Economics of New Zealand planted kauri forestry – a model exercise

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Abstract

This paper presents the development of a calculator for the estimation of productivity, yields and returns from kauri (*Agathis australis* (D Don) Lindl.) grown in even-aged planted forests. The calculator is based on models of height, basal area and volume developed from 25 planted stands of kauri throughout New Zealand. The calculator can determine potential returns from kauri forestry and through various scenarios suggests some regimes for its establishment and management. Returns on investment from kauri forestry will initially be strongly influenced by land ownership models and by the incorporation of non-timber benefits over rotations longer than for exotic forestry species. From this modelling study, the financial returns from kauri were influenced by the land ownership model, thinning regime, stand rotation age and discount rate.

Introduction

Kauri timber, highly valued for its appearance and working properties, is now difficult to obtain. Exploitation through the late 1800s and early 1900s left a mature natural resource of only 6,000 to 7,000 hectares (Bergin & Steward, 2004) and a second-growth resource of approximately 60,000 hectares (Halkett, 1982). Most of these natural stands are in widely dispersed populations in the conservation estate and under current legislation are effectively unavailable for management and harvesting. Until recently the growth and productivity observed in these stands was believed to be directly relevant to kauri in planted forests.

An extensive nationwide survey of native species plantations was undertaken from 1986 (Pardy, Bergin, & Kimberley, 1992) from which height and diameter graphs for a range of species, including kauri, were developed. The data gathered was from unbounded growth plots and stand density, and basal area, and volume per hectare could not be estimated.

Herbert et al. (1996) produced preliminary stand productivity models and an economic case for plantation-grown kauri from two planted stands in New Plymouth, around 100 kilometres to the south of the natural range of the species. Stand density was high – 1,444 stems per hectare and 1,348 stems per hectare, respectively, at the time (age 60 years) their models were developed. Tree height of 25 metres and diameter of 34 centimetres at 80 years of age were predicted. At this age, total stand volume estimates at a stocking of 1,300 stems per hectare were 1,103 cubic metres per hectares, although little of this volume would likely be heartwood (Steward & Kimberley, 2002).

Economic analysis indicated internal rates of return (IRR) of 2.3 to 2.9 per cent, depending on rotation length and whether silvicultural treatments such as pruning and thinning were applied and using a discount rate of 10 per cent. The predictions of Herbert et al. (1996) for a continued basal area increment to well in excess of 100 square metres per hectare was not supported by later studies of basal areas from further planted stands (Chikumbo & Steward, 2007).

A 55-year-old planted kauri stand – mean diameter at breast height 33.8 centimetres, mean tree height 21.8 metres, 645 cubic metres per hectare. Many of the stems in this stand were merchantable based on studies of wood quality from other young, fast-grown planted kauri forests

Kauri has many natural attributes that make it an ideal forestry species including superior wood properties (stiffness, density, and stability), natural branch shedding, monopodial growth habit, and good growth on selected sites, as shown in the first photo. Where the New Zealand timber market has been left with a continuing interest in kauri, but without a sustainable supply, the obvious solution is to grow it in planted forests.

In planted forests, how fast does kauri grow, what are the rotation lengths, and what are the returns in timber and value likely to be? In 2011 models of height, basal area and volume production were developed from kauri in planted forests (Steward, 2011). These models and predictions of growth and productivity have indicated the potential for growing kauri in plantations for a range of timber outcomes over differing rotation lengths. The models have been incorporated into a kauri calculator available on the Future Forest Research website: http://kauricalc.ffr.co.nz (Steward, Milne, & Hansen, 2012).

Kauri potential

During the development of the growth models a site in the Bay of Plenty stood out for its extraordinary growth and productivity compared with all other planted kauri forests. At age 14, diameter at breast height (DBH) averaged 24.8 centimetres and height averaged 12.4 metres. Diameter mean annual increment had been over 1.7 centimetres per year, with the first of the kauri reaching 30 centimetres DBH. To reach the same DBH would require 90 to 150 years in natural stands, 12 years for radiata pine on an average site, while *Cupressus lusitanica* would reach the same DBH in about the same length of time as this kauri stand.

