and optimum risk-adjusted rotation in *Eucalyptus* plantations. The current simulation model may need to incorporate others sources of risk, which will have an impact on financial return and financial risk. Future analysis that includes precise sources of risk in the simulation model should be conducted. However, these results are applicable to *Eucalyptus* plantation investments in Thailand. In addition, it is valuable information for the decision-making process for private sectors that want to invest in *Eucalyptus* plantations. Extension service foresters can also use the results to advise landowners and other potential plantation investors.

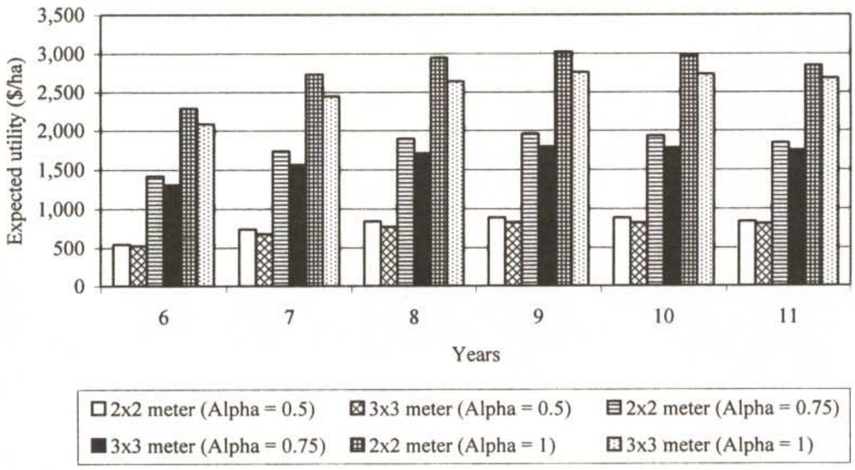

Figure 1. Expected utility of *Eucalyptus* plantations for risk-aversion levels (Alpha) 0.5, 0.76, and 1 (5.6% discount rate)

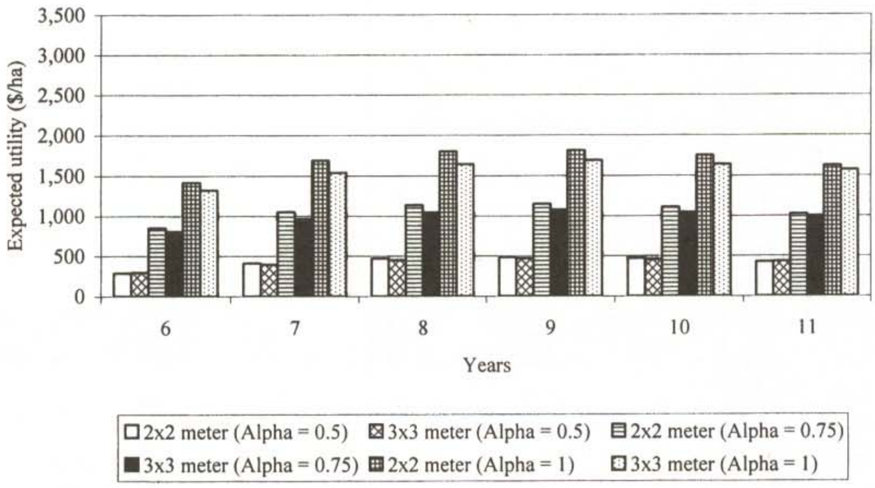

Figure 2. Expected utility of *Eucalyptus* plantations for risk-aversion levels (Alpha) 0.5, 0.75, and 1 (7.6% discount rate)

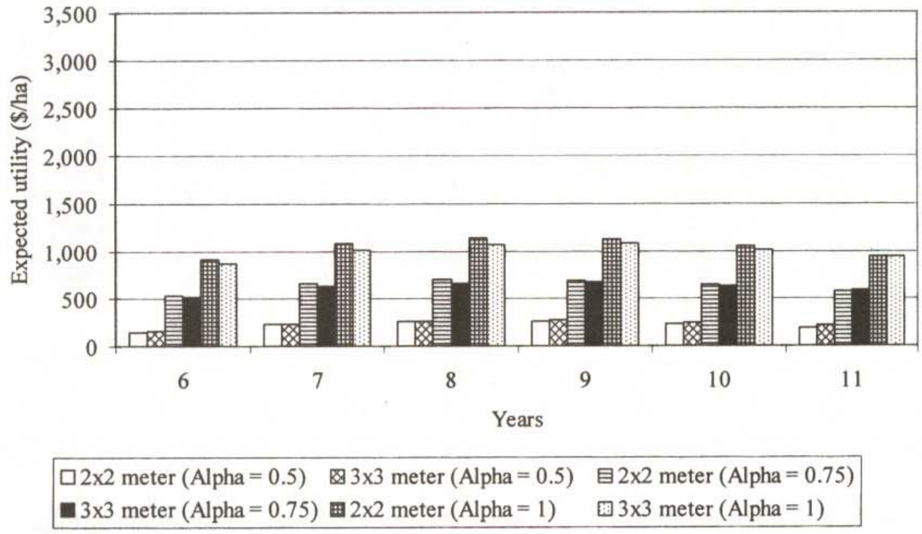

Figure 3. Expected utility of *Eucalyptus* plantations for risk-aversion levels 0.5, 0.75 and 1 (9.6% discount rate)

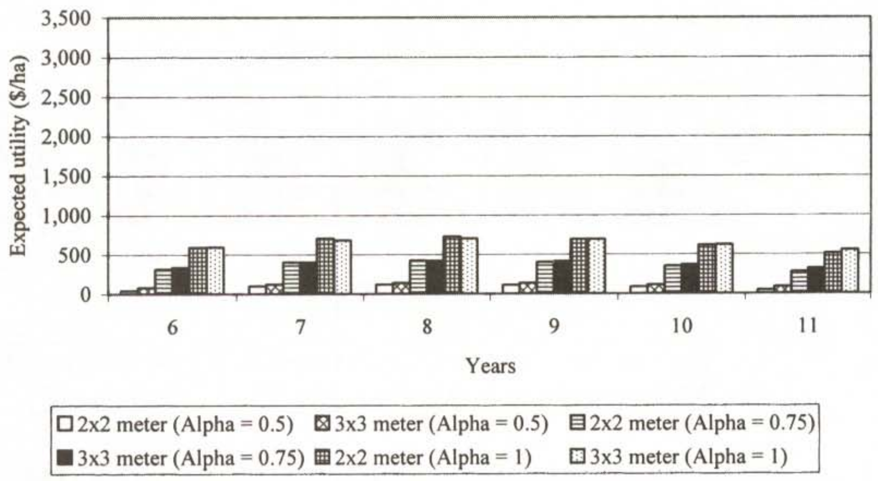

Figure 4. Expected utility of *Eucalyptus* plantations for risk-aversion levels 0.5, 0.75 and 1 (11.6% discount rate)

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