GROWTH AND PROFITABILITY OF RADIATA PINE FARM FORESTRY IN HAWKE'S BAY AND WAIRARAPA

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Report No. 89 **May 2004**

FOREST AND FARM PLANTATION MANAGEMENT COOPERATIVE

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EXECUTIVE SUMMARY

GROWTH AND PROFITABILITY OF RADIATA PINE FARM FORESTRY IN HAWKE'S BAY AND WAIRARAPA [1]

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Many farmers in Hawke's Bay and Wairarapa are interested in planting woodlots for erosion control and income diversification. Growth of the main tree species (radiata pine) is quite variable, particularly in the summer-dry country from the mouth of the Mohaka river and south along the East Coast to Cape Palliser.

The purpose of this study was to:
1) Use local knowledge to classify growth conditions on ex-pasture sites in the area, particularly on summer-dry country.
2) Build a regression model that predicts indices for stand growth from the classifications.
3) Develop a set of yield classes for Hawke's Bay and Wairarapa.
4) Identify 'best' management regimes for the yield classes.
5) Compare the profitability of woodlots and pastoral farming for the yield classes.
6) To advise farmers of the results, so they can better decide whether to convert land into trees, and if so, on which types of land.

The developed model used for predicting yield classes is fairly robust and enables easy prediction of radiata pine stand growth on bare land, which through the Farm Forestry Calculator allows for analysis of the physical and economic performance of radiata pine woodlots. The profitability of planting woodlots on farmland in Hawke's Bay and Wairarapa is highly variable. For land carrying 6 lsu/ha or less, there is an obvious economic case for tree planting. On land carrying 12 lsu/ha or more there is little economical incentive to change land-use. Woodlots on land carrying between 6 and 10 lsu/ha are about as profitable as pastoral farming, and other considerations, such as erosion control and water quality improvement, can be addressed without endangering the profitability.

[1] This document is an output under the Sustainable Farming Fund Contract 00/69 'Farm Forestry for Economic and Environmental Sustainability'. Further copies are available from: New Zealand Farm Forestry Association, PO Box 1122, Wellington.

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INTRODUCTION

Background

Much of the pastoral land in Hawke's Bay and Wairarapa is erosion-prone hill country, and soil erosion is recognised as a major ecological problem in the region. Soil erosion can be prevented or reduced by planting trees, or by allowing native bush to grow in areas that are at risk from erosion (Hicks 1991, Maclaren 1996). Recent studies of hill country farms on the East Coast (McElwee 1998) and in Hawke's Bay (Halliday and Knowles 2003) showed that tree roots have a vital role in holding erosion prone soils onto steep slopes. Farm forestry can thus make a significant contribution to the environmental sustainability of eroding farmland. Furthermore, by displacing livestock, woodlots can reduce the nutrient inputs to soil and ground water, thus, helping to improve water quality of streams and lakes in the longer term (Biggs *et al.* 1990, Smith *et al.* 1993, O'Loughlin 1994).

Profitability analyses of farm forestry on a 'summer-moist' farm in Hawke's Bay (Halliday and Knowles 2003) and the Taupo basin (Knowles, Hansen, and Ritter 2003) have shown that woodlots of radiata pine may be more profitable than pastoral farming, especially on land that has below-average livestock carrying capacity. Many farmers on summer-dry country in Hawke's Bay and Wairarapa are also interested in planting woodlots for erosion control, and income diversification. Radiata pine is the species of choice and has been widely applied in the past. Growth of radiata pine in Hawke's Bay and Wairarapa is, however, quite variable, particularly in the summer-dry country from the mouth of the Mohaka river and south along the East Coast to Cape Palliser.