Initial height growth was 1.0 metres per year. This stand was established at four metre × four metre spacing (625 stems per hectare). Most other planted stands were established at approximately 1,000 to 1,600 stems per hectare, a stand density rate similar to that used for closely related *Agathis* species in Australia and New Caledonia. Despite this, height growth and form have largely been maintained, while wood density was similar to other older planted kauri and even to natural second-growth kauri up to 240 years old. Despite many unknowns about its establishment and origins, such as the source of the seed, this stand indicates the ability of kauri to grow at rates not previously observed or predicted.

The calculators

Leith Knowles and Mark Kimberley developed the concept of the 'calculators' around 2001. The first rather simple calculator compared the economic returns of radiata pine (*Pinus radiata*) plantation forestry (Halliday & Knowles, 2003). This was followed in 2003/2004 by a more sophisticated version for Douglas fir (*Pseudotsuga menziesii*) (Knowles, 2005), which employed a stand growth model to explore different kinds of Douglas fir management such as stocking, thinning and pruning.

A 17-year-old kauri planted near Tauranga. This high-performing stand already has stems of 34 centimetre diameter at breast height and mean annual diameter at breast height increment of almost 2.0 centimetres per year. Recent density analysis of this stand indicates growth rate is not affecting wood density, and that this density is similar to other planted and second-growth kauri of 80 to 240 years of age

In 2010 a simpler and web-based calculator for Cypress (*Cupressus spp.*) was released through Future Forest Research (FFR, 2010), followed in 2011 by another for *Eucalyptus fastigata* (FFR, 2011). Recently a calculator for New Zealand kauri has been developed employing the new growth model by Steward (2011).

The fundamental idea of all the calculators is to estimate the growth and yield of a one hectare stand using a growth model and through this estimate the economic return for one rotation. This is achieved through a classical discounted cash-flow analysis. Discounting all costs and revenues throughout the stand's life to the present and adding them up gives net present value (NPV). Cash-flows are also used to calculate the internal rate of return, i.e. the discount rate at which the investment breaks even. Net present value and internal rate of return are standard economic statistics used for immediate comparison of alternative investments, and in this case also different management regimes. The calculators therefore provide a simple economic decision-support tool.

The calculators offer the facility to add or remove costs associated with establishment, maintenance, thinning and harvesting. One further cost about which there is much discussion is land value. This may or may not be applied to forest growing when considering kauri plantations, particularly for multiply-owned land where ownership is intergenerational and for which no other land use is or was applied. Large areas of Māori-owned land and land owned by regional authorities will fall into this category.

Net present value and internal rate of return were calculated for the same stand grown under different management and cost regimes using the calculator given above, and the respective net present values and internal rates of return are compared and discussed below. The discount rate used for all scenarios was eight per cent.

The stand/growth conditions

Site condition is modelled on one of the better existing stands described above (Steward, 2011) and represents a 'good' to 'very good' site. The stand has been developed as if it had been established at three × three metres (1,089 stems per hectare). It was modelled from age 12 years and onwards. The stand characteristics at age 12 were: site index (SI: height at age 50) 28.4 metres, basal area 36.5 square metres per hectare, initial stocking of 1,089 stems per hectare reduced through natural mortality to 925 stems per hectare (15 per cent mortality).

Costs

The model stand was planted at 1,089 stems per hectare. Each seedling cost $2.50. One pre- and three post-planting releases, each at $0.18 per plant, were scheduled in years 0, 1, 2 and 3. Planting cost was $0.35 per plant. There was an annual administration fee of $50 per hectare. Land value was set to $1,500 per hectare when included, i.e. land is bought at the start and sold for the same amount at the end of the rotation. The land value assigned was for land in the Northland and East Cape regions where some distance to processing or port facilities was implied. Thinning was costed at $28 per cubic metre, harvesting at $40 and transport at $35.

Management regimes

The regimes cover the following management options:

Two types of ownership:

1. Investment-type owner (including land value).
2. Māori ownership (no land value).

Three thinning-regimes:

1. No thinning.
2. Mid-rotation production thinning at age 40 to 500 stems per hectare from below using a thinning coefficient of 0.8.
3. Mid-rotation production thinning to 500 stems per hectare from above using a thinning coefficient of 1.5.

