PROFITABILITY OF CONVERTING PASTORAL FARMLAND TO FORESTRY IN THE TAUPO BASIN

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FOREST AND FARM PLANTATION MANAGEMENT COOPERATIVE

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EXECUTIVE SUMMARY

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PART 1: MARGINAL ANALYSIS AT THE ONE-HECTARE LEVEL

Leith Knowles and Lars Hansen

ABSTRACT

The past 40 years has seen an increasing eutrophication of Lake Taupo, mostly due to intensified land-use. Leaching and run-off of nutrients is reduced when pastoral farmland is converted to production forestry. This study examined the marginal profitability of replacing pasture with production forest through farm-forestry and government land purchase. Radiata pine production forestry was as profitable or better than pastoral farming on poor to medium land, while Douglas-fir was profitable only on poorer sites and at low discount rates. The environmental benefits of tree planting can be achieved without endangering long-term profitability of land-use in the Taupo basin.

PART 2: FARM-LEVEL SUSTAINABILITY

Lars Hansen, Leith Knowles, Andre Laroze

ABSTRACT

This study applied linear programming to analyse farm-level sustainability of replacing pasture with radiata pine production forestry in the Taupo basin. The analyses were based on land-use optimisation for a model farm when subject to social, ecological and economic constraints. The results showed that despite being more profitable at the one-hectare-level the farm-level implementation of farm-forestry was severely limited by the availability of capital. It was not possible to simultaneously maintain the annual gross margin enjoyed from pastoral farming and achieve the target 20% reduction in nitrogen loss. More profitable solutions, which resulted in immediate tree plantings and decreased nitrogen loss, were available, but these solutions required external capital or labour to be feasible at the farm-level.

PART 1: MARGINAL ANALYSIS AT THE ONE-HECTARE LEVEL

ABSTRACT

The past 40 years has seen an increasing eutrophication of Lake Taupo, mostly due to intensified land-use. Leaching and run-off of nutrients is reduced when pastoral farmland is converted to production forestry. This study examined the marginal profitability of replacing pasture with production forest through farm-forestry and government land purchase. Radiata pine production forestry was as profitable or better than pastoral farming on poor to medium land, while Douglas-fir was profitable only on poorer sites and at low discount rates. The environmental benefits of tree planting can be achieved without endangering long-term profitability of land-use in the Taupo basin.

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INTRODUCTION

Intensified use of pastoral land in the Taupo basin over the past 40 years has contributed to increasing concerns about the amount of nitrogen entering Lake Taupo. Recent monitoring confirms that the Lake Taupo ecosystem is nitrogen limited, and if land use in the catchment (and its associated nitrogen loading) stay at the same level as today, the Lake's health will worsen (Elliot *et al.* 2003, Vant 2004).

The main non-point source of nitrogen leaching to New Zealand surface waters is agriculture (Wilcock 1986, Hamilton 2004, Monaghan *et al.* 2004). Clearance of hill and riparian forests for farming decreases interception of rainfall and water uptake by plants, and thus increases surface run-off, water percolation, and peak flows in streams (McColl *et al.* 1977, Cooper *et al.* 1987, Cooper and Thomsen 1988). Dissolved or attached to soil particles, nutrients are transported to streams and lakes or percolate with seepage water to the groundwater reservoir. Eventually high nutrient levels build up in the aquifers, and water quality is reduced. It can take many decades to decrease nutrient levels again, especially in groundwater reservoirs (Vant 2004).

The "100 Rivers Project" (Biggs *et al.* 1990) and a study of 49 rivers (Smith *et al.*1993) showed that water samples taken in the upper parts of the catchments dominated by undisturbed natural vegetation contained low nutrient levels, while water quality declined when the rivers ran through agricultural land. The main advantages of native forest cover are that no fertilisers are added, livestock are excluded, and the soil is covered continuously with vegetation, avoiding soil erosion, reducing surface run-off and water flow rates (Quinn and Ritter 2004).

Agricultural land that is taken out of production would be lost for direct financial return, but studies have shown that production forestry, where parts or all of the farmland are converted to forest, also reduces both leaching of nutrients and the quantity of water draining to groundwater (O'Loughlin 1994). In turn, this will positively affect water quality in adjacent watercourses and aquifers. Hence, production forestry offers an opportunity to combine environmental improvement of waterways and lakes with financial returns.

In the tree establishment phase (0-8 years), nutrient uptake by the young trees is high since they build up biomass and expand their crowns rapidly. After crown closure and until harvest (about 8 –28 years for radiata pine), nutrient uptake is reduced, but as trees are deep feeders, nutrient cycling commences and soils will not be depleted from nutrient reserves (Quinn and Ritter 2004). The most critical phase with respect to water quality will be the period immediately following harvesting, when tree cover is removed and subsequently leaching of nutrients and erosion can increase again. Fortunately, nutrient concentrations in streams have been found to quickly decline back to pre-harvest levels again following replanting (Quinn and Ritter 2004), and even a decrease in nitrate leaching after clear-felling has been reported (Parfitt *et al.* 2002). Progressively harvesting a catchment over time will also limit nutrient run-off and leaching.

In New Zealand, radiata pine (*Pinus radiata* D. Don) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) account for 95 percent of the land area planted in production forests. Both species grow well in the Taupo basin, and are suited to utilisation in existing nearby industrial plants. The New Zealand Farm Forestry Association, with support from the MAF Sustainable Farming Fund, is keen to discover if a careful application of woodlots can match the medium to long-term profitability of pastoral-based farming. Similarly, another land-use change with similar prospects of environmental benefit is land purchase by the government and subsequent conversion to production forests. The purpose of this study was to analyse the marginal profitability of planting woodlots of Douglas-fir and radiata pine through two options: farm forestry, and farm-scale land purchase by the government.

METHOD

Farm forestry 'calculators' (Knowles 2003) that were developed previously with assistance from the Sustainable Farming Fund for evaluations of woodlots in Hawkes Bay, were calibrated for use at Taupo. Using the calculators, the financial returns from growing trees were examined at the one-hectare level for two scenarios. In the first scenario, termed '*Farm Forestry'*, land tenure remains unchanged, but land-use progressively changes to a combination of pastoral agriculture and production forest. In the second scenario, termed '*Crown Land Purchase*', the Government buys complete farms and plants them in trees.

Benchmarks

Farming gross margins (the annual return per livestock unit for sheep and beef farms) for existing livestock-based farming operations were obtained from the MAF Sheep and Beef Farm Monitoring Report using the '*Central North Island Hill Country'* and '*Waikato/Bay of Plenty Intensive*' farms as benchmarks (see http://www.maf.govt.nz). For the 2002-03 year the former had revenues of $53.81/lsu, and direct livestock oriented costs (variable costs) of $18.75/lsu. Subtracting the variable costs from the total revenue gave a farming gross margin of $35.06/lsu. Similarly, the more intensive '*Waikato/Bay of Plenty Intensive*' farms had gross revenue of $75.57/lsu and costs of $19.38/lsu, yielding a farming gross margin of $56.22/lsu (see Appendix A for details). Gross margins were not computed for dairy farms. It was assumed that land on dairy farms in the Taupo basin deemed marginal for dairying because of topography or proximity to streams, is quite limited, and is either supporting sheep and beef, or already planted in trees. This may change in the future.

Rural property sales statistics for open-market freehold farmland for the Bay of Plenty and Waikato for the year ending June 2003 were obtained from 'Quotable Value', P O Box 5098, Wellington. The values represent average sale values for sheep and beef 'fattening' farmland and dairy farms in the Waikato and Bay of Plenty for the six-month period ending June 2003.