The Hawke's Bay and Taupo studies employed the Farm Forestry Calculators (Knowles, Kimberley, and Hansen 2003, Knowles 2003). These are user-friendly, spreadsheet-based software designed for easy evaluation of the physical and financial output from farm forestry. The fundamental driver of the calculator for radiata pine is two growth indices: site index[2] and 300-index[3] (Knowles and Halliday 2003b). By setting these indices, the calculators can be calibrated to a specific site. However, because of the diverse growth conditions in Hawke's Bay and Wairarapa it is not possible to use one set of indices for the entire region. Furthermore, it presently requires expert knowledge and reliable data to estimate growth indices for a particular site, especially if there is no history of woodlots in the area.

The purpose of this study is therefore to

1) Use local knowledge to classify the growth conditions for existing stands in Hawke's Bay and Wairarapa
2) Build a regression model that predicts site index and 300-index from the above classification
3) Develop a set of yield classes covering the range of existing sites
4) Identify the 'best' management regime for each yield class
5) Compare the profitability of woodlots and pastoral farming for a range of sites using the yield classes as examples
6) To advise farmers of the results, so they can better decide whether to convert land into trees, and if so on which types of land.

[2] The site index is the mean top height, in metres, at age 20 years
[3] The 300-index is the mean annual volume increment, in m^3/ha/yr, at age 30 years, assuming a final stocking of 300 stems/ha, timely pruning to 6m, and thinning to final crop at completion of pruning

MATERIAL AND METHODS

Site classification and yield classes

A total of 242 stands on ex-farm sites in Hawke's Bay and Wairarapa were studied. All the stands contained either inventory plots or permanent sample plots, from which data were extracted. Based on these data, the site index and 300-index were estimated for each stand/site, using the growth model in the radiata pine calculator (Knowles and Halliday 2003b).

In estimating the site index and 300-index from inventory data it is assumed that tree growth follows a similar pattern to that modelled in the calculator. Tree growth in the summer-dry country (rainfall classes 1 and 2), however was found to follow a different trajectory. The trees grow as predicted whilst young, but after canopy closure the growth slows down markedly. In effect, growth forecasts based on inventory data from young stands in the summer-dry country therefore tend to be overestimated, and the younger the stand the greater the bias. To counter this bias, the estimates of 300-index and site index for sites in rainfall classes 1 and 2 were corrected for the age of the stand (at the time of assessment) by the following relationship

$$I = I - a(T - Age)$$

Where a and T are constants with values 0.39 and 30 respectively, and I is either 300-index or site index. For example, a 17-year-old stand in summer dry country has an estimated 300-index of 26.4 m^3/ha/yr. When corrected for age the 300-index is 26.4 – 0.39*(30-17) = 21.3 m^3/ha/yr.

Based on local knowledge, the stands were also classified using five indicators, each evaluated on a scale from one to five according to Table 1.

Table 1: Land classification matrix

	1	2	3	4	5
Terrain	Very steep (>35°)	Moderate to steep	Moderate	Easy (<15°)	Flat
Soil depth	Skeletal	Shallow	Medium	Deep	Very deep (>2m)
Fertility	Very low	Low	Medium	High	Very high
Exposure	Very exposed	Exposed	Medium	Sheltered	Very sheltered
Rainfall	<750mm, obvious seasonal moisture deficiency	750-850mm	850-950mm	950-1200mm	>1200mm

Once the 300-index and site index for each stand were corrected for age at assessment, the stands were divided into five yield classes based on the corrected 300-index values. The yield classes were set at approximately the 20 percentiles, as follows:

1) 300-index less than 16
2) 300-index between 16 and 19
3) 300-index between 19 and 22
4) 300-index between 22 and 25
5) 300-index more than 25

Estimating growth indices based on site classification

The 300-index was modelled as a multiple linear function of the land classification indicators, as shown in Table 1. The significant indicators ($P<0.05$) and the corresponding constants were estimated by least-squares regression. Likewise, the index ratio (300-index divided by site index) was modelled as a function of the land classification indicators plus the estimated 300-index. Again, the significant indicators and their corresponding constants were estimated using least-squares regression.