Table 1. Effect of rotation length on net present value and internal rate of return from kauri planted in even-aged planted stands managed under different regimes

Rotation length (years)	REGIMES									
	1 Land value $1,500 /ha[1]		2 Land value $0/ha[2]		3 Thin from below @40 years[3]		4 Thin from above @40 years[4]		5 Discount rate 5%[5]	
	NPV ($/ha)	IRR (%)	NPV ($/ha)	IRR (%)	NPV ($/ha)	IRR (%)	NPV ($/ha)	IRR (%)	NPV ($/ha)	IRR (%)
60	−3,954	5.8	−2,350	6.4	−499	7.7	4.0	8.0	4,789	6.4
70	−4,829	5.0	−3,216	5.5	−1,308	7.1	−480	7.7	1,586	5.5
80	−5,270	4.4	−3,653	4.8	−1,736	6.7	−671	7.6	−583	4.8

[1] Discount rate 8%, land value $1,500/ha, no thin
[2] Discount rate 8%, land value $0/ha, no thin
[3] Discount rate 8%, land value $0/ha, thin from below
[4] Discount rate 8%, land value $0/ha, thin from above
[5] Discount rate 5%, land value $0/ha, no thin.

Three rotation ages were explored:

1. 60 years.
2. 70 years.
3. 80 years.

Log prices stumpage:

Herbert et al. (1996) estimated a stumpage of $150 to $152 for a planted stand with average DBH of 33.8 centimetres at age 80 years (clearfell) given 80 per cent merchantable yields. More recently, values of $300 to $500 have been suggested. Based on the later values around average stumpage this study uses the following values, expressed as a function of stand mean DBH:

25 < DBH < 35: $300/m^3$

35 < DBH < 45: $350/m^3$

45 < DBH < 55: $400/m^3$

55 < DBH: $500/m^3$.

Stumpage values included marginal harvesting related costs, including transport to the mill (see Herbert et al., 1996). The revenue from logging was estimated as total standing volume multiplied by average stumpage value. For example, if the mean DBH of the trees felled was 37 centimetres, the total standing volume was 654 cubic metres per hectare and the revenue was $350 × 654 cubic metres per hectare, which totalled $228,893. For thinnings, an extra $10 per cubic metre was subtracted to account for thinning-related reductions or complications such as smaller log sizes and hindrance.

Results

As examples, three different rotation lengths were tested with five different costing and management regimes, as shown in Table 1. Outcomes in cubic metres per hectare and values in dollars per hectare were estimated. Recoverable volume was estimated to be between 631 to 675 cubic metres per hectare and gross values $220,678 to $236,250 per hectare. Regimes with early value recovery from production thinning, whether from below or above, produced better economic returns than unthinned stands, particularly rotations of 80 years, as shown in Table 1 and Figures 1 and 2.

The inclusion of land value ($1,500 per hectare) reduced the internal rate of return by an average 0.5 per cent, with the greatest effect in shorter rotations. Thinning returned on average an extra 1.9 per cent to the internal rate of return over unthinned stands. Reducing the discount rate to five per cent did not impact on the internal rate of return but substantially improved the net present value by an average $5,003. The only regimes that demonstrated a significant and positive net present value were those with no land value and a lower discount rate – five per cent compared with eight per cent.

Discussion

The results in this study showed that getting early revenues from production thinning significantly improved the internal rate of return, typically an absolute increase in it of 0.5 to 2.0 per cent. This is a logical consequence of the longer rotation of kauri, i.e. because of the time-preference (discount rate) early revenues should be given more weight than later ones. However, the significance of early revenues may be slightly exaggerated due to over-estimation of the market value of the thinned wood i.e. the prices for thinned (very young) kauri wood may be significantly less than for more mature wood. To account for this, we subtracted an extra $10 per cubic metre for the thinned wood on top of already accounting for piece size in the stumpage values.

Another important effect of thinning is its beneficial effect on the dimension (DBH) of the final crop. First, the study used a thinning from below, which leaves the fattest trees behind. Kauri responds well to silviculture thinning and pruning (Steward, 2011). Hence, the average DBH of the final crop will also benefit from the extra resources available after thinning.