	Dairy farms	Fattening farms
Region	**Average sale price ($/ha)**	**Average sale price ($/ha)**
Waikato	19,648 (80 sales)	5,646 (12 sales)
Bay of Plenty	16,255 (27 sales)	7,551 (2 sales)

Table 1: Current average land prices

There were a total of 14 sales of 'fattening' farms in the Bay of Plenty/Waikato region, a category that would be relevant to sheep and beef farming in the Taupo basin, with a weighted average price of $5,918/ha. Similarly, there were 107 sales of dairy farms in the Bay of Plenty /Waikato with a weighted average price of $18,792/ha.

Profitability indicators

The *'Farm Forestry'* scenario compares the ability of woodlots to compete with the marginal returns from sheep and beef in terms of Equivalent Farming Gross Margin (EFGM $/lsu). The EFGM translates the net present value of the tree crop into an equivalent annual return per livestock unit displaced, which can be compared with the conventional farming gross margin.

Under the default setting it was assumed that no credit was generated by the sale of livestock initially displaced by the tree crop. The effects of this assumption were investigated through sensitivity analysis.

The indicator for evaluating the *'Crown Land Purchase'* scenario was land expectation value (LEV $/ha). LEV was calculated as the sum of all future cash flows discounted to the present, and excluding the initial investment of land purchase. The land expectation values were compared with the current land prices. It was assumed that the farms were bought without livestock, and therefore there were no initial revenues from the sale of displaced livestock.

An economic indicator that applies to both scenarios is the stumpage price. The stumpage price expresses the value of the tree crop at the time of clear felling, and was calculated as the revenue from log sales minus the costs associated with logging and transportation.

Assumptions

The 'calculators' were calibrated for the conditions in the Taupo basin by examining a range of existing stands. For radiata pine, inventory data was obtained from 24 sample plots located in semi-mature and mature stands growing on ex-pasture sites in the Taupo basin. All plots were located in the North and Northwest areas of the basin, at altitudes of between 450 m and 580 m above sea level (the lake is at 357 m asl). These stands did not cover the geographical range of the basin, however, it was considered more important to measure stands growing on ex-pasture sites only, as previous farming history is known to have significant effects on tree growth. Unfortunately, the main growth indicator in the growth model (the 300-index[1]) cannot be accurately estimated for stands of less than 12 years of age, which ruled out assessment of extensive younger stands that were available further south, e.g. Hauhangaroa forest. The data from the observed plots was converted into two key indices - site index (mean top height at 20 years) and 300-index. The overall arithmetic mean (over 24 plots) was 30 m for site index and 27.2 m^3/ha/yr for 300-index. This gave a ratio of 300-index to site index of 0.9, which coincidentally is the NZ average for radiata pine. The derived site index was slightly higher than the New Zealand average.

The key indices for Douglas-fir are site index (mean top height at 40 years), and site basal area potential (SBAP). Unfortunately no sample plot data of mature or semi-mature Douglas-fir stands were available from ex-pasture sites in the Taupo basin. Instead, data were used from stands raised from the currently recommended seed sources (ex coastal California) at two extensive 42-year-old Douglas-fir provenance trials located some 50 km away on the Kaingaroa plateau (425 m asl), and on an ex-pasture site near Kinleith (470 m asl). This gave a site index of 34 m and an SBAP of 2.1.

Domestic log grades were used for both species. Merchantability (on-truck volumes as a percentage of total standing volumes) was set at 85 percent for radiata pine, and 88 percent for Douglas-fir.

[1] 300-index for radiata pine: The mean annual volume increment, in m^3/ha/yr, at an age of 30 years, assuming a final stocking of 300 stems/ha, timely pruning to 6m, and thinning to final crop at completion of pruning (Knowles 2003).

For radiata pine, MAF 12-quarter prices published on their web site in October 2003 (http://www.maf.govt.nz/forestry/statistics/logprices/index.html) were used. Prices for pruned logs were assumed to relate to a PLI (pruned log index) of 6.0, with a premium of $15/PLI unit applying around the base price. For Douglas-fir, prices were 12-quarter average prices and were provided by a major Central North Island grower during October, 2003.

The calculators incorporate a 'solver' facility for identifying the silviculture that maximises the profitability indicators (EFGM, LEV) consistent with various other constraints such as meeting certain log quality parameters. For radiata pine, a regime which yielded mean PLI of 7 or more, and unpruned-log branch indices (BIX) of 6 cm or less, was identified. This involved an initial stocking of 685 stems/ha, pruning to achieve a 'diameter over stubs' of 18cm or less, thinning to waste at completion of pruning to a final crop stocking of 250 stems, and a rotation age of 28 years.

For Douglas-fir a regime was sought that produces logs with an average branch index of less than 4 cm, log small end diameter (SED) of 300 mm or greater, and less than 20 percent juvenile wood. This was achieved with an initial stocking of 1,650 stems/ha followed by a thinning to waste at 14 m stand height to 740 stems/ha. Natural mortality reduces this stocking to 550 stems/ha by the clear felling age of 50 years.

The calculators incorporate NZ Forest Service work-study standards in allocating labour content against specific silvicultural operations. Although dated, these were considered sufficiently accurate to be used. They assume moderate hindrance and easy terrain. The labour rate was set at $26 /hr together with a supervision allowance of an additional 12 percent. This assumed that all the silvicultural work (planting, releasing, pruning, thinning) was done on contract. Plant material costs, which include herbicide, was set at 50 cents/tree for radiata pine, and 72 cents/tree for Douglas-fir. Logging costs (incl. temporary roading and trucking to mill) of $\$33/m^3$ for radiata pine and $\$40/m^3$ for Douglas-fir were used. For the *'Farm Forestry'* scenario overheads were not included, as the EFGM evaluation was a marginal analysis. For the *'Crown Land Purchase'* scenario, annual fixed costs of $46/ha were used, based on information from Crown Forestry, the forest management unit of MAF, based in Rotorua. This unit is responsible for the management of 43,000 ha of production forest on Crown land and leased Maori land, much of it in the Taupo area.

In the *'Farm Forestry'* scenario, the landowner also had the option of doing the silviculture work (planting, releasing, pruning, and thinning to waste) instead of employing contractors. This placed the woodlots on the same basis as the livestock enterprise whereby the farmer does all the day-to-day operations such as shepherding. The effects of setting the labour rate and supervision costs to zero were addressed in the sensitivity analysis.

Forestry activities, including woodlots, may involve a more intensive network of permanent roads than is usually required by agriculture. In this exercise, permanent roads were considered a capital expenditure, which eventually could be recouped against the long-term value of the asset, thus not included in the analyses. Road maintenance was included in the annual management fee of $46/ha.

The average carrying capacity of the Waikato/Bay of Plenty fattening farms described by 'Quotable NZ' for the year ended June 2003 was 10.5 lsu/ha. Under the *'Farm Forestry'* scenario, it was assumed that tree planting would commence only on the least productive areas of the farm, which would carry 8 lsu/ha. Sensitivity analysis was carried out to determine the effect of planting on more productive land by varying the livestock carrying capacity of the land over the range of 4-12 lsu/ha.

For both scenarios it was assumed that no grazing took place after tree planting. In the *'Farm Forestry'* scenario with radiata pine, there was, however, an opportunity for understorey grazing. The effects of including understorey grazing in radiata pine woodlots were therefore addressed in the sensitivity analysis.
For '*Central North Island Hill Country'* an average land price of $5,646/ha and an average stocking rate of 10.5lsu/ha gave an average land value per lsu of $538. For '*Waikato/Bay of Plenty intensive*' a land price of $7,551/ha and an average stocking rate of 11.4lsu/ha gave an average land value per lsu of $662. Setting the capital value of livestock to $95/lsu, excluding wages of management, and applying the average farming gross margins of $35.06/lsu and $56.22/lsu the marginal rate of return on capital came to 5.54 percent and 7.42 percent. This indicated that the average marginal rate of return for sheep and beef farms ranges from 5.5 to 7.5 percent.