Identification of 'best' management regimes for the yield classes
A 'best' management regime is one that maximises the net present value of a woodlot, while at the same time producing good quality logs. To ensure the latter, identification of regimes for each yield class were attempted that achieved a branch index (BIX) of less than 6.1 and a pruned log index (PLI) of more than 7. For some yield classes it was not possible to achieve all three goals and still stay within the scope of the radiata pine calculator, e.g. rotation age should be less than 35 years and the final crop stocking should be 200 stems/ha or more. In that case, the PLI had highest priority, followed by BIX. The NPV was then maximised using the 'solver' facility available in the calculator. Caution is needed in interpreting the regime for yield class one as such stands are not well represented in the calculator.

Profitability comparison by yield class
The Farming Gross Margin (FGM) is the annual return per livestock unit for sheep and beef farms. This is the gross revenue less the variable costs, such as shearing and animal health. Benchmark FGM from existing livestock-based farming operations were obtained from the MAF Sheep and Beef Farm Monitoring Report. For the 2002-03 year the average '*Hawke's Bay/Wairarapa Summer Moist'* farm had an FGM of $53.20/lsu. The '*Hawke's Bay/Wairarapa Summer Dry*' farms had an average FGM of $45.06/lsu (see Appendix A for details).

The Farm Forestry Calculators estimate the returns from woodlots at the one-hectare level, and express the return in terms of Equivalent Farming Gross Margin (EFGM in $/lsu). The EFGM translates the net present value (NPV) of the tree crop into an equivalent annual return per livestock unit displaced, which subsequently compares to the conventional FGM (Knowles and Halliday 2003a).

Default values for the financial inputs entered into the calculator were the same as used for the recent Taupo study (Knowles, Hansen and Ritter, 2003). Sensitivity analysis was carried out to determine the effects of varying livestock carrying capacity, discount rate, logging costs, establishment costs, labour costs, log prices and understorey grazing.

RESULTS

Site classification and yield classes
The distribution of sites to each of the land classification indicators is presented in Figure 1. The distribution of sites to yield classes is presented in Figure 2. The average site indices and average land classification indicators for the yield classes are presented in Table 2.

