Impact of the New Zealand Emissions Trading Scheme on forest management\textsuperscript{1}

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Abstract

We evaluated the impact of carbon trading on forest management. Questions examined were: whether to plant at all; if so, what species and silviculture to use; and when to harvest. Revenue from annual sales of carbon units greatly increases the profitability of all species and regimes. Indeed, if the price remains at $30 per tonne of carbon dioxide equivalent then nearly all forestry investments - regardless of site quality - are capable of paying $3000/ha for the land and still achieving an 8\% real rate of return or higher.

If the price of carbon is zero, the most profitable species/ regimes are, in order: radiata pine grown on a clearwood regime; radiata pine grown on a framing regime; radiata pine with a plant-and-leave regime; Douglas-fir; \textit{Eucalyptus nitens}; and indigenous forestry. This ranking alters substantially with high carbon prices. Radiata regimes which have higher volume become favoured over regimes that produce trees of large piece-size or clearwood. Eucalypt regimes become relatively more profitable than low-volume radiata regimes. Radiata pine on a high-volume regime, however, remains the most profitable species under the scenarios we examined. With regard to the details of radiata pine regimes, a rising carbon price favours late thinning, and high final stocking - and discourages pruning. As the carbon price increases, a plant-and-leave regime dominates and there is a general lengthening of optimum rotation age. These trends apply across all site qualities.

The benefits of carbon trading are less obvious for stands that were planted in the 1990s compared with future stands, because much of the carbon sequestration has already taken place with no payment. Nevertheless, carbon trading is still worthwhile. Whatever the date of planting, there are still some risks in “opting in” to the ETS, particularly with regard to cash-flow difficulties at time of harvest. Most of these risks can be avoided or mitigated by careful estate planning, albeit with a reduction in profitability.

Growers can choose to retain sufficient units to cover any future liabilities, and to avoid situations where carbon liabilities at harvest greatly exceed expected revenues from the sale of timber. Alternatively, they may choose to modify their estates (by mixing species, regimes, or age-classes) so as to smooth out the future profile of their carbon stocks. Planting a normal forest achieves almost zero risk - because there are no further carbon losses anticipated - but it is more profitable to achieve normality by harvesting rather than by planting alone. Tree-breeding promises some carbon advantages, particularly where the gain is through volume growth rather than the lesser benefit of increased wood density.

**Introduction and Approach**

The 2008 \textit{Climate Change (Emissions Trading and Renewable Preference) Act}, that became law on September 10 2008, presages major changes in the way forestry is practised in New Zealand. The costs and revenues of carbon sequestration may cause fundamental shifts in species, regimes, age classes, forest profitability and risk. Policy-makers, forest owners and those seeking to buy NZ Emission Units should be alerted to some of these likely changes.

The School of Forestry, University of Canterbury, successfully tendered for a Ministry of Agriculture and Forestry (MAF) contract to investigate the likely effects of the proposed Emissions Trading Scheme on forest management. To this end, a class of Year Four students at the School of Forestry, University of Canterbury was tasked, as part of their Management Case Study, with optimising profitability under a range of inputs in a carbon-trading environment. The following inputs were varied: discount rates, carbon price, rotation age, date of planting (1995 or 2008), site quality, and silvicultural regime (initial and final stocking, timing and intensity of thinning and pruning). Genotypes were simulated that gave more volume or higher wood density.

Three standard regimes were specified for radiata pine to represent contrasting silviculture:

- **Clearwood** (Plant 800 stems/ha, prune to 5.5 m in 2 lifts, thin to 250 stems/ha at age 7.8 years).
- **Framing** (Plant 800 stems/ha, thin to 375 stems/ha at age 7.8 years).
- **Plant & leave** (Plant 800 stems/ha, no thinning).

Regimes adopted for other species:

- **Douglas fir** (Plant 1650 stems/ha, thin to 500 stems/ha at age 15).
Site quality was determined on a two-dimensional scale: using height index and volume index as listed in Table 1, together with corresponding latitudes and wood densities.