To determine the discount rate appropriate for the *'Crown Land Purchase'* option, the methodology developed by Young (2002) in determining discount rates for Government projects was followed. This methodology utilises the concept of 'social rate of time preference', which reflects social preferences and not just financial sector considerations. Through this methodology a discount rate of 5-6 percent was estimated.

Based on the above, a discount rate of 6 percent was used as a benchmark, and the sensitivity analysis examined discount rates ranging from 4 to 9 percent

The full sets of default settings applied in the farm forestry calculators can be found in Appendix B.

RESULTS

'Farm Forestry'

The sensitivity of the EFGM to changes in discount rate, site index, livestock carrying capacity, log prices, and rotation age are shown in Table 2 and Table 3. The analysis also examined the sensitivity to variation in establishment costs, logging costs, log conversion, and final crop stocking, but none of these variables significantly influenced the economic results.

Douglas-fir generally gives lower EFGM values than radiata pine, matching benchmark farming gross margins of $35.06/lsu and $56.22/lsu at discount rates of 5.6 and 4.8 percent. Radiata pine woodlots match the same farming gross margins at 8.0 and 6.4 percent, respectively.

	Discount rate (%)					
Site index (m)	4	5	6	7	8	9
26	80	64	50	38	28	19
28	88	71	56	43	32	22
30	***96***	***78***	***62***	***48***	***36***	***25***
32	105	85	67	52	39	28
34	112	91	73	57	43	31

	Discount rate (%)					
LCC (lsu/ha)	4	5	6	7	8	9
4	193	156	123	95	71	50
6	129	104	82	64	47	33
8	***96***	***78***	***62***	***48***	***36***	***25***
10	77	62	49	38	28	20
12	64	52	41	32	24	17

	Discount rate (%)					
Log prices	4	5	6	7	8	9
-20%	64	50	39	28	19	11
-10%	80	64	50	38	27	18
0%	***96***	***78***	***62***	***48***	***36***	***25***
10%	113	92	73	57	44	32
20%	129	105	85	67	52	39

	Discount rate (%)					
Rotation age (yr)	4	5	6	7	8	9
24	96	80	66	53	42	32
26	98	80	65	51	39	29
28	***96***	***78***	***62***	***48***	***36***	***25***
30	93	73	57	43	31	20
32	86	66	50	36	25	15

Table 2: Equivalent Farming Gross Margin for radiata pine ($/lsu). Shading indicates cells where the EFGM of woodlots is higher than the benchmark farming gross margins, i.e. ( ) > $56.22/lsu and ( ) > $35.06/lsu.

	Discount rate (%)					
Site index (m)	4	5	6	7	8	9
30	61	38	21	8	-2	-10
32	69	44	25	11	0	-8
34	***78***	***51***	***30***	***14***	***2***	***-7***
36	87	57	35	18	5	-5
38	97	64	40	21	7	-3

	Discount rate (%)					
LCC (lsu/ha)	4	5	6	7	8	9
4	155	101	60	28	5	-14
6	104	67	40	19	3	-9
8	***78***	***51***	***30***	***14***	***2***	***-7***
10	62	40	24	11	2	-5
12	52	34	20	9	2	-5

	Discount rate (%)					
Log prices	4	5	6	7	8	9
-20%	52	32	17	5	-4	-11
-10%	65	41	23	10	-1	-9
0%	***78***	***51***	***30***	***14***	***2***	***-7***
10%	91	60	37	19	6	-5
20%	103	69	43	24	9	-2

	Discount rate (%)					
Rotation age (yr)	4	5	6	7	8	9
40	61	42	27	15	5	-3
45	71	48	30	16	4	-5
50	***78***	***51***	***30***	***14***	***2***	***-7***
55	79	49	27	11	-1	-10
60	77	45	23	7	-4	-12

Table 3: Equivalent Farming Gross Margin for Douglas-fir ($/lsu). Shading indicates cells where the EFGM of woodlots is higher than the benchmark farming gross margins, i.e. ( ) > $56.22/lsu and ( ) > $35.06/lsu.

If understorey grazing of the first rotation is included, the EFGM values in Table 2 increase by $2-8/lsu. As an example, the sensitivity analysis of livestock carrying capacity is repeated while including understorey grazing (Table 4). Under these conditions the woodlots match the benchmark farming gross margins at discount rates of 8.83 and 7.29 percent.

	EFGM ($/lsu)					
	Discount rate (%)					
LCC (lsu/ha)	4	5	6	7	8	9
4	198	162	130	103	79	59
6	134	110	89	71	55	42
8	***102***	***84***	***69***	***55***	***44***	***33***
10	83	69	56	46	36	28
12	70	58	48	39	32	25

	Increase ($/lsu)					
	Discount rate (%)					
LCC (lsu/ha)	4	5	6	7	8	9
4	2	3	3	4	4	5
6	3	4	5	5	5	6
8	***4***	***5***	***5***	***6***	***6***	***6***
10	4	5	6	6	6	7
12	4	5	6	6	7	7

Table 4: EFGM ($/lsu) of radiata pine including understorey grazing, and the increase in EFGM ($/lsu) when compared to radiata pine without understorey grazing. Shading indicates cells where the EFGM of woodlots is higher than the benchmark farming gross margins, i.e. ( ) > $56.22/lsu and ( ) > $35.06/lsu.

If the farmer does the silvicultural work, the marginal cost of establishing and tending the woodlot is reduced, and the profitability increases. As an example, the sensitivity analysis of livestock carrying capacity is repeated assuming no labour and supervision costs for the silviculture (Table 5). The equivalent farming gross margin increases by $12-15/lsu at the default carrying capacity of 8 lsu. Under these conditions the woodlots match the benchmark farming gross margins at discount rates of 9.79 and 7.58 percent.

	EFGM ($/lsu)					
	Discount rate (%)					
LCC (lsu/ha)	4	5	6	7	8	9
4	220	184	153	126	103	84
6	146	123	102	84	69	56
8	***110***	***92***	***77***	***63***	***52***	***42***
10	88	74	61	51	41	33
12	73	61	51	42	34	28

	Increase ($/lsu)					
	Discount rate (%)					
LCC (lsu/ha)	4	5	6	7	8	9
4	24	25	26	27	28	30
6	16	17	17	18	19	20
8	***12***	***12***	***13***	***14***	***14***	***15***
10	9	10	10	11	11	12
12	8	8	9	9	9	10

Table 5: EFGM ($/lsu) for radiata pine without labour and supervision costs, and the increase in EFGM ($/lsu) compared to radiata pine with contract labour and supervision costs. Shading indicates cells where the EFGM of woodlots is higher than the benchmark farming gross margins, i.e. ( ) > $56.22/lsu and ( ) > $35.06/lsu.

If the farmer does the silviculture work, and the understorey of the first rotation is grazed, the EFGM of woodlots increase by $18/ha under the default setting. The woodlots match the benchmark farming gross margins at discount rates of 11.00 and 8.88 percent under the default setting. At 10.5 lsu/ha, (i.e. over the whole farm), production forestry breaks even with pastoral farming at a discount rate of 9.8 and 7.8 percent.

Selling the livestock displaced by the trees creates an income, which is not included in the default evaluation. As an example, the sensitivity analysis of livestock carrying capacity is repeated including this income, and the corresponding EFGM values are presented in Table 6.

