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A TARGET MOTAD ANALYSIS OF FORESTRY DEVELOPMENT ON A PASTORAL HILL COUNTRY FARM

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ABSTRACT

This paper builds on a recent study on sustainable land use options for a 651 ha pastoral hill country farm by providing an analysis of the effect of downside risk on pastoral and forestry enterprise mix. A Target MOTAD model is developed to determine the risk efficient combination of sheep, traditional bred cattle, bull beef and forestry enterprises.

The results indicate that the optimum enterprise mix of 250 ha in forestry and 401 ha in bull beef can be farmed with little or no downside risk. The transition from the current pastoral system to a risk efficient enterprise mix increases the downside risk. This is due to the loss of income when significant areas of the farm are in immature forest.

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* The views expressed in this paper are those of the authors and do not necessarily reflect the official view of the New Zealand Ministry of Agriculture and Fisheries. The typing assistance of Pekina Gabriel and comments from colleagues are very much appreciated.

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INTRODUCTION

Revenue from the sale of timber from exotic forest plantations in New Zealand has increased significantly over the past 5 years due to a doubling in the real price of export logs. This has resulted in an increased demand for Pinus radiata seedlings for afforestation. Based on a survey of nurseries, the Ministry of Forestry estimates that 70,700 ha of forests was planted in the season ended 31 March 1993. The area planted was made up of 23,100 ha of restocking and 46,600 ha of new planting (MOF, 1992). (The area of forest planted in the previous season was 15,440 ha).

During the year to June 1992, the exotic forest plantation on farms increased by about 7% to 113,837 ha, while the area of plantations not on farms declined slightly (0.12%) to about 1.2 million ha. It is believed that a higher proportion of new forest planting would take place on existing farm lands.

It is expected that farmers will increase the rate of farm conversion into plantation forest on the basis of expected good future return from forestry. Also, soil erosion on hill country pastoral farms in New Zealand concerns both policy makers and local communities. Changes to livestock management systems and accelerated afforestation schemes have been proposed to arrest soil erosion, improve the long term viability of these farms and for the sustainable management of land resources (Keoghan and Cossens, 1990; Korte, 1990; MAF, Landcare and TRC, 1993).

The choice of farm diversification options must address not only the sustainable management of the physical resources of a farm, but also farm viability and the reduction of the risk of farm business failure. The objective of this paper is to provide an analysis and a rationale for considering a forestry enterprise option during the diversification of a pastoral farming system. Improvements in the management of the existing pastoral system that could complement forestry development is examined. Increased risk associated with the transition from a current pastoral system to a system that contains a mature crop forest is analysed.

A PREVIOUS STUDY

This study builds on a recent study of sustainable land use options on hill country in the Taranaki region of New Zealand (MAF, Landcare and TRC, 1993). A detailed assessment of the sustainable management of seven land classes, based on slope, pasture growth, stock carrying capacity and suitability for forestry was undertaken for a 651 ha farm. The present farming system is pastoral, carrying approximately 5000 stock units of sheep (70%) and cattle (30%). Pinus Radiata is an appropriate forest plantation species for the area, and yields of between 637 m3/ha to 747 m3/ha recoverable volume are possible after 28 years of growth.

An evaluation of the profitability of a number of pastoral and forestry enterprise options was undertaken using deterministic prices and yields (Spall and Meister; 1988; MAF, Landcare and TRC, 1993). The exclusion of price and yield variability meant that the riskiness of the proposed farm plans could not be determined. This could limit the applicability of the results from the study to only those farmers who are risk takers (Parton and Cumming, 1990).

In the present study, a model that uses the downside risk concept to determine the optimal combination of risky pastoral and forestry enterprises for a hill country pastoral farm in the Taranaki region is developed.

THE RISK MODEL

Management of risk in farming has also been receiving increased attention as a result of the deregulation of the financial sector, and the phasing out of farm input and output subsidies over the last decade (Martin and Lee, 1990; Johnson 1992). When considering options for the diversification of an existing farming enterprise, one needs to consider both business risk is (i.e. risk associated with variable yields and prices) and financial risk (i.e. risk associated with not being able to meet a fixed target income, such as debt repayment, using cash generated from the farm).

