Farm forestry for economic and environmental sustainability – A new decision support system for farm foresters

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Abstract
The objective of this programme is to provide farm foresters and others with knowledge about sustainable and profitable land use with commercial tree crops.

Initially the study examined the role of trees in stabilising soils when planted on eroding hill country pasture. Three species – radiata pine, Douglas-fir, and poplar – were compared for effects in reducing erosion. Tree size, tree stocking per hectare, root tensile strength, and rate of decay of roots after harvest were found to be important. Erosion control becomes effective once a stand of trees reached the equivalent of 30 tonnes/ha of radiata pine root biomass. Silviculture, and choice of species, determines to what extent this critical threshold is achieved.

Decision support software, developed in this programme as "calculators', estimate the 'Equivalent Farming Gross Margin' of crops of radiata pine, and Douglas-fir, compared to the livestock previously grazing the land. The calculators, which run under Microsoft EXCEL™, also allow the identification of the most profitable silviculture for the tree crop, and generate yield tables.

The calculators are being applied in two case studies; the first involves calibrating the radiata pine calculator for Hawkes Bay and the Wairarapa against actual tree data. Calibration of the calculator for bare land is also being studied. The second study will investigate how well tree crops can compete financially with pastoral farming systems in the Lake Taupo catchment, where there are increasing concerns about nutrient in-flows from pastoral farming.

Further enhancements of the calculators are planned which will permit calibration against younger stands, and evaluation of a much wider range of silviculture.

Keywords: farm forestry, erosion, root biomass, root strength, financial return, IRR, PNW, farming gross margin, *Pinus radiata*, Douglas-fir, poplar

Introduction

How can a farm forester compare the returns from radiata pine (*Pinus radiata*) or Douglas-fir (*Pseudotsuga menziesii*) plantations with pastoral farming? How often has a farm forester been faced with this question when attempting to justify planting a block of trees, or encouraging a neighbour to do so?

A problem with farm forestry programmes is in valuing the inputs (labour, capital, livestock income foregone) relative to outputs (revenues from log sales, environmental benefits), so that the farm business as a whole can prosper. For example, at maturity, farm woodlots of radiata pine can provide returns ranging between $50,000/ha to a loss, depending on the site they are planted on, the management they receive, and current market prices for logs. Thus good business planning is essential for making wise investments in farm forestry. To do this, farm foresters need suitable decision support systems to identify the most profitable and appropriate management options.

Together with a group of farm foresters, we took the opportunity offered by the Ministry of Agriculture and Forestry's Sustainable Farming Fund to initiate a programme entitled "Farm Forestry for Economic and Environmental Sustainability". We wanted to discover if farm forestry could at least match the medium-to long-term profitability of pastoral-based farming on hill country, and at the same time meet long-term environmental values of reduced soil erosion and improved water quality. Support was obtained from the New Zealand Farm Forestry Association, and the Hawke's Bay Regional Council (HBRC).

The initial study property was the Thomsen family farm, "Falomai", one of four currently monitored Hawke's Bay farms, so information on both land capability (from HBRC) and financial performance (from Agfirst Consultants NZ Ltd) were readily available. There was also a history of tree planting on the farm for environmental benefits (shelter, and erosion control), and an emphasis on family succession.

The purpose of the study was not to plant highly-producing farmland in trees, but to identify at-risk and lower-production areas using land use capability mapping, and then to quantify the livestock-carrying capacity at which forestry became more profitable.

Environmental aspects

An initial focus of the programme was to determine how trees provide environmental protection, and especially the role of tree roots in holding soils on eroding hills, currently in pasture. We compared three species nominated for planting by the Thomsen family – radiata pine, Douglas-fir, and poplar.

Some of the key elements emerging from the literature were:

- Roots hold the soil together, providing significant reinforcing (Maclaren, 1996).
- Root tensile strength is important, but differs between species (Hathway and Penny, 1975; Phillips and Watson, 1994).
- Roots decay after felling (half-life varies between 14–36 months for the three species (O'Loughlan and Watson, 1979).
- The effect of trees in reducing erosion is a function of tree size, tree stocking per hectare, root tensile strength, and rate of decay after harvest.
- The benefit of a fully-stocked stand of radiata pine is clearly noticeable when it reaches eight years of age (Franson and Brownlie 1995; Hicks 1991). At that age its root system has about 30 tonnes/ha of biomass.
- Silviculture, and choice of species determine to what extent this critical threshold is achieved.

Root biomass was found to increase with tree diameter, with radiata pine having the greatest root biomass for a given tree size, followed by Douglas-fir, then poplar (Watson and O'Loughlan 1990; Kuiper and Coutts 1992; Tandon *et al*. 1991).

The reverse is true, however, when it comes to root tensile strength, with poplar roots being the strongest, followed by Douglas-fir and then radiata pine. When root biomass is multiplied by root tensile strength to develop an index of 'soil holding ability', all three species were found to be surprisingly similar.

The soil holding ability of the three species were then compared at rotations and final crop stockings relevant to each – 28 years and 250 stems/ha for radiata pine, 25 years and 50–100 stems/ha for poplar, and 40 years and 500 stems/ha for Douglas-fir. Differences in root decay following harvest were taken into account. Over a rotation, and following the initial establishment phase, Douglas-fir meets the critical level of '30 tonnes/ha of radiata pine equivalent root biomass' for 91% of the time; radiata pine exceeds it for 66%; poplar at 100 stems/ha exceeds it for only 23% of the time. Poplar at 50 stems/ha never reaches this threshold. Once established in perpetuity, because of its slow rate of root decay, Douglas-fir never falls below 26 tonnes/ha. Similar minimum values are 10 tonnes/ha for radiata pine, and 0.5 tonnes or less for poplar.