By including the sale of displaced livestock the EFGM increases by $1-$7/lsu, with an average of $4/lsu for the default setting. The woodlots now match the benchmark farming gross margins at discount rates of 6.81 and 8.76 percent.

If the farmer does the silviculture work, the understorey of the first rotation is grazed and the income from sale of displaced livestock is included, the EFGM of woodlots increase by $22/ha for the default setting. The woodlots match the benchmark farming gross margins at discount rates of 12.35 and 9.65 percent.

EFGM ($/lsu)							
		Discount rate (%)					
		4	5	6	7	8	9
LCC (lsu/ha)	4	197	160	129	102	78	58
	6	132	108	88	70	54	41
	8	100	82	67	54	43	33
	10	81	67	55	44	35	28
	12	68	56	47	38	31	25

Increase ($/lsu)							
		Discount rate (%)					
		4	5	6	7	8	9
LCC (lsu/ha)	4	1	1	2	3	3	4
	6	2	2	3	4	5	5
	8	***2***	***3***	***4***	***4***	***5***	***6***
	10	2	3	4	5	6	6
	12	3	3	4	5	6	7

Table 6: EFGM ($/lsu) for radiata pine when the return from sales of the displaced livestock is included, and the increase when compared to the default values. Shading indicates cells where the EFGM of woodlots is higher than the benchmark farming gross margins, i.e. ( ) > $56.22/lsu and ( ) > $35.06/lsu.

'Crown Land Purchase'

The results (Table 7 and Table 8) show the sensitivity of the land expectation value (LEV) to changes in site index, livestock carrying capacity, log prices, and rotation age. The analysis also addressed sensitivity to establishment costs, logging costs, contract labour costs, log conversion, and final crop stocking, but none of these had any significant influence on the result.

		Discount rate (%)					
		4	5	6	7	8	9
Site index (m)	26	15341	9740	6249	3945	2368	1262
	28	17148	10963	7103	4553	2806	1579
	30	***18868***	***12125***	***7914***	***5130***	***3220***	***1877***
	32	20550	13261	8706	5693	3624	2167
	34	22195	14371	9480	6242	4017	2448

		Discount rate (%)					
		4	5	6	7	8	9
Index ratio	0.7	11611	7179	4421	2607	1370	507
	0.8	15430	9782	6260	3936	2345	1229
	0.9	***18868***	***12125***	***7914***	***5130***	***3220***	***1877***
	1.0	22096	14324	9467	6251	4042	2484
	1.1	25295	16505	11006	7363	4857	3088

		Discount rate (%)					
		4	5	6	7	8	9
Log prices	-20%	12134	7516	4641	2748	1456	553
	-10%	15501	9820	6277	3939	2338	1215
	0%	***18868***	***12125***	***7914***	***5130***	***3220***	***1877***
	10%	22235	14429	9551	6322	4103	2539
	20%	25602	16734	11188	7513	4985	3201

		Discount rate (%)					
		4	5	6	7	8	9
Rotation age (yr)	24	18748	12462	8473	5786	3902	2544
	26	19097	12495	8337	5562	3636	2264
	28	***18868***	***12125***	***7914***	***5130***	***3220***	***1877***
	30	18045	11357	7219	4512	2678	1405
	32	16623	10205	6272	3730	2030	869

Table 7: Land Expectation Value ($/ha) for radiata pine. Shading indicates cells where the LEV of production forestry is higher than the benchmark land prices, i.e. ( ) > $7,551/ha and ( ) > $5,646/ha.

Site index (m)	Discount rate (%) 4	5	6	7	8	9
30	11451	5489	2187	285	-835	-1502
32	13147	6475	2777	643	-616	-1367
34	14968	7537	3414	1033	-375	-1218
36	16876	8648	4080	1438	-126	-1064
38	18884	9820	4785	1870	142	-896

SBAP	Discount rate (%) 4	5	6	7	8	9
1.9	11673	5614	2259	325	-814	-1492
2.0	13324	6577	2837	679	-595	-1355
2.1	14968	7537	3414	1033	-375	-1218
2.2	16581	8478	3981	1380	-160	-1083
2.3	18129	9379	4520	1708	42	-958

Log prices	Discount rate (%) 4	5	6	7	8	9
-20%	9619	4417	1540	-115	-1087	-1663
-10%	12294	5977	2477	459	-731	-1440
0%	14968	7537	3414	1033	-375	-1218
10%	17642	9097	4352	1606	-20	-995
20%	20316	10657	5289	2180	336	-773

Rotation age (yr)	Discount rate (%) 4	5	6	7	8	9
40	11425	6155	3049	1128	-96	-890
45	13633	7151	3439	1217	-149	-1002
50	14968	7537	3414	1033	-375	-1218
55	15338	7326	3030	641	-712	-1486
60	14730	6582	2370	121	-1097	-1760

Table 8: Land Expectation Value ($/ha) for Douglas-fir. Shading indicates cells where the LEV of production forestry is higher than the benchmark land prices, i.e. ( ) > $7,551/ha and ( ) > $5,646/ha.

Stumpage value
The stumpage value for both species and a range of site indices are presented in Table 9. From this it is evident that the stumpage represents a considerable value, and the non-discounted stumpage value for Douglas-fir is about twice that of radiata pine.

Radiata pine	
Site index (m)	Stumpage ($/ha)
26	47,456
28	50,199
30	***52,564***
32	54,714
34	56,794

Douglas-fir	
Site index (m)	Stumpage ($/ha)
30	93,502
32	103,897
34	***114,991***
36	126,671
38	138,867

Table 9: Stumpage value ($/ha) for radiata pine and Douglas-fir at a range of site indices.

Sensitivity analyses
The profitability of the tree crop is quite sensitive to changes in the LCC, and the higher the LCC the less profitable it is to plant trees. For example, at 6 percent discount rate there is an increase in EFGM of $6/lsu for each unit decrease in LCC. Also, the lower the discount rate the larger the effect of changes in LCC. As a consequence, Douglas-fir is in general more sensitive to changes in LCC than radiata pine, which again is explained by the longer rotations required for Douglas-fir. The *'Crown Land Purchase'* scenario is not influenced by LCC as it assumes the purchase of farms without livestock.

The growth potential (e.g. site index, SBAP, 300-index) influences the profitability directly - the higher the growth potential, the higher the profitability. For example, at a discount rate of 6 percent, for each metre increase in site index for radiata pine the LEV increases by some $400/ha. Again the effects of changes in growth potential are larger at lower discount rates, and the profitability of Douglas-fir is likewise more sensitive to changes than radiata pine.

The profitability is also sensitive to changes in log prices, e.g. at a discount rate of 6 percent, an overall ten percent increase in log prices for radiata pine increases the LEV in the order of $1,600/ha. The effect of changes in log prices is stronger for lower discount rates, and thus also stronger for Douglas-fir than for radiata pine.

DISCUSSION

The returns from radiata pine for the default settings equal or exceed that for pastoral farming at discount rates of 8 percent and less in the '*Central North Island Hill Country*'. At discount rates of 5.6 percent and less Douglas-fir also matches or exceeds current returns from sheep and beef farming. Similarly, the returns from radiata pine equal or exceed that of the '*Waikato/Bay of Plenty Intensive*' farms at interest rates of 6 percent and less. Hence, existing sheep and beef farmers can slowly change their land-use from pastoral farming to a mix of pastoral farming with woodlots without comprising their long-term profitability.