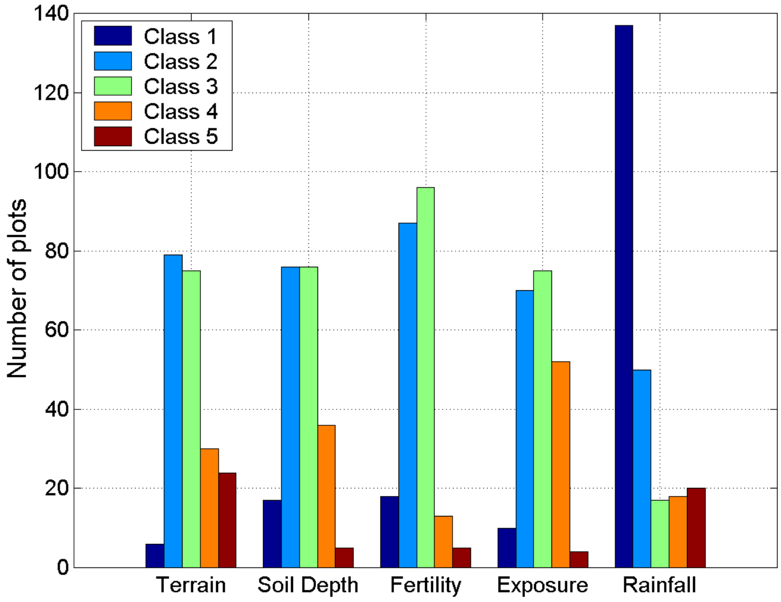

Figure 1: Distribution of sites to land classification indicators

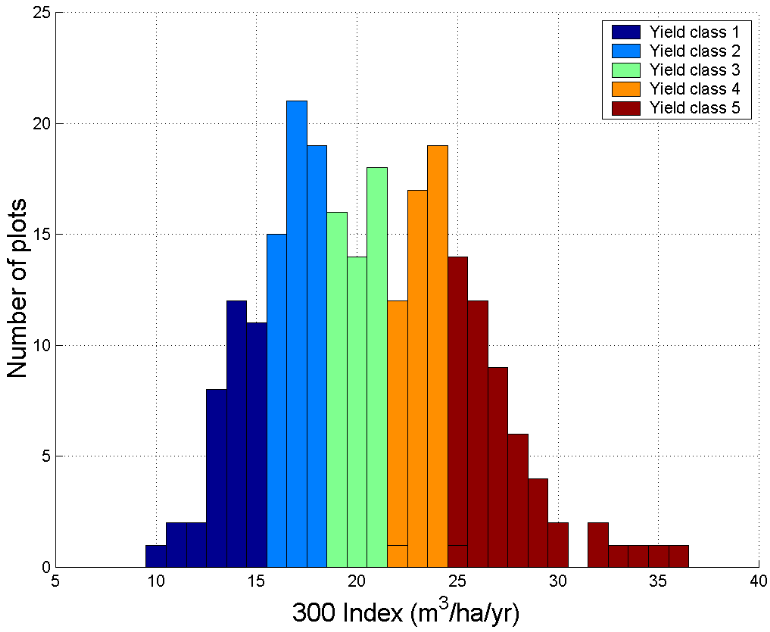

Figure 2: Distribution of sites to yield classes

Table 2: Definition of yield classes, number of stands in each class and average growth indices and land classification indicators

Yield class	No. of stands	Site index (m)	300-index (m^3/ha/yr)	Index Ratio	Terrain	Soil depth	Fertility	Exposure	Rainfall
1	36	20.5	14.2	0.70	2.33	1.85	1.81	2.08	1.41
2	55	22.6	17.5	0.79	2.61	2.55	2.39	2.49	1.36
3	49	24.0	20.6	0.86	3.12	2.76	2.55	2.86	1.35
4	49	25.5	23.6	0.93	3.06	3.98	2.80	3.21	2.02
5	53	28.5	27.8	0.98	3.32	3.22	2.97	3.47	3.19

Estimating growth indices from site classification

The model of 300-index (I_{300}) is

$$I_{300} = a + a_S S + a_F F + a_X X$$

Where S is soil depth, F is fertility, X is Exposure, and the constants are $a = 8.21$, $a_S = 1.42$ $a_F = 1.25$ and $a_X = 1.71$.

The model for index ratio (IR) is

$$IR = b + b_T T + b_R R + b_I I_{300}$$

Where T is terrain, R is rainfall, and the constants are $b = 0.46$, $b_T = 0.0320$, $b_R = 0.0134$, and $b_I = 0.0125$.

An example: *A site is classified as Terrain 2, Soil depth 3, Fertility 4, Exposure 3, and Rainfall 4. The models predict the following indices:*

300-index:	*8.21 + 1.42*3 + 1.25*4 + 1.71*3*	*= <u>22.6</u>*
Index ratio:	*0.46 + 0.0320*2 + 0.0134*4 + 0.0125*22.6*	*= <u>0.86</u>*
Site index:	*22.6 / 0.86*	*= <u>26.3</u>*

Identification of 'best' management regimes for the yield classes

The following 'best' regimes were identified and applied in the profitability analyses.

Table 3: 'Best' management regime for the yield classes. (* Caution is needed as the regime for yield class 1 is outside the range of the calculator)

	Yield class				
	1*	2	3	4	5
Initial stocking (sph)	396	536	622	650	740
Final crop stocking (sph)	150	200	230	240	270
Rotation age (yrs)	35	34	32	29	28
Merchantable volume (m^3)	449	470	515	535	647
BIX (cm)	NA	5.2	6.1	6.8	6.7
PLI	6.2	7.0	7.0	7.0	7.0

Profitability comparison by yield class

The equivalent farming gross margins of woodlots on land carrying 8 lsu/ha are presented in Table 4. The EFGM of planting woodlots on land with different livestock carrying capacities, as compared to land carrying 8 lsu/ha, are presented in Table 5. Results from the general sensitivity analyses are presented in Table 6.