Profitability of plantations versus pasture

The standard criteria for comparing the profitability of different land uses are Internal Rate of Return (IRR) and Net Present Value (NPV). IRR is the discount rate a project will support and still break even. NPV is the surplus or loss that is generated at the beginning of the rotation at a given discount rate. If land cost is excluded from the analysis, NPV is the value that could have been spent on land, and is then called Land Expectation Value (LEV).

These criteria are not widely understood or used by pastoral farmers, who instead prefer the concept of Farming Gross Margin. This is calculated as the gross revenue per livestock unit, less variable costs, and is expressed as $/lsu grazed on the land in question. For the Patoka, Hawke's Bay farm where the initial study was centred, the gross margin per livestock unit has varied considerably over the past decade, but in the four years prior to the commencement of the project averaged $40/lsu.

As a result, a new measure was developed – the Equivalent Farming Gross Margin (EFGM) of the tree crop. This is the gross margin per hectare per year, which is generated by the tree crop over a rotation or more, divided by the number of livestock previously grazed on that hectare. Because of the long time frames in farm forestry projects, the selection of a discount rate is necessary. A simple and easy-to-use system was then designed for farm foresters to calculate the EFGM for the tree crop. Initially it consisted of a series of 'look-up' tables where a range of scenarios was evaluated using the STANDPAK stand-level computer model (Whiteside 1990) and the Agroforestry Estate Model (Knowles *et al*. 1991). Some variations were introduced into the tables, so a more flexible decision support system was designed that was also applicable to other New Zealand regions. We have termed these 'calculators'.

Farm Forestry Calculators

A relatively comprehensive calculator has been developed for Douglas-fir, and applied in a simpler format for radiata pine. In addition to estimating the EFGM, the calculators can be used to design the 'optimum' silviculture for each species, given various site and financial parameters, and log quality constraints. The calculators can also be used to generate yield tables for use in the Agroforestry Estate Model, so that farm forestry options can be evaluated with respect to the impact on the long-term viability of the overall farm business.

The calculators were constructed by completing a very large number of runs through the stand-level modelling system, STANDPAK, and many more runs through the Agroforestry Estate Model. This created a very large database of outputs, including EFGM, but also IRR, NPV, and many other physical and financial outputs, such as volume by log grades, and log quality parameters. These include branch size and Pruned Log Index (PLI). By fitting mathematical surfaces linking the database to the input values, and including these into the calculators, the project has solved the EFGM and other outputs for a large area of interest.

In the future, it is hoped to improve the capacity of the radiata pine calculator and to develop much more flexibility for both calculators in the range of silviculture they can deal with. The calculators have the potential to deliver much of the relevant knowledge resident within STANDPAK and the Agroforestry Estate Model at the one-hectare level, and make it available to farm foresters in a much simpler system. The calculators have been designed so that all the essential inputs (what

the user enters) and outputs (information the calculator generates) are on a single screen. Ancillary information is available on tabs at the screen base, as a series of 'look-up' tables, or supporting software. By using these tabs, it is relatively simple for a user to calibrate the calculator to their own particular circumstances.

Calibrating the Calculators

Calibrating the calculator for radiata pine is currently being done using data from throughout Hawkes Bay and Wairarapa. The calculator for radiata pine uses two indices to predict stand growth for a site. These indices are:

Site index – the mean top height of the stand (in metres), at age 20 years.
300 index – the mean annual volume increment, corrected to stocking of 300 stems/ha, pruned to 6 m, at age 30 years.

A facility is provided in the calculator for a farm forester to estimate these two indices by utilising sample plot or inventory data gathered from nearby woodlots. At present this facility only operates for stands that have grown 3–4 years beyond their final pruning lift (i.e. minimum stand age of 10–12 years, or older). It is intended to re-develop the '300 index' so that much younger stands can be used to calibrate the calculator.

Data from a wide selection of permanent sample plots and temporary inventory plots throughout Hawke's Bay and Wairarapa are currently being used to see if the radiata pine calculator can also be calibrated from site descriptors, including slope, exposure, soil depth, soil fertility, and rainfall, thus permitting calibration for bare land.

As part of another case study, we are also using the calculators to estimate how well stands of trees can compete financially with pastoral farming in such sensitive catchments as Lake Taupo, where there are concerns about the long-term consequences of nutrient inflows to the lake from pastoral farming systems. Extensive tracts of forests are already planted on the eastern side of the lake. We are using the calculators to estimate the EFGM ($/lsu) and LEV ($/ha) for crops of radiata pine and Douglas-fir on the western side of the lake.

The calculators[2] developed by this project encourage sound land use, with both environmental and economic benefits. These benefits apply when commercial tree species are planted on erosion-prone hill country pasture. They may also apply on riparian and paddock-wide plantings on farms where nutrient enrichment of waterways and ground water is of concern, especially where pastoral farming systems are intensifying.

[2] The calculators, which run under Microsoft EXCEL 97™ or later, are available at a cost of $50 each from NZ Farm Forestry Association, P O Box 1122, Wellington. This includes updates and manuals.

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