The Average site for radiata pine represents an average New Zealand ex-farm site, Good sites were assumed to be ex-farm sites from the Central North Island, and the Poor Site was typical of South Canterbury. The Douglas-fir site is an average New Zealand site, while the Eucalyptus nitens site is a good Southland site. The indices for all radiata and Douglas-fir site types were extracted from the national PSP table that is included in the Calculators. Indigenous sequestration was taken be 3 tonnes CO₂-e per hectare per year as assumed in the proposed ETS regulations.

Log prices were estimated using current prices. All Eucalyptus nitens volume was priced as pulplogs.

Alternative trading systems were examined, whereby growers could sell their credits annually whenever they were generated or else retain some credits to avoid cash-flow difficulties at time of harvest. There was also a substantial focus on estate-level options, such as staggered planting of a forest resource, or mixing species and regimes. Two further options that may prove to be of interest were: achieving normality by harvesting rather than by planting, and planting without any intention of harvesting.

In most situations, Land Expectation Value³ was employed as an index of profitability. Carbon sequestration was estimated for radiata pine and Douglas-fir using Green Solution software (also known as the Farm Forestry Calculators) and for other species was custom-made from a carbon allocation model (C_Change) originally designed for radiata pine. A fixed cost ($60/ha/year) was assumed for the costs of measurement, auditing, registration and trading the carbon.

Results

Initial examination of silviculture for radiata pine

Carbon payments favour higher volumes throughout the rotation, and so encourage: higher final stockings, delayed thinnings, and the avoidance of pruning. At 8% discount rate, even modest carbon prices would lead to an unpruned regime where thinning is delayed until age 14 (possibly including production thinning), and final stocking is held at 600 stems/ha or more. Carbon payments always increase rotation length, the exact amount depending on site quality, discount rate and the regime choice. A typical 25-year-rotation framing regime with no ETS is extended to 36 years when carbon is worth $30/t.

Species and Regimes

At carbon prices of $10/t or more, the preferred regime for radiata pine on an average site is to plant the trees and walk away (ie no thinning or pruning), delaying harvesting to between years 31 and 33 depending on discount rate. This regime outperforms even Eucalyptus nitens - renowned for spectacular volume growth - and is substantially more profitable than Douglas-fir or indigenous options. Eucalyptus would become more profitable than a radiata clearwood regime if the carbon price rose to $34/t, but would not outstrip the radiata pine plant-and-leave option.

Revenue from annual sales of carbon units greatly increases the profitability of all species and regimes. Indeed, if the price reaches $30 then all investments in radiata pine are capable of paying $3000/ha and still achieving an 8% or even a 10% rate of return. ($30/t is insufficient to meet this target for Douglas-fir and indigenous forestry, but a lower

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Table 1: Site quality features used

<table>
<thead>
<tr>
<th>Site Quality</th>
<th>Height Index¹</th>
<th>Volume index²</th>
<th>Wood density³</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good radiata</td>
<td>32.6</td>
<td>32.6</td>
<td>460</td>
<td>38</td>
</tr>
<tr>
<td>Average radiata</td>
<td>30.2</td>
<td>29.0</td>
<td>440</td>
<td>38</td>
</tr>
<tr>
<td>Poor radiata</td>
<td>23.7</td>
<td>18.2</td>
<td>420</td>
<td>44.5</td>
</tr>
<tr>
<td>Douglas-fir</td>
<td>31.3</td>
<td>18.4</td>
<td>418</td>
<td>42</td>
</tr>
<tr>
<td>E. nitens</td>
<td>25.6</td>
<td>n/a</td>
<td>472</td>
<td>n/a</td>
</tr>
</tbody>
</table>

¹ Height index (or Site Index) is the MTH at age 20 for radiata pine, and 40 for Douglas-fir. The height at age 15 was used for E. nitens.
² Volume index (m³/ha/yr) for radiata pine used the 300 Index and for Douglas-fir the 500 Index.
³ Wood density (kg/ m³) for outerwood at breast height at age 20 (radiata) and age 30 (D-fir) or for whole tree at age 12 (E. nitens)