The above conclusion is further underlined by the fact that the default setting does not include understorey grazing, the revenue from sales of displaced livestock, or take into account that the farmers can do the silviculture work. Applying all three, the EFGM of woodlots with radiata pine exceeds that for sheep and beef farming even at discount rates of up to 10 percent, depending on livestock carrying capacity.

At the government-based discount rate of 6 percent, and based on recent sales of Waikato and Bay of Plenty 'fattening' land, the Government stands to recoup all its investment in purchase of sheep and beef farms for conversion to radiata pine production forest. This conclusion is valid for both the benchmark land prices of $5,646/ha and $7,551. It is also worth noting, that at this discount rate, the profitability calculations are relatively insensitive to variations in land price.

Dairy farms are more costly to acquire, which reflects on the profitability, as the interest on the initial investment becomes significant compared to the overall cash flow. The LEV of production forest just exceeds the current average dairy-farm land value of $18,792/ha at a discount rate of 4 percent. Using a discount rate of 5 percent there is a significant shortfall of about $6,400/ha. At 6 percent discount rate this shortfall increases by a further $4,240/ha. Hence, land use change from dairying to production forest may seem quite costly, however, this is also the change that brings about the greatest environmental benefit.

From the results it is evident that the profitability is largely determined by the choice of discount rate. Low discount rates favour conversion to forestry, and longer rotations, while high discount rates favour continuation of pastoral farming. How does one make a decision on which course is the most profitable? There is no simple answer and the choice of discount rate in investment analyses is under continuing debate. However, as a base it is worth noting that the so-called 'social discount rate' based on Government standards is around 5-6 percent (Young, 2002). As also found in this study, this discount rate is very similar to the current marginal rate of return on sheep and beef farms in '*Central North Island Hill Country*'. Using an overall discount rate of around 6 percent therefore seems reasonable.

Under the scenarios examined here Douglas-fir is less profitable than radiata pine, giving a similar return to '*Central North Island Hill Country*' and '*Waikato/Bay of Plenty Intensive*' farms at discount rates of 4.8 and 5.6 percent respectively. Further more, Douglas-fir is more sensitive to changes in the key variables. However, at the time of clear felling Douglas-fir stands also represent a much greater value, e.g. under the default setting the stumpage price is

$114,991/ha for Douglas-fir at age 50 years in comparison to $52,564/ha for radiata pine at age 28 years. Furthermore, through its longer rotation and therefore fewer logging interventions, there is likely to be less soil disturbance. The seemingly greater environmental benefit of planting Douglas-fir in the Taupo basin should therefore be taken into account before simply choosing the higher financial returns of radiata pine.

CONCLUSION

The analyses shows that there is a good opportunity for sheep and beef farmers in the Taupo basin to change their land-use from pastoral farming to a mix of pastoral farming with woodlots, particularly on their least productive land, without compromising their long-term profitability. Similarly, at a discount rate of 6 percent, the Government stands to recoup all its investment in purchase of sheep and beef farms for conversion to radiata pine production forest in the Taupo basin. Where the Government already owns such farmland in the Taupo basin, as in the case of the Department of Corrections and LandCorp Farming Ltd, and given the environmental consequences of continuing with pastoral farming, there would seem to be a clear case for the conversion of such land into tree crops. Using a 4 percent discount rate, Government purchase of dairy farms and subsequent conversion to radiata pine is also a viable option.

The results and conclusions presented are all made at the one-hectare level. Whole-farm analysis of cash flow and overall feasibility should be made before the results are widely applied.

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APPENDIX A: AVERAGE FARMING GROSS MARGIN FOR '*CENTRAL NORTH ISLAND HILL COUNTRY*' AND '*WAIKATO/BAY OF PLENTY INTENSIVE*' FARMS

Source: Ministry of Agriculture and Forestry website: http://www.maf.govt.nz. October, 2003

	Hill country 2002/2003	Hill country 2003/2004 forecast	Intensive 2002/2003	Intensive 2003/2004 forecast
	$/lsu	$/lsu	$/lsu	$/lsu
Gross farm revenue	**53.81**	**51.27**	**75.57**	**74.38**
Fertiliser	7.26	7.38	9.08	8.13
Shearing costs	5.92	6.02	4.84	4.93
Animal health	3.23	3.16	2.55	2.32
Feed	0.81	0.70	1.22	1.41
Regrassing costs	0.53	0.53	0.52	0.52
Freight	0.46	0.39	0.64	0.59
Seeds	0.28	0.27	0.25	0.25
Breeding	0.26	0.27	0.25	0.25
Expenses	**18.75**	**18.72**	**19.35**	**18.40**
Farming gross margin	**35.06**	**32.55**	**56.22**	**55.98**

APPENDIX B: DEFAULT CALCULATOR SETTINGS - RADIATA PINE

Radiata pine			
Input Variable		Farm forestry	Crown Land Purchase
Land & Livestock	Land Value ($/ha)	0	0
	Livestock Carrying Capacity (LSU/ha)	8	10.5
	Livestock Capital Value ($/LSU)	0	0
	Livestock Gross Margin ($/LSU/yr)	0	0
	Grazing (Y/N)	n	n
Financial	Annual Fixed Costs ($/ha)	0	46
	Establishment Costs (cents/tree)	50	50
	Logging Cost ($/m^3)	33	33
	Labour Cost ($/hr)	26	26
	Labour Supervision (%)	12	12
	Discount rate (%)	6	6
Growth & Quality	300 Index / Site Index	0.9	0.9
	Site Index (m)	30	30
	Conversion (%)	85	85
	B.H. Outerwood Density (kg/m^3)	410	410
	Outerwood Measurement Age (yrs)	15	15
Silviculture	Rotation (yrs)	28	28
	Final Crop Stocking (stems/ha)	250	250
Log Prices	Log Prices global adjustment (%±)	0	0
	Pruned Log PLI unit increase	15	15
	Pruned (price for PLI = 4)	141	141
	S1	95	95
	S2	87	87
	S3	65	65
	L1	68	68
	L2	68	68
	L3	65	65
	Pulp	42	42

APPENDIX B: DEFAULT CALCULATOR SETTINGS - DOUGLAS-FIR

Douglas-fir			
Input Variable		Farm forestry	Crown Land Purchase
Land & Livestock	Land Value ($/ha)	0	0
	Livestock Carrying Capacity (LSU/ha)	8	10.5
	Livestock capital value ($/LSU)	0	0
Financial	Annual fixed costs ($/ha)	0	46
	Establishment costs (cents/tree)	72	72
	Clearfell Logging Cost ($/$m^3$)	40	40
	Production Thin Logging Cost ($/$m^3$)	50	50
	Labour Cost ($/hr)	26	26
	Labour Supervision (%)	12	12
	Discount rate (%)	6	6
Growth & Quality	SBAP	2.1	2.1
	SI (m)	34	34
	Clearfell Conversion (%)	88	88
	Thinning Conversion Reduction (%)	10	10
	B.H. Outerwood Density (kg/m^3)	418	418
	Outerwood Measurement Age (yrs)	30	30
Silviculture	Rotation (yrs)	50	50
	FCS (stems/ha)	550	550
	Ht waste thin (m)	14	14
	Ht prod. thin (m)	0	0
	Waste thin : Total thin stems (%)	50	50
	Prune ? (Y/N)	N	N
Log Prices	Log Prices global adjustment (%±)	15	15
	Pruned Log PLI unit increase	15	15
	Pruned (price for PLI = 4)	160	160
	S1	170	170
	M1a	170	170
	M1b	170	170
	S2	170	170
	L1	110	110
	L2a	75	75
	L2b	75	75
	Ari	70	70
	Pulp	45	45

PART 2: FARM-LEVEL SUSTAINABILITY

ABSTRACT

This study applied linear programming to analyse farm-level sustainability of replacing pasture with radiata pine production forestry in the Taupo basin. The analyses were based on land-use optimisation for a model farm when subject to social, ecological and economic constraints. The results showed that despite being more profitable at the one-hectare-level the farm-level implementation of farm-forestry was severely limited by the availability of capital. It was not possible to simultaneously maintain the annual gross margin enjoyed from pastoral farming and achieve the target 20% reduction in nitrogen loss. More profitable solutions, which resulted in immediate tree plantings and decreased nitrogen loss, were available, but these solutions required external capital or labour to be feasible at the farm-level.