For the sake of simplicity, the present study examined one regime with a single, quite severe thinning only. However, regimes with less drastic yet more regular thinning once individual trees reach merchantable size may prove more profitable, every 10 to 20 years. This is not only because income will occur sooner and more regularly, but also because one could carefully select both thinned trees as well as final crop trees. This in turn could also lead to some sort of continuous cover forestry, such as plenter-wald or coup systems, which with carbon credits in mind seems to be a good idea. However, the latter is mere speculation.

One very important factor in estimating the net present worth of planting kauri is putting a price on the wood produced. Very little plantation-grown kauri is sold and the prices achieved are unlikely to reflect a market with full information, i.e. the current prices cannot be considered equilibrium prices. An average stumpage of $300 to $500 may at first seem quite high compared to more traditional values for other species.

On the other hand, off-the-mill prices of $1,400 per cubic metre or more for kauri wood is normal and it seems likely that plantation-grown kauri will remain a highly sought-after niche-product in any foreseeable future. Hence, kauri is likely to be worth markedly more than 'bulk' wood. Finally, the merchantability/price of kauri wood may even increase over time as the existing kauri resource is very scarce (Steward, 2011). Using a DBH-adjusted version of the stumpage estimated by Herbert et al. (1996) therefore seems reasonable and not overly optimistic.

The models of growth and productivity on which this calculator were based were developed from 25 planted stands located throughout New Zealand. They