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³ Land Expectation Value (LEV) is a special case of the better-known Net Present Value (NPV) - it assumes a perpetual series of rotations on land that is currently bare of trees. It is the maximum that can be paid for land to achieve a given rate of project return.
carbon price would suffice for the cheaper land appropriate for those species). Indeed, the land-price hurdle of $3000/ha (assuming 8% real rate of return) could be overcome by the following carbon prices, expressed in “New Zealand dollars per tonne of carbon dioxide equivalent”:

- Radiata Clearwood regime: $13.08/t
- Radiata Framing regime: $11.70/t
- Radiata Plant-and-leave: $9.55/t

**Stands planted in 1995**

Regardless of the price of carbon, there is limited scope for changing already-established stands. There are only two decisions to make: whether to register for the ETS, and if so, whether to extend the rotation.

Our analysis showed that “opting in” is indeed a profitable decision (except possibly for the cashflow factor to be discussed later); in terms of Net Present Value, the gain could amount to $10,000/ha or more. This would provide a major boost to forest values of existing post-1990 forests. Secondly, rotations may increase by as much as fifteen years depending on the regime, carbon price and discount rate.

**Site quality**

Even on a good site a superior radiata pine clearwood regime usually cannot afford to pay $3000 per hectare and still make 8% real return on the investment - unless carbon is included. (Table 2). Given such a high (but typically encountered) discount rate, forest enterprise on a poor site cannot justify the cost of land at any positive value. But with carbon trading (and a price of $30/t) even the poorest sites can achieve this rate of return if land costs less than $1700/ha.

**Table 2: The LEV ($/ha) of forestry (revenue from timber plus carbon) for radiata pine clearwood regime on three site qualities (figures in brackets are optimum rotation ages).**

<table>
<thead>
<tr>
<th>Price of carbon</th>
<th>$0.00</th>
<th>$7.50</th>
<th>$15.00</th>
<th>$30.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount rate</td>
<td>6%</td>
<td>6%</td>
<td>6%</td>
<td>6%</td>
</tr>
<tr>
<td>Good site</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg site</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4117 (25)</td>
<td>1215  (25)</td>
<td>-241  (25)</td>
<td>4855  (25)</td>
<td></td>
</tr>
<tr>
<td>Poor site</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>634 (25)</td>
<td>-938  (33)</td>
<td>-1549 (30)</td>
<td>718   (38)</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1: Effect of carbon price on LEV of different species.
Alternatively, if the discount rate threshold is relaxed to 6%, with carbon trading poor land can justify land payments of over $4000/ha, and good land can afford to pay prices similar to those currently being paid for dairy conversion (ie >$13,000/ha).

Optimum rotation ages are always extended by carbon payments, but tend to be relatively longer for poorer quality sites, lower discount rates and higher carbon prices.

Genetic deployment

The increase in revenue from extra carbon sequestration resulting from genetic improvement means that growers can afford to pay more per plant and end up with the same LEV. In fact, the price could rise by $1.20 per seedling, with 74c being for improved growth and the remainder for increased wood density. This result assumes an average site and a discount rate of 8%, an increase of 5% in terms of 300 Index and 6% in terms of age 10 wood density. Wood density has the lesser impact here because density is not included in the log specifications used. In contrast, an increase in productivity improves both the quantity of carbon and the value of harvested wood.

Risk

The profitability of forestry increased with a rising carbon price. The risk of “opting in” is dictated not by the future price of carbon, but by other factors: the liability associated with unpredicted carbon loss (not all of which is insurable, such as disease-induced risk); cash-flow constraints; and the choice of a regime which may be sub-optimal or valueless if the price of carbon collapses.

For example: a plant-and-leave regime is distinctly superior to any other radiata regime, given even a modest price for carbon, but a fall in the carbon price leaves a second-rate crop. Unlike a framing regime, it has not been thinned so piece-size is lower than sawmillers would prefer.

Moreover, the tall spindly trees would be very unstable and liable to windthrow. A similar dilemma concerns pruning: pruning is a disadvantage in a high-carbon, low-clearwood price environment but if the relativity of these prices should reverse, there is no going back.