Table 4: Equivalent Farming Gross Margin ($/lsu) for woodlots on land carrying 8 lsu/ha. Light grey and dark grey shading indicates where woodlots are more profitable than pastoral farming of '*Summer Dry*' and '*Summer Moist*' country, respectively. The results for yield class one are outside the range of the calculator, and should be treated with caution.

8 lsu/ha		Yield class				
		1	2	3	4	5
Discount rate	4%	$ 58	$ 61	$ 67	$ 81	$ 103
	5%	$ 44	$ 46	$ 52	$ 65	$ 83
	6%	$ 33	$ 34	$ 38	$ 50	$ 66
	7%	$ 22	$ 23	$ 27	$ 38	$ 51
	8%	$ 13	$ 14	$ 18	$ 27	$ 38

Table 5: The effect of livestock carrying capacity on the EFGM ($/lsu) as compared to a carrying capacity of 8 lsu/ha, assuming a discount rate of 6%.

Livestock carrying capacity	Change for Yield class 2 ($/lsu)	Change for Yield class 3 ($/lsu)	Change for Yield class 4 ($/lsu)	Change for Yield class 5 ($/lsu)
4	+34	+38	+50	+66
6	+11	+13	+17	+22
8	0	0	0	0
10	-7	-8	-10	-13
12	-11	-13	-17	-22
14	-14	-16	-21	-28

Table 6: Sensitivity of EFGM ($/lsu) to changes in various input variables, assuming a carrying capacity of 8 lsu/ha and a discount rate of 6%

Variable	Range	Yield class 2 ($/lsu)	Yield class 3 ($/lsu)	Yield class 4 ($/lsu)	Yield class 5 ($/lsu)
Initial sale of livestock credited	-	+5	+5	+5	+5
Understorey grazing exploited	-	+14	+11	+11	+10
On-farm labour for silvicultural work	-	+11	+14	+15	+17
Log prices (%)	± 20	± 13	± 16	± 19	± 25
Logging costs ($/m^3)	± 10	± 5	± 7	± 9	± 11
Establishment costs (cents/plant)	± 10	± 0	± 1	± 1	± 1

DISCUSSION

The land classification employs a combination of objective criteria, but evaluated on nominal and somewhat subjective scales. The advantage of this approach is that it is very simple, and it requires little effort and no specialist equipment to assess a site. Anybody with a little background knowledge of their land should thus be able to classify it, and estimate tree growth accordingly. The drawback of the method is that the classes are not uniquely identified, and may vary with the assessors' frame of reference. In other words, different persons don't necessarily come to the same result. Another problem is that such nominal scales may not be applicable outside of Hawke's Bay and Wairarapa. Also, the regression model does not capture all the variation, and therefore tends to give under-estimates for high-productivity sites and over-estimates for low-productivity sites. However, within the context of this study, the classification matrix and corresponding model performed reasonably well and quite independent of the persons classifying.

The correction of growth indices on 'summer-dry' country for age is approximate only. The underlying model is very simple and linear with respect to age, is not supported by much data, and assumes that the uncorrected estimates are true for 30-year-old stands. In conclusion, it is recommended to use the correction model as a guideline only. In future it is intended to release a national '300-index' growth model that includes an adjustment for low rainfall sites, thus providing more accurate growth estimates for summer-dry country, such as Hawke's Bay and Wairarapa.

The 300-index yield classes were determined as approximate 20 percentile classes. All yield classes are thus equally well represented in the data set. Whether the distribution of sites to yield classes also represents the distribution for Hawke's Bay and Wairarapa is somewhat questionable, since the sites were not randomly selected. However, the yield classes do represent a wide range of sites from the very good to the very poor, which is reflected in the profitability analyses.