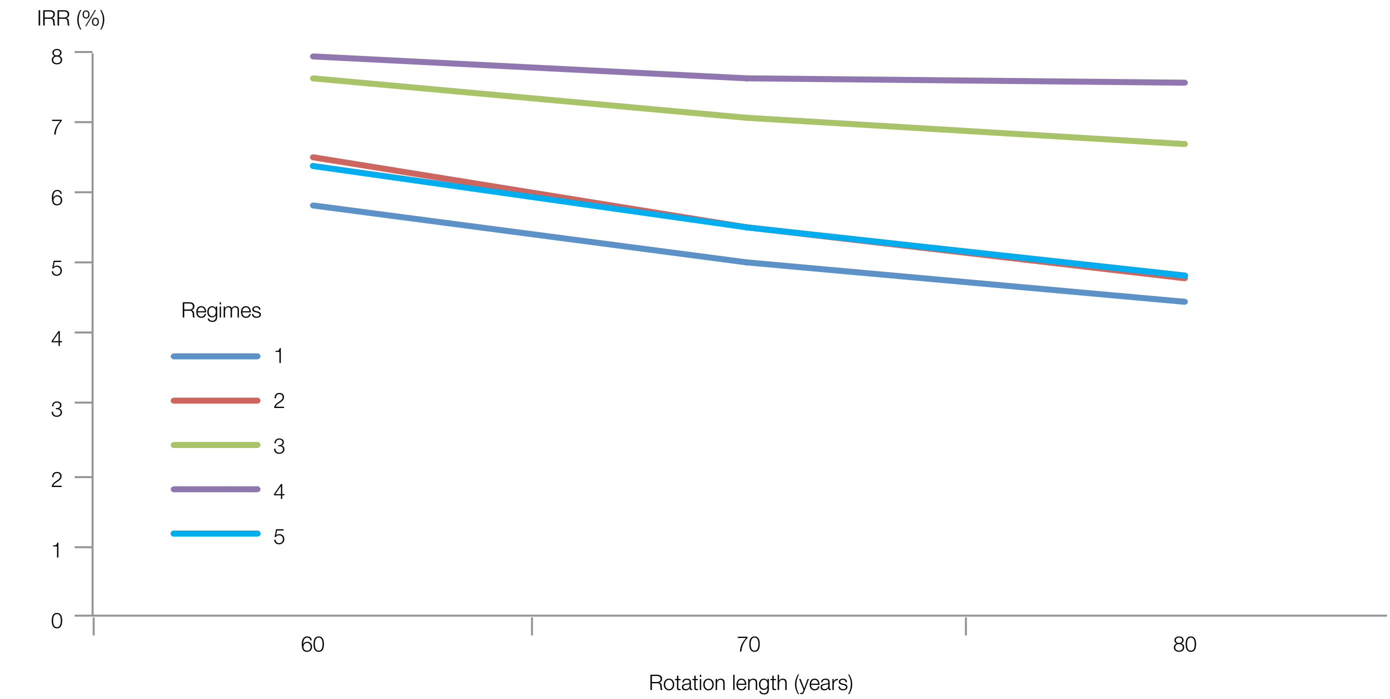

Figure 1. Effect of rotation length and management regimes on internal rate of return in planted kauri forests. Regime 4 has no land value and thins from above and Regime 1 includes land value and has no thinning – see Table 1 for regimes

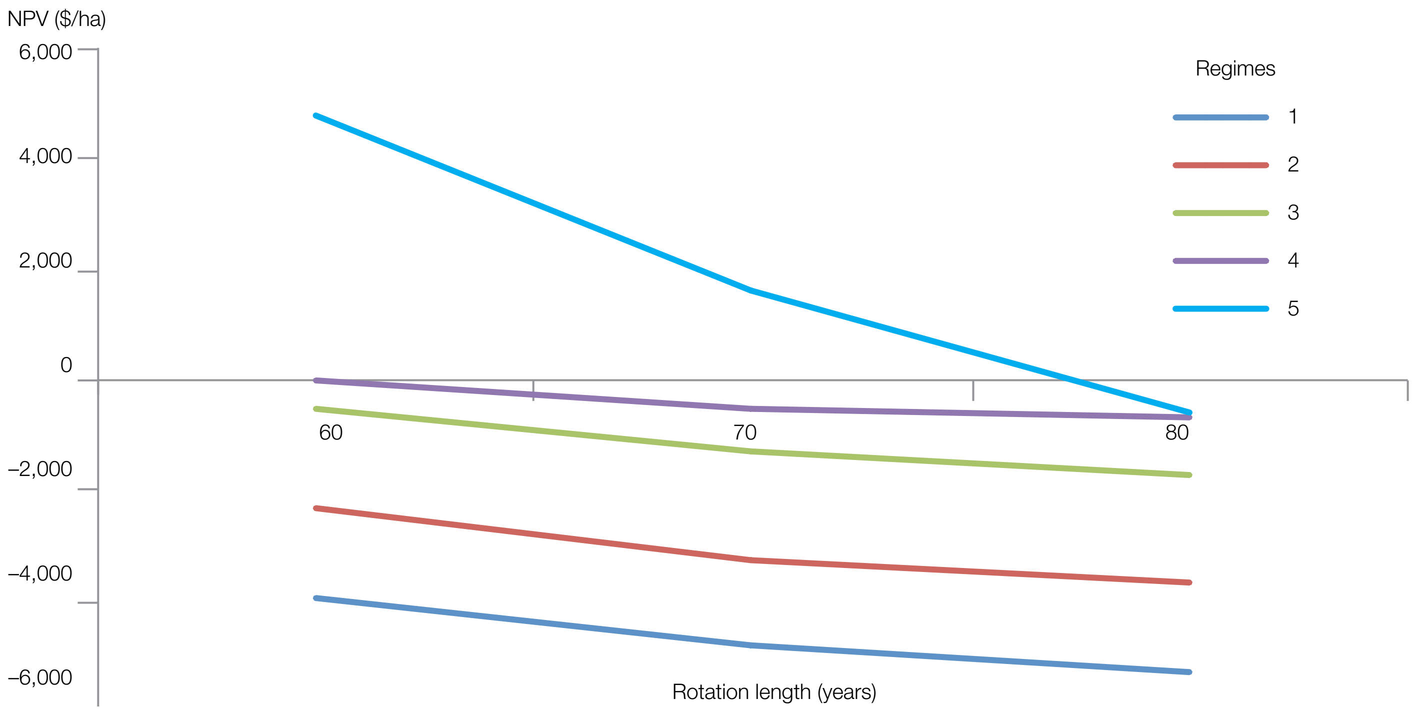

Figure 2. Effect of rotation length and management regimes on net present value in planted kauri forests – see Table 1 for regimes. Regimes 2 and 5 indicate the effect that different discount rates have on net present value

ranged in size from relatively small stands to plantings of many hectares. At initial stocking they were from 320 to 2,000 stems per hectare. None of the stands received the maintenance or silviculture after planting that would have maximised their productivity, and many remained at high stand density at their latest measurement.