The combined effects of these risk factors may be measured by the expected net farm income and the distribution of net farm income about the mean or target income. The model used in the study is derived from ‿ MOTAD (Minimisation of total absolute deviation) risk programming technique (Hazell, 1971). An application of the MOTAD model used in this study is the Target-MOTAD model which is concerned with minimising negative deviation of net revenue from a target income (Zimet and Spreen, 1986; Parton and Cumming, 1990).

A comparison of Target MOTAD to MOTAD carried out by Watts, Held and Helmers (1984) indicates that Target MOTAD is a more appropriate framework for risk analysis in situations where a high dis-utility is attached to returns from low income years. Such a condition would apply to many pastoral hill farmers with high debt levels, where returns from enterprise combinations unable to cover adequately debt repayments is of concern.

The risk model, in essence, selects enterprise combinations in order to maximise expected net revenue subject to constraints on available land classes, seasonal pasture yield, target income and an acceptable mean negative deviation of revenue from a target income (Figure 1). The optimum enterprise combination is said to be risk efficient since it yields the highest expected net revenue for a given level of risk.

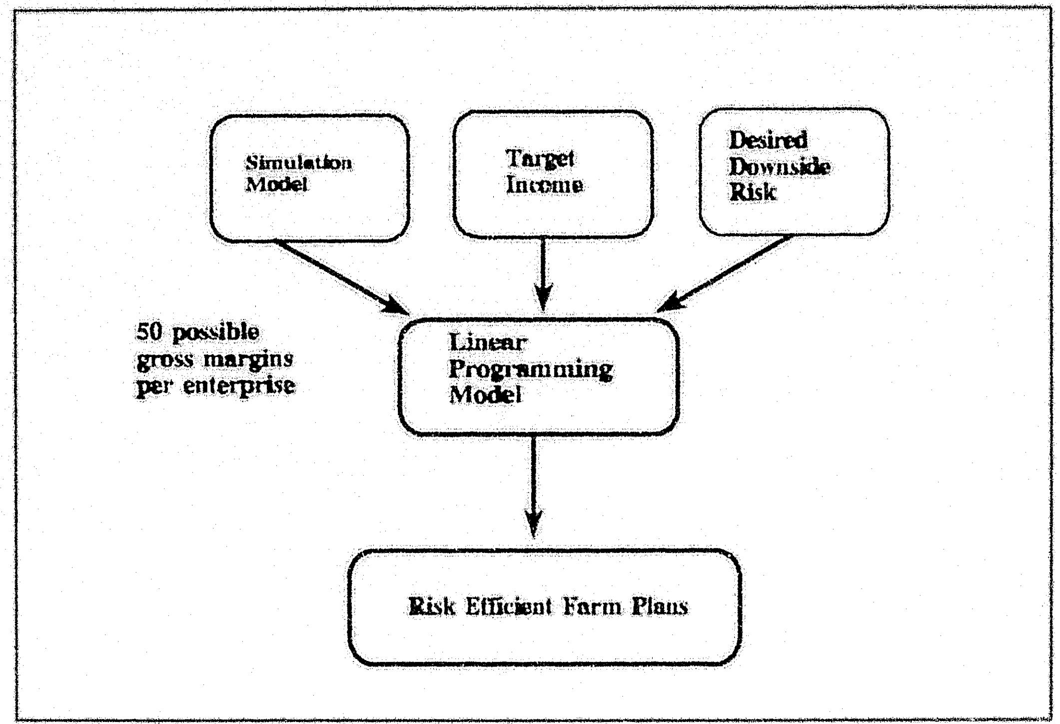

FIGURE 1 The risk model

The risk model comprises two main components, a simulation model and a linear programming model. These are described briefly below.

Simulation Model

Gross margin templates were developed for a number of livestock and forestry enterprises. A Monte Carlo simulation approach was used to select values from statistical distributions of animal production, stock mortality, plantation forestry yield and prices which were then used to calculate possible gross margin values. Correlation between variables were maintained using Spearman's rank correlation coefficients.