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INTRODUCTION

Recent monitoring confirms that the Lake Taupo ecosystem is nitrogen limited, and if land-use in the catchment (and its associated nitrogen loading) stay at the same level as today, the Lake's health will continue to deteriorate (Vant 2004). Several studies have shown that leaching and run-off of nutrients is much less from land under forests than it is from pastoral farmland (Biggs *et al.* 1990, Smith *et al.* 1993, O'Loughlin 1994). The first part of this study found that radiata pine woodlots in general were at least as profitable as pastoral farming at the one-hectare-level on medium-to-poor farmland. Likewise, it was found that woodlots were even more profitable if silvicultural work was done by on-farm labour. However, it was not addressed if any of these options were sustainable, likewise the farm-level economic feasibility of planting woodlots was not addressed.

Most existing decision support systems in forest management, for example FOLPI (Manley 1991), assist the estate planning process by finding the most profitable strategy given the economic variables, i.e. maximising the net present value (NPV). An increase in ecological and social awareness has, however, increased the need for inclusion of other criteria than economic. Forest Research Ltd has developed a strategic planning and optimisation tool called '*AFM*' (Laroze 2003), which is based on the mathematical modelling language LINGO (see www.lindo.com for details). '*AFM*' includes the option to address other issues than economic in strategic land-use optimisation.

The purpose of the study was to use '*AFM*' to optimise the land-use for a model farm in the Taupo basin, and hereby evaluate the economic, social and ecological sustainability of replacing pastoral farming with woodlots, which ultimately is seen as a means to reduce nutrient leaching to Lake Taupo. For more background information see the first part of this study.

METHODS AND MATERIAL

A model farm was constructed based on MAF monitoring farms '*Waikato/Bay of Plenty Intensive*' and '*Central North Island Hill Country*' (see http://www.maf.govt.nz for details). The model farm was assumed to cover an area of 550 ha, all in pasture, and to carry a total of 5,700 livestock units (lsu). The land was divided into 3 site classes (28% good, 54% medium and 18% poor), and the livestock carrying capacity was defined for each class (Table 10). The capital value of livestock was set at $95/lsu and the farming gross margin to $50/lsu. The discount rate was set at 6.5%, which is the current average return on capital for farms in the Taupo basin (see the first part of the study). The on-farm labour requirement was set at 30 minutes per lsu per year (slightly more than the average for the MAF model farms), which for the whole farm equalled a total workload of 2,850 hrs/year. Finally, it was assumed that some capital (NZ$ 25,000) was available at the beginning of the planning horizon.

Site class	Good	Medium	Poor
Land area (ha)	150	300	100
Livestock carrying capacity (lsu/ha)	14	10	6
Radiata pine Site index	30	28	26
Radiata pine Index ratio	0.9	0.85	0.85
Radiata pine 300-index	27	23.8	22.1
Nitrogen load (kgN/ha/year)	9	7	5

Table 10: Model farm area availability, classification and productivity

Management regimes

Five management regimes, that were available to the model farm, were defined with respect to their economic, social and environmental variables:

1) Pastoral farming,
2) Pruned radiata pine woodlots with silvicultural work by contract labour.
3) Pruned radiata pine woodlots with silvicultural work by on-farm labour.
4) Unpruned radiata pine woodlots with silvicultural work by on-farm labour.
5) No management (neither farming nor forestry)

The forest management regimes (2-4) applied the same silviculture, except for the unpruned regime where no trees were pruned. A summary of the management regimes is given in APPENDIX .

For the forestry regimes, a set of site indices for each site class was assumed (Table 10), and the forest growth and yield was modelled using the 'Radiata pine Calculator' (Knowles *et al.* 2002). The calculator distributed the yields to log grades and the value of the woodlots at the time of clear-felling was thus estimated. Finally, the on-farm labour requirements for silvicultural work were estimated using NZ Forest Service Work Study Standards as implemented in the calculator. Harvesting of woodlots was considered to require specialist knowledge and equipment, thus clear-felling was always assumed done by contract labour.

Quantification of the environmental impact of different management regimes is a highly complex issue. However, according to recent studies (Vant 2004) Lake Taupo is nitrogen limited. Hence, nitrogen loss was applied as an indicator of the environmental impact, and approximate values were obtained from Environment Waikato (Tony Petch pers.comm.). The base nitrogen loss from each hectare of land was assumed to be 2 kgN/year irrespective of land-use, while livestock added another 0.5 kgN/lsu/year. For example, the nitrogen loss from land carrying 14 lsu/ha was 9 kgN/ha/year. The nitrogen loss from plantation forestry was assumed to equal the base loss of 2 kgN/year. However, based on Quinn and Ritter (2004) it was assumed that loss from plantation forests in the four years following land-use conversion was twice the base leaching, i.e. 4 kgN/ha/year. Similarly, it was assumed that the loss doubled in the year following clear-felling.

Optimisation scenarios

A series of scenarios was designed to reflect the environmental, social and economical consequences of a compulsory (forced) reduction in nitrogen loss. The optimal, annual, farm-level mix of land-uses over the planning horizon (50 years) was identified for each of the scenarios using linear programming, i.e. the allocation of area to different management regimes which maximises the net present value (including future land value). Finally, the scenarios were compared based on net present value, environmental impact, annual net results, and on-farm-labour requirements.

The scenarios were:

1. Farming only: Continuation of the present management
2. No restrictions: All management regimes were allowed, it was possible to borrow capital, unlimited on-farm-labour was available and there were no limits on environmental impact.

The rest of the scenarios successively added more restrictions to Scenario 2 in the following order:

3. Restrictions on the allowed nitrogen loss: From year 5 and onwards, the average annual farm-level nitrogen loss had to be less than 20% of what it was when all land was in pasture, i.e. 3,160 kgN/year as compared to 3,950 kgN/year. This resembles the currently recommended 20% reduction (Tony Petch, pers. comm.).

4. Restriction on maximum debt: No debt was allowed.
5. Restriction on the annual gross margin: Annual gross margin was required to be more than 80% of the gross margin when all land was in pasture, i.e. NZ$ 228,000 as compared to NZ$ 285,000.
6. Restriction on the on-farm-labour available: On-farm workload could not exceed the normal farming workload by more than 10 percent in any one year, i.e. 3,135 hours per year as compared to 2,850 hours per year.

RESULTS

The objective function value (net present value - NPV) for the optimal solution for each scenario is presented in Table 11. The development over time of annual environmental impact, annual on-farm labour requirements and annual net result is presented in Figure 1 - Figure 3. The development over time of land-use is presented for the full model in Figure 4.