The risk from Douglas-fir is very low, because the timber revenue is high relative to the carbon revenue, but the returns are also very low. The risks from eucalypts are extremely high (they’re worth little without the value of carbon) but the profitability is still low in comparison to a radiata crop. This suggests that estate portfolios that incorporate Douglas-fir would reduce the overall risk, but at considerable cost. On the other hand, there would be no advantage in adding eucalypts to the mixture of radiata pine because risk would be greatly increased with no benefit to profitability.

Alternative carbon trading strategies

The grower may choose to sell credits in the year they were sequestered. Alternatively, a proportion could be retained to use at harvest or to mitigate risk unrelated to cashflow problems (for example, another type of risk is that the standing carbon stocks decline as a result of fire or disease).

Sell up to minimum level of stocks

The grower might decide to sell only up to the minimum level of stocks that is likely to be present over the long term (Figure 2). This can be expressed as the carbon remaining in roots, stumps and slash after harvest. Selling such credits has a very low risk because at least that level of carbon is likely to persist throughout a cycle of successive rotations.

Sell up to average level of stocks

Another approach might be to trade an amount that is intermediate between the maximum achieved immediately prior to harvest and the previously described “minimum

| Table 3: The inverse correlation between profitability and risk (at 8% discount rate). |
|---------------------------------|---------------------|---------------------|---------------------|---------------------|
| Regimes                  | Max LEV | Rotation | Risk* (%) | Max LEV | Rotation | Risk (%) |
| Clearwood                 | 1215    | 25       | 0         | 6647    | 30       | 47       |
| Framing                   | 863     | 25       | 0         | 8200    | 36       | 70       |
| Plant & Leave             | 421     | 27       | 0         | 11,038  | 40       | 80       |
| Douglas-fir               | -1917   | 40       | 0         | 1359    | 44       | 30       |
| E. nitens                 | -1193   | 19       | 0         | 6427    | 25       | 162      |

* “The Risk Index is the ratio of the value of units that must be surrendered at harvest relative to the value of the harvested wood”
stocks” level. An owner might plant a stand with the confidence to trade carbon up to the stand’s long-term average carbon stock (Fig. 3).

The alternative trading strategies do reduce the level of risk - however LEV decreases particularly for the “Sell to minimum” strategy (Table 4).

Establish a normal forest

We also evaluated estate-level scenarios for managing the risk associated with carbon trading. As an extension of the “sell to average level of carbon stocks” strategy we looked at the establishment of a normal forest.

If a 30-year rotation is assumed, then one thirtieth of the estate can be planted every year. Once harvest has begun,
there will be no liabilities because the carbon loss from the oldest stand undergoing harvest will be exactly compensated by the carbon gain from the total of the immature stands. This situation can continue indefinitely. A normal forest is carbon-neutral: in other words, harvest liabilities in the oldest stand are counter-balanced by sequestration in all the other stands.

Planting small amounts of a forest estate every year is sub-optimal, because much of the land remains in an inferior land use until the entire area has been planted. This problem can be overcome by planting the entire area simultaneously and achieving normality by varying the timing of harvest.

This strategy can be illustrated by a simple example. Assume that the optimum rotation age for radiata pine on a given site is 30 years, but the species can be harvested anytime between 25 and 54 years without great economic loss. The entire estate could be planted out at once, and harvesting commenced at age 25 on 1/30th of the area. Every year thereafter, a further 1/30th is felled and replanted. After 54 years, therefore, an estate is developed where each annual age-class is equally represented and the entire forest is normalised on a 30-year rotation after age 54.

This simple strategy presupposes that there is a wide range of near-optimum harvest ages available with the species or regime, so that no great economic loss results from the fluctuations in harvest age that will occur until normality is reached. For example, a sceptic may well argue that 54 years is too long to delay harvest for radiata pine, and that the real economic limits of rotation age lie between 25 and 40 years.