Linear Programming Model

The linear programming sub-model selects enterprise combinations in order to maximise expected net revenue (Z) subject to constraints on available land classes, seasonal pasture growth, seasonal feed deficit, target income and an acceptable mean negative deviation of revenue from a target income. The linear programming model may be stated as (Parton and Cumming, 1990):

Maximise $Z = R X$

subject to: $A X < B$; $R^* X + d- > T$; $Pd- < D$; $X, d- > 0$

Where

- R^* = is a series of m, 1 x n simulated net revenues for each enterprise opuon derived from the simulation model described above;
- R = 1 x n vector, the mean of R^*;
- X = 1 x n vector of activity (enterprise) levels;
- B = 1 x k vector of resource constraints ;
- A = k x n matrix of resource requirements (mainly seasonal pasture dry matter required by each class of livestock stock, area required to grow forest trees);
- T = m x 1 vector of equal target income (fixed financial obligation);
- d- = 1 x m vector of negative deviations from target;
- P = 1 x m vector of probabilities (each equal 1/m);
- D = a scalar, parameterised from 0 to large value (desired expected negative deviation from T);
- n = number of activities (1 sheep class, 8 beef cattle classes, 2 forestry enterprises);
- m = Number of observations (50);
- k = number of resource constraints (7 land classes, available seasonal pasture dry matter growth on each land class, maximum winter feed deficit).

The model maximises the expected net farm income subject to constraints shown above and for specific levels of downside risk. Results for different levels of risk aversion are achieved by solving the model successively for parameterised values of D, from 0 to a large number. The solution for D equal to zero corresponds to a (safety first) no risk decision rule, while the solution for very large D is equivalent to the solution from a deterministic linear program.

MODEL SPECIFICATION AND DATA SOURCES

The enterprises included in this study were (a) Sheep breeding flock, (b) breeding cow, selling weaners, and calving 3 yr old heifers, (c) bull beef policy and (d) Pinus radiata plantation forestry. These enterprises are farmed in the Taranaki hill country region. A typical policy in the study area combines sheep and cattle in the ratio of 70/30 stock units.

The distributions used in the Monte Carlo simulation were estimated from time series data applicable to the Taranaki hill country. The main sources of data were a number reports on the weighted average schedule meat prices from the NZ Meat and Wool Boards Economic Service, and Farm monitoring reports from the Ministry of Agriculture and Fisheries; McRae (1988); New Zealand forestry statistics, Ministry of Forestry (1993); Financial Budget Manual, Lincoln University (1992). The prices were deflated to 1992 values. Estimated parameters of some of the distributions are shown in Table 1.

Spearman's Rank Correlation coefficient between variables were estimated from time series data. Using a two tailed test, coefficients that were significant at the 15% level were used in the Monte Carlo simulation model.

Data on pasture dry matter production of each of the 7 land classes used in the study was obtained from MAF, Landcare and TRC (1993). Research data was used to estimate seasonal pasture yield and seasonal feed required by each of the livestock policies used in the study (Scott, et al, 1980; McCall, 1993).

TABLE 1 Distribution of some of the variables used to simulate enterprise gross margins.

	Mean	Min	Max	Beta distribution shape parameters* α_1	α_2
<u>Production Parameters</u>					
Lambing-survival to sale (%)	92	87	99	1.3	2
Wool weight (kg/stock unit)	5.4	5.1	5.8	1.0	1.6
Prime wether lamb carcase wt (kg)	13.7	12.4	15.0	1.6	1.4
Calving-survival to sale (%)	85	83	88	1.3	1.5
Bull beef carcass wt (kg)	229	208	247	1.0	0.8
Pinus radiata recoverable yield site rating 34, age 28yrs (m3/ha)	679	0**	747	0.9	0.1
Pinus radiata recoverable yield site index 28, age 28yrs (m3/ha)	580	0**	638	0.9	0.1
<u>Prices</u>					
Prime wether lamb schedule price (c/kg)	237	129	465	0.8	1.7
Wool price (c/kg)	480	240	730	1.5	1.5
Pinus radiata stumpage ($/m3)	29	19	38	1.7	1.3
Heifers 30 month schedule price (c/kg)	277	193	379	1.4	1.7
Bull beef schedule price (c/kg)	298	208	406	1.4	1.7

*The shape parameters can be used to infer the skewness of the distribution (Anderson, Dillon and Hardaker, 1977).