Optimisation step	Objective function value (NZ$)
1. Pastoral farming	4,710,176
2. No restrictions	5,557,336
3. Environmental restrictions	5,557,336
4. No debt restriction	5,557,336
5. Minimum gross margin required	5,233,832
6. Full model	5,086,845

Table 11: Optimal net present value for each of the six scenarios

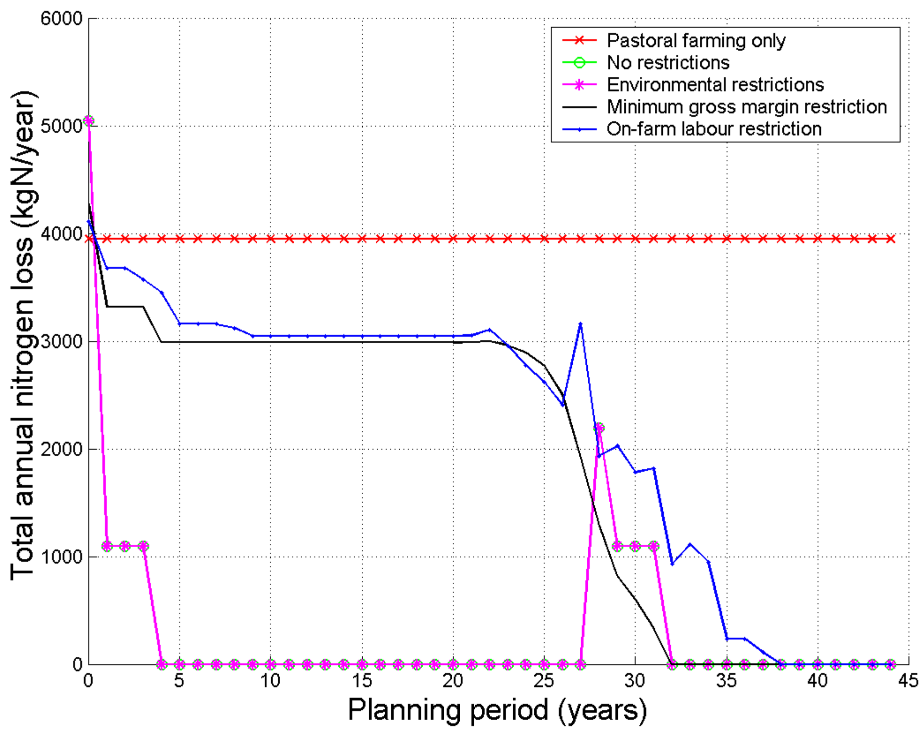

Figure 1: Development of annual farm-level nitrogen loss (kgN/year)

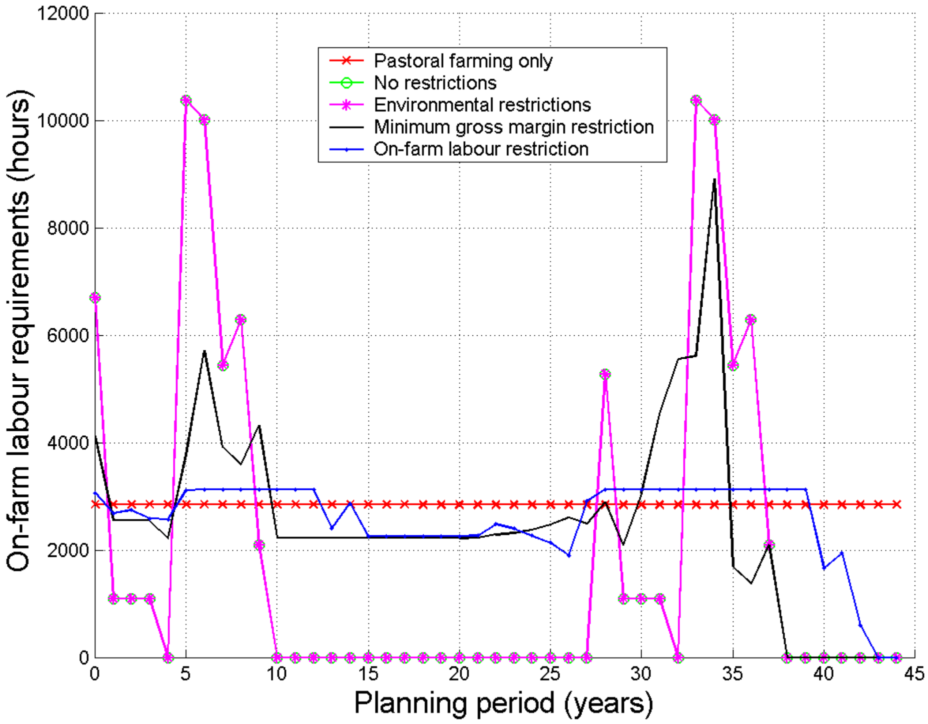

Figure 2: Development of on-farm labour requirements (hours) over time

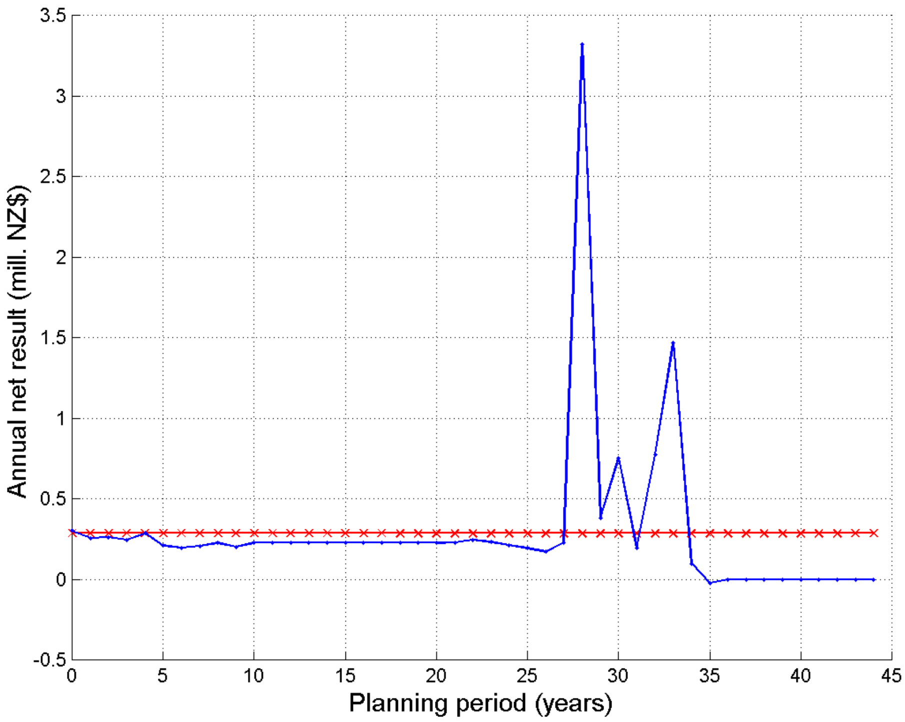

Figure 3: Development of annual net result (mill. NZ$ per year) - the dotted curve represents the full model and the 'crossed' curve the model with pastoral farming only