To label the applied silvicultural regimes as 'the best' for each yield class is an exaggeration, as some of them do not achieve the various log-quality goals. Furthermore, the calculator only allows for pruned regimes, and has other limitations, being based on only 75 STANDPAK runs. Several of the regimes also violate the intrinsic boundaries of the calculator, and for none of the regimes is it economically optimal to achieve the set log-quality attributes.

Despite these shortfalls the analyses still revealed the following findings:

- The existing yield-model in the calculator over-estimates the long-term growth predictions on shallow soils on low-rainfall sites. As an interim measure, a correction factor has been developed.
- The longer the rotation and the lower the stocking, the larger the pruned log index.
- The branch index decreases for increasing stocking rate, but as branch size comes down so too does pruned log index. The economically optimal trade-off between branch index and pruned log index depends on how each element is valued at the mill, and how the optimal log-mix can be achieved.
- To produce comparable log-qualities from sites of different productivity the general rule is: The lower the productivity of the site, the longer the rotation age and the lower the final crop stocking rate.

Comparison of the profitability of woodlots and pastoral farming gave the following:

- Woodlots obviously grow the best and are most profitable on sites in yield class 4 and 5. The profitability of woodlots also increases for decreasing discount rate and quite dramatically for decreasing livestock carrying capacity.
- There is only a relatively small difference in EFGM between yield classes 1, 2 and 3. From yield class 3 and above the EFGM increases by ca. $20/lsu per yield class.
- On summer-dry country and a discount rate of 6%, woodlots are more profitable than pastoral farming on yield class 5 sites carrying less than 10 lsu/ha, and yield class 4 sites carrying less than 8 lsu/ha. Woodlots on yield class 3 sites and poorer break even with pastoral farming at around 6 lsu/ha.
- Because both farming and forestry are more profitable on summer moist country, the result is almost identical to that for summer-dry country, except that the break-even discount rate is one percent point less, or the break-even carrying capacity 2 lsu/ha less.
- If the understorey is grazed during the first rotation, the sale of displaced livestock is credited to the woodlots and the farmer does the silvicultural work, then the break-even carrying capacity generally increases by 4 lsu/ha.
- The results are relatively insensitive to changes in establishment costs, however, changes in log prices and logging costs may alter the results more significantly.

CONCLUSION

The profitability of planting woodlots on farmland in Hawke's Bay and Wairarapa is highly variable and depends very much on the livestock carrying capacity and the yield class of the land. For land with a carrying capacity of 6 lsu/ha or less, there is an obvious economic case for tree planting. On land carrying 12 lsu/ha or more there is little economical incentive to change land-use. However, if woodlots are required for other reasons, such as erosion control, they can still make a significant economic contribution. Woodlots on land carrying between 6 and 10 lsu/ha are about as profitable as pastoral farming, and other considerations, such as erosion control and water quality improvement, can be addressed without endangering the profitability. At the level of the individual woodlot, issues such as logging costs and log pricing can affect these general conclusions. The results reported here have not addressed the issue of feasibility and cash flow, which require whole-farm analyses. These should be made before commencing with any significant tree planting.

ACKNOWLEDGEMENTS

The project was funded by the 'MAF Sustainable Farming Fund', contract 00/69. The authors would like to thank John Aitken, 'Hau Ora', Havelock North, Graham Dick, Forest Enterprises, Masterton and Mark Dean, Forest Research, Rotorua for their assistance with providing the stand growth data, and for classifying the sites.

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APPENDIX A – BENCHMARK FARM ACCOUNTS

MAF Sheep and Beef Farm Monitoring Report – '*Hawke's Bay/Wairarapa*'

	Summer moist	**Summer dry**
Farm Gross Revenue	77.21	66.94
Animal health	3.26	3.28
Breeding	0.29	0.29
Feed	0.84	1.25
Fertiliser	9.84	8.63
Lime	0.45	0.09
Freight	1.09	0.87
Regrassing	0.99	0.65
Seeds	0.55	0.49
Shearing costs	5.81	5.57
Weed and pest control	0.89	0.76
Total costs	24.01	21.88
Farming Gross Margin	53.2	45.06