** The harvest of that year could be lost due to fire

RESULTS AND DISCUSSION

Estimated distribution of enterprise net revenue

The distribution of enterprise gross margins derived from the simulation model are shown in Table 2. Bull beef was the most profitable and least risky pastoral enterprise since the expected, minimum and maximum gross margins were higher than corresponding values of the other pastoral enterprises.

The gross margins per ha calculated for Pinus radiata was based on a rotation of 28 years, and assumed all age classes were equally represented in the forest crop. The simulation model indicated that the minimum gross margin from forestry could be negative when that years yield was lost due to some adverse event eg. fire.

TABLE 2 Enterprise net revenue distribution (Livestock $/stock unit; Forestry $/ha) (Sites carry between 5.2 - 12.3 stock units /ha) (1992 prices)

Enterprise	Mean	Min	Max	Beta Distribution Parameters	
				α_1	α_2
Sheep breeding flock	35.7	18.1	57.0	2.15	2.59
Breeding cows - weaner policy; calve 3 yr old heifers	39.6	27.0	59.1	1.62	2.50
Bull Beef policy	95.1	57.6	136.9	1.95	2.18
Pinus radiata - site index 34	667.0	-23.9	940.0	3.55	1.40
Pinus radiata - site index 28	548.6	-26.5	782.0	3.64	1.48

Optimal (target) enterprise combination

When no restrictions were placed on the stock policy and sheep/cattle ratio, results from the Target MOTAD model indicated the optimum enterprise mix was 250 ha in forestry and 401 ha (or 3,791 stock units) in bull beef irrespective of target income. This combination of pastoral and forestry enterprises could be farmed with little or no downside risky, as indicated by the zero mean negative deviation. The expected net revenue was $497,591 per farm. The results were expected since the bull beef enterprise was more profitable and less risky than either the sheep or breeding cattle policies.

TABLE 3 Risk efficient farm plans for target income levels of $60,000, $120,000 and $180,000 per farm. (No Sheep-Cattle ratio restriction; No restriction on stock policy; Farm Size 651 ha)

Target Income	$60,000	$120,000	$180,000
Mean Negative Deviation	$0	$0	$0
Expected Revenue	$497,591	$497,591	$497,591
Pastoral (ha)	401	401	401
Forestry (ha)	250	250	250
Sheep (su)	0	0	0
Cattle (su) Bull Beef Policy	3,791	3,791	3,791

The most common livestock policy in the study area combines sheep breeding and breeding cows in the ratio of 70/30 stock units. The risk efficient production frontier, when this restriction on sheep/cattle ratio and stock type was enforced in the model, is shown in Figure 2. The minimum risk level was $1829 mean negative deviation with an optimum expected net revenue of $258,130. The optimal enterprise mix at this level was 195 ha forestry and 456 ha in pastoral farming (70% sheep and 30% breeding cow).

Increasing the level of acceptable risk, as expected, resulted in an increase in net revenue. At the highest level of risk, (mean negative deviation of about $5000), the expected optimum net revenue was about $360,000 per farm. Forestry was the preferred enterprise at this high level of acceptable risk.