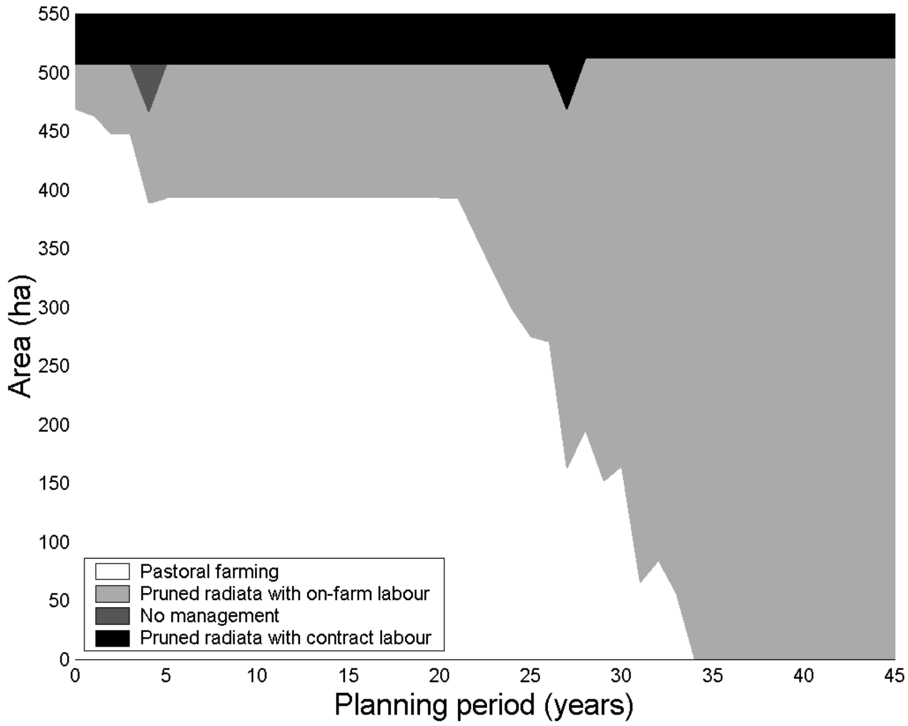

Figure 4: Development of land use over time for the full model

DISCUSSION

Overall, it was evident from Table 11 that without any restrictions, a combination of farming and forestry provided the most profitable alternative, with a net present value of NZ$800,000 (20%) more than farming alone. The NPV for Scenarios 2-4 was similar, indicating that restrictions on environmental impact and debt were not immediately limiting. However, with the restrictions on annual gross margin and on-farm labour, the solutions were successively less profitable. Clearly, the restriction on annual gross margin was crucial, and provided a decrease in net present value in the order of NZ$300,000. In comparison, the restriction of on-farm labour caused a further reduction of NZ$150,000. The net present value of the full model (including all restrictions) was still NZ$350,000 more than pastoral farming. Hence, if a 20% reduction in annual gross margin was allowed the target of reducing the nitrogen loss by 20% was easily achieved, and the mix of farming and forestry was more profitable than pastoral farming alone by a wide margin.

Allowing the optimisation model to reduce the annual gross margin by 20% was a substantial degree of freedom. Limiting the full model to a 15% reduction in annual gross margin reduced the net present value by further NZ$400,000, making pastoral farming more profitable than farm-forestry. Further iteration of the optimisation with more restrictive conditions on annual gross margin showed that for reductions in annual gross margin less than 12% there was no feasible solution, everything else being equal. Consequently, because few people are willing to accept an immediate 15-20% reduction in income despite prospects of an increased long-term profitability, it is unlikely that any major tree plantings will take place without external capital. This also emphasises that cash-flow considerations and farm-level feasibility studies are essential for the successful application of farm forestry.

The chart of temporal development of nitrogen loss (Figure 1) showed that there were limitations to the usefulness of the environmental restriction (objective) as formulated in this study of reducing the annual nitrogen loss with 20% after year 5. The main problem was that this reduction was automatically achieved if the land was managed for the highest profitability, i.e. planting trees. Also, due to discounting of financial parameters, a reduction of the nitrogen loss in the future influenced the NPV less than if the issue was addressed right away. Looking at the models with few restrictions it was obvious that a very significant and fast reduction in nitrogen loss could be achieved if there were no restrictions on on-farm labour or required annual gross margin – this also resulted in an increase in NPV of about NZ$800,000. This illustrates that if external capital is available, it is likely to be profitable to displace livestock with production forestry and the nitrogen loss will be reduced simultaneously.

The labour requirements (Figure 2), like the net annual results, became more variable with the introduction of woodlots. For the full model, the workload was slightly higher than normal for the first 12 years, and then decreased markedly to 75% of that of farming until year 28, when a new series of woodlots needed thinning and pruning. All the models without restrictions on on-farm labour exploited this extensively, for example the no-restrictions model required more than 10,000 hours annually. However, this was followed by long periods of reduced or zero requirements for on-farm labour.

From Figure 3 it was evident that the net annual result was more variable over time if some of the land was planted in woodlots. For the full model, the result decreased until year 5, and then remained at this lower level until year 28 and 29 when it increased to several million dollars. This was obviously because income from farming reduced as land was successively planted in woodlots, and no income was generated from the woodlots until the first harvest in year 28. It was also obvious that once mature, the woodlots were very valuable. For example, for the no-restrictions scenario (not shown), where all medium and poor land was planted in trees immediately, the forest stands were worth more than $20 million at the time of harvest (undiscounted at stand age 28 years).

Evaluating the environmental impact using nitrogen loss as a sole measure was appealing because of the nitrogen-limited nature of Lake Taupo ecosystem, and it allowed for a simple low-cost environmental comparison of management regimes. This approach is of course simplistic and its greater validity may be questionable. A more diverse assessment of the environmental impact for each land-use/management regime could lead to different results. This would, however, require extensive knowledge and studies of a multitude of environmental factors, of which some are still not fully understood. Future studies may want to address or attempt to quantify the wider environmental impact of various management regimes.

CONCLUSION

The first part of the study concluded that there was a good economic case for reducing the environmental impact (nutrient leaching) from pastoral farming by planting parts or all of the farmland into woodlots. From the present study it was evident that not only could the nitrogen loss from the present pastoral-based enterprises be greatly reduced, the introduction of farm-forestry could also be of considerable economic benefit to the farmer. The economically optimal extensive tree plantings, however, caused short-term shortage of on-farm labour and reductions in annual gross margin. When these issues were addressed, the net present value was reduced significantly. If no reduction in annual gross margin was allowed, the transition from pastoral-based farming to production forestry was very slow, and it was not possible to attain the target of reducing the nitrogen loss by 20% from year 5. Allowing reductions in annual gross margin of up to 20% the transition was much quicker, the environmental impact target was easily achieved, and the net present value increased by NZ$400,000.

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APPENDIX C

Planning period	Operation	Costs ($)	Labour (hours)
Year 0	Planting	562	9.6
Year 1	Pest control		2
Year 2	Pest control		2
Year 3	Pest control		2
Year 5	1st pruning and thinning		21.4
Year 6	2nd pruning		16.8
Year 7	3rd pruning and 2nd thinning		25
Year 28	Clearfell	19942	

Table 12: Management of woodlots on good sites

Planning period	Operation	Costs ($)	Labour (hours)
Year 0	Planting	562	9.6
Year 1	Pest control		2
Year 2	Pest control		2
Year 3	Pest control		2
Year 5	1st pruning and thinning		23.9
Year 6	2nd pruning		17
Year 8	3rd pruning and 2nd thinning		21
Year 28	Clearfell	17419	

Table 13: Management of woodlots on medium sites

Planning period	Operation	Costs ($)	Labour (hours)
Year 0	Planting	562	9.6
Year 1	Pest control		2
Year 2	Pest control		2
Year 3	Pest control		2
Year 6	1st pruning and thinning		23.9
Year 7	2nd pruning		17
Year 9	3rd pruning and 2nd thinning		21
Year 28	Clearfell	15996	

Table 14: Management of woodlots on poor sites

Management	Site class	Pruned (m^3)	S1, S2 (m^3)	S3 – L3 (m^3)	Pulp (m^3)
Pruned	Good	219	98	237	51
Pruned	Medium	197	85	198	49
Pruned	Poor	186	69	183	47
Unpruned	Good	0	317	237	51
Unpruned	Medium	0	282	198	49
Unpruned	Poor	0	255	183	47

Table 15: Harvested volume by log grade, management regime and site class