The seed source or the number of parents that the plantings represented could not be determined for most stands. It is likely that productivity estimates from the model will be on the conservative side. Experience with managed *Agathis* forestry in New Caledonia indicates that productivity can be increased up to 50 per cent within one breeding cycle. Greater productivity from planted kauri, without loss of wood quality, will assist with improving returns.

Conclusion

This basic economic model study showed with some confidence that the economics of plantation-grown kauri is likely to be quite a lot better than previously thought. Planted on suitable land the forecasted economic return (internal rate of return) for kauri is four to eight per cent. While this range may not be as high as for radiata pine or Douglas fir, kauri is not lagging far behind economically. Kauri plantations are also likely to be more stable and ecologically viable forests, with the added benefit of product diversification and therefore risk aversion. Research that improves growth and productivity resulting in lifting the site index to 35 metres, reducing rotation length to 50 years, and a production thin at age 40 would see an increase in internal rate of return to 8.6 per cent.

The presence of the kauri dieback disease *Phytophthora* taxon *Agathis* is a major consideration for the future of kauri in plantations, particularly within the northern limits of the species' natural range. Research being undertaken by Scion, the Kauri Dieback Joint Agency and others that identifies natural resistance to *Phytophthora* taxon *Agathis* and/or controls its effect or spread will mitigate the risks associated with the species.

Finally, kauri forest is the natural habitat for many native plant and animal species. Kauri plantations can therefore provide a wide range of non-market or ecosystem services values, while still producing highly sought-after wood. The ability to account for ecosystem services in the calculator will see some marginal regimes or sites deliver positive returns beyond timber value alone.

References

Bergin, D.O. and Steward, G.A. 2004. Kauri: Ecology, Establishment, Growth and Management. *New Zealand Tree Bulletin No. 2.*

Chikumbo, O. and Steward, G.A. 2007. A Stand Basal Area Model for Plantation Grown New Zealand Kauri. *Ecological Modelling*, 209(2–4): 367-376.

Future Forest Research. 2010. New Maps Analyse Potential Forest Production. *Four Corners*, 4 (June).

Future Forest Research. 2011. *Future Forest Research: Annual Science Report*. Rotorua, NZ: FFR.

Halkett, J.C. 1982. *Kauri Forest Management Review*. Auckland, NZ: Kauri Management Unit, Auckland Conservancy, NZ Forest Service.

Halliday, M.M. and Knowles, R.L. 2003. *Farm Forestry for Economic and Environmental Sustainability: A New Decision Support System for Farm Foresters*. Paper presented at the Proceedings of the New Zealand Grasslands Conference, Palmerston North, NZ on 17 October 2003.

Herbert, J.W., Glass, B. and Kimberley, M.O. 1996. *A Preliminary Stand Productivity and Economic Case Study of Plantation Growth Kauri*. Paper presented at 'An Alternative Approach to Forestry – Time to Review'. Proceedings of the New Zealand Institute of Forestry Conference, Invercargill, NZ on 29 April – 1 May 1996.

Knowles, R.L. 2005. Development of a Productivity Index for Douglas-fir. *New Zealand Journal of Forestry*, 50(1): 13–16.

Pardy, G.F., Bergin, D.O. and Kimberley, M.O. 1992. Survey of Native Tree Plantations. *Forest Research Institute Bulletin*, 175.

Steward, G.A. 2011. *Growth and Yield of New Zealand Kauri (Agathis Australis (D Don) Lindl.)*. Master of Forestry Science, University of Canterbury, Christchurch, NZ.

Steward, G.A. and Kimberley, M.O. 2002. Heartwood Content in Planted and Natural Second-Growth New Zealand Kauri. *New Zealand Journal of Forestry Science*, 32(2): 181–194.

Steward, G.A., Milne, P. and Hansen, L.K.W. 2012. *The Kauri Calculator Manual*. Rotorua, NZ: FFR Limited (Contract Report).

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