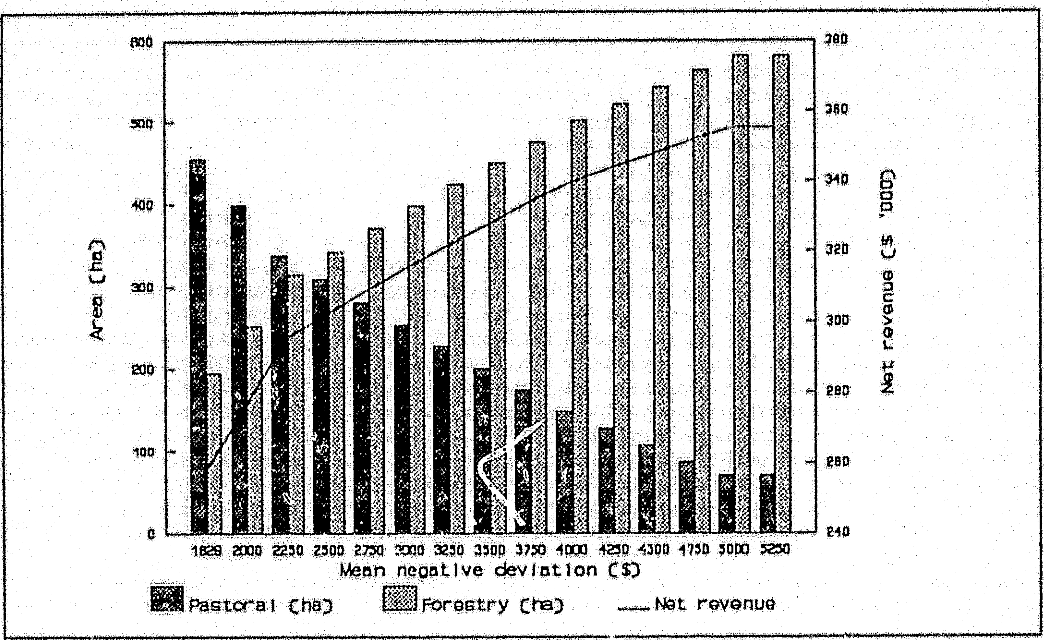

FIGURE 2 Risk efficient production frontier and enterprise mix: target income $180,00; farm size 651 ha; sheep\breeding cow ratio 70/30 stock units

Figure 3 shows the result of a scenario in which the sheep/cattle ratio was kept at 70/30 stock units, and bull beef was used instead of breeding cattle. This farming system clearly dominated the system shown in Figure 2, since the bull beef policy yielded a higher expected net revenue for all levels of risk (compare Figures 2 and 3).

At zero mean negative deviation, the optimum net revenue was $348,884, the optimum enterprise mix was 310 ha forestry and 341 pastoral (70% sheep and 30% bull beef). As expected net revenue and the area under forestry increased with risk.

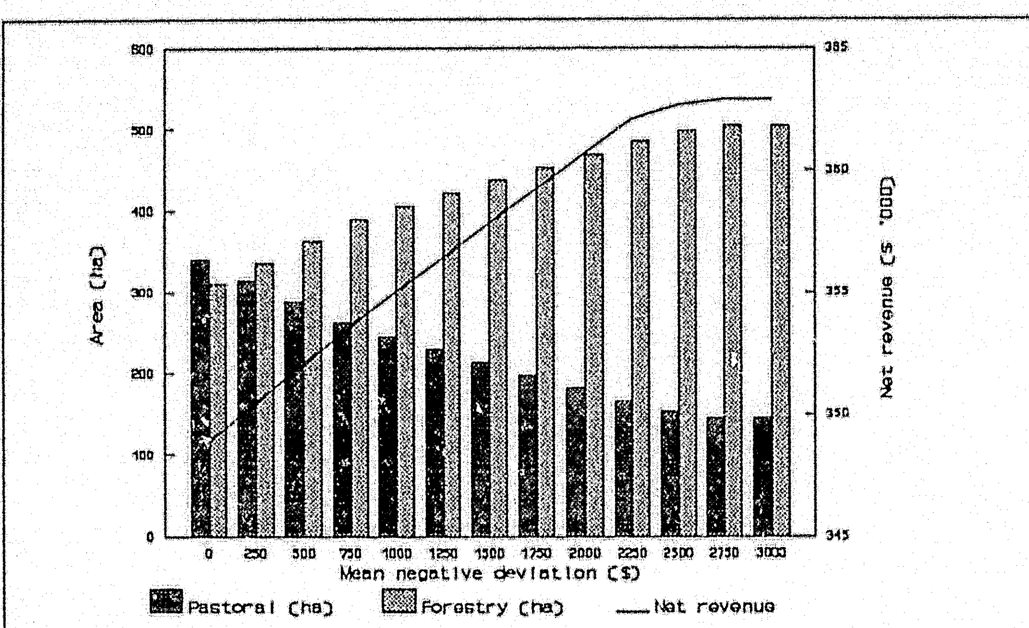

FIGURE 3 Risk efficient production frontier and enterprise mix: target income $180,00; farm size 651 ha; sheep\bull beef ratio 70/30 stock units

Transition to a Mature Forest Crop

The analysis has so far examined the case when all enterprises were developed and yielding a sustainable, albeit, variable annual earnings. It was assumed that all age classes were equally represented in the forestry plantation and the rotation was 28 years. The development phase of livestock enterprise is relatively short or alternatively matured livestock may be purchased and transported to the farm.

The development phase of a forestry plantation is relatively long (over 28 years). It is generally believed that the financial risk associated with having large tracts of farm land in immature forests may not be acceptable to most farmers. The Target MOTAD framework developed in this study is used to quantify the risks associated with excluding parts of the farm land from immediate production.

(a) 70/30 sheep/breeding cattle ratio

In the case of the 70/30 sheep/breeding cattle policy analysed in Figure 2, it was shown that the optimum area of forestry enterprise corresponding to the lowest level of risk was 195 ha. At maturity, the risk associated with this enterprise would be $1829 mean negative deviation. The maximum negative deviation would be $40,583, and it could be expected that 3 years out of 50 net revenue would not be sufficient to meet the target income of $180,000 (Table 4).

When a part of the farm was temporarily removed from production the risk to the farmer was increased. For example when 100 ha of the farm was taken out of production, The mean negative deviation increased by over 100% from $8,808 to over $18,312. The expected net revenue fell by about 10% to $174,182. At this level, the probability that net revenue would not be sufficient to achieve the target income increased from 19/50 to 32/50. The maximum negative deviation would be expected to reach $80,000.

Increased risks associated with the development phase of forestry could limit the area the farmer planted in trees. An opportunity to harvest the forest crop before the 28 year maturity period used in this study would assist in managing the downside risk. Studies on the reservation price of forestry indicated that the opportunity existed to harvest forest plantation at any age class when the prevailing price exceeds the reservation price for the age class (Lohmander, 1985).

TABLE 4 Changes in the level of risk and expected net farm revenue when part of the farm area is temporarily removed from production

Sheep Cattle Ratio 70/30; Traditional Breeding Cow Policy; Farm area 651 ha.

Immature Forest Crop (ha)	Risk Level: Target Income $180,000			Expected Revenue $
	Mean Neg Deviation ($)	Max Neg Deviation ($)	No Neg Deviation	
0	8,808	68,529	19/50	195,325
50	12,996	74,561	27/50	184,757
75	15,424	77,576	29/50	179,471
100	18,312	80,592	32/50	174,182
Target Mature Forest				
195	1,829	40,583	3/50	258,130

(b) 70/30 sheep/Bull Beef ratio

The risks associated with having large areas in immature forests would be reduced considerably if the breeding cattle component of the livestock was replaced with bull beef enterprise (Table 5). In this case the target area of farm that should be planted into forestry was 310 ha at the zero (safety first) risk level. At maturity, the expected net revenue would be $348,884 per farm. For example if 100 ha was temporarily excluded from production the expected level of downside risk would be $199 mean negative deviation compared to $18,314 if the breeding cow policy was continued (See Table 4). The maximum negative deviation and probability that net farm would fall below the target income was reduced considerably.

TABLE 5 Changes in the level of risk and expected net farm revenue when part of the farm area is temporality removed from production
Sheep Cattle Ratio 70/30; Bull Beef Policy; Farm area 651 ha.

Immature Forest Crop (ha)	Risk Level: Target Income $180,000			Expected Revenue $
	Mean Neg Deviation ($)	Max Neg Deviation ($)	No Neg Deviation	
0	0	0	0/50	283,414
50	0	0	0/50	268,079
75	21	1,033	1/50	260,409
100	199	6,302	2/50	252,745
250	4,198	37,917	11/50	206,741
Target Mature Forest				
310	0	0	0/50	348,884

CONCLUSION

The aim of this paper is to develop a methodology for including financial risk consideration when strategies are being developed for the sustainable management of marginal pastoral hill country farms. In particular, the paper sought to provide a rationale for including forestry as an enterprise within the farm. The results of the study indicated that it was risk efficient for pastoral farmers to plant Pinus radiata forest on a portion of the farm. A risk taker would allocate a higher proportion of the farm to forestry.

This paper shows that the risks associated with forestry development on pastoral farms can be reduced, by improving profitability of the accompanying livestock enterprises. In this example, replacement of a beef breeding herd with bull beef reduced downside risk considerably.

The downside risk associated with forestry development increases as the area under an immature forest crop increases. The management or reduction of risk would also entail the improvement of the pastoral system. The ability to harvest the forest crop before the 28 year maturity period used in this study would assist in the management of downside risk during the forestry development phase.

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