A compromise solution that will achieve a normal forest in only two rotations involves manipulations in both planting and harvesting dates. For example, 16/30 of the forest could be established immediately with the remaining 14/30 established in 16 years time. The initial planting would be harvested, 1/30 of the forest area per year, between age 25 and 40. The second block of planting would be harvested, 1/30 of the area per year, between age 25 and 38. After 54 years a normal forest is achieved. This is the general approach that has been followed here.

The result is that, given the greater profitability of trees compared to pasture, it is more profitable to achieve normality via variations in harvesting dates rather than by successive plantings on bare land.

A mixture of species and regimes

Mixtures of species and regimes can be used to reduce the cash-flow and other risks, but the unsurprising conclusion of many such studies is that while such mixtures do indeed reduce the risk, they also commensurately reduce the profitability of the entire forestry investment. The exact trade-off between maximising profitability and minimising risk will depend on the risk aversion of the investor. If “hedging” is required to reduce risk (albeit at some cost to profitability) this can be done in numerous ways including the normalisation strategy already discussed.

Planting without any intention of harvest

The introduction of the ETS might encourage some growers to reap their rewards purely from the yield of carbon credits, without any intention of harvest. At some time in the future, there is little doubt that any sort of simultaneously-planted forest would eventually experience periods where growing stock would decline, with an implied carbon liability. Trees will collapse and decay because of wind damage or merely through senescence. Yet the owner of the “no-harvest” forest might intend to “farm” carbon during his (or his company’s) lifetime and leave the liabilities to a successor. Would this be a sensible, albeit selfish, strategy?

Unfortunately, the existing models are inadequate to address the benefits or dis-benefits of this option. There are little data for over-mature plantation forests in New Zealand. We cannot quantify the risks of windthrow, the profile of collapse and decay in senescent stands, and the recruitment of replacement trees following such a collapse. We can be sure that only a portion of the sequestered carbon would be lost (analogous to the loss from harvest) and that it would eventually be compensated, at least in part, by subsequent regrowth.

A tentative result is that existing growth models imply that:

*=E. nitens* would have a higher NPV under a no-harvest strategy than under a harvesting strategy - this is a reflection of the log price assumptions used; ie, pulplogs only.
The NPV for the radiata pine plant-and-leave regime is higher than that of *E. nitens* under a no-harvest strategy.
Radiata pine regimes have a higher NPV under a harvest strategy than under a no-harvest strategy.

Conclusions

**Choice of species and regime**

Whatever regimes are chosen, it is clear that without carbon payments, forestry could not - at current returns for logs - be justified on poor sites unless extremely low discount rates are used. Forestry struggles to pay for realistic land prices even on good sites. Yet when carbon price is included, the case for forestry becomes very strong. Best of all are radiata pine regimes which favour volume per hectare over large piece-size. The accepted strategy in New Zealand has...
long been to sacrifice volume per hectare for higher volume
per tree, but the decline in clearwood prices (as has occurred
recently as a result of the sub-prime mortgage crisis in the
US housing market) has recently tilted the table towards
framing regimes and higher stockings. The advent of carbon
payments reinforces this trend.

The economic case for alternative species and regimes is
currently weaker than for radiata pine, but with high carbon
prices some non-radiata species (for example, *E. nitens*) may
become preferable to the most commonly employed radiata
regimes, but nevertheless do not seriously challenge the
dominance of radiata pine when it is purposefully grown
for carbon benefit under the assumptions made in our
analysis.

**Stands planted in 1995**

Although there are definite advantages to a grower in
“opting in”, even if a stand is already up to 18 years
through a 25-year rotation, this presupposes a fixed price
for carbon. The grower obtains the carbon revenue (less
the measurement and transaction costs) for sequestration
occurring during CP1 but must surrender an equal amount
of units at harvest. At best, the grower gains only “the time-
value of money” but, at worst, runs a serious risk because if
the price of carbon rises it may be too expensive to re-acquire
the necessary units for surrender. The problem here is not
one of profitability - the value of forestry improves under
any carbon price scenario - but one of cash-flow.

One possibility is for an existing forest grower to harvest
only a proportion of the estate, relying on growth from
the remainder to cover the carbon liabilities. Subsequent
harvests would need to involve a progressively lesser area,
or else be spaced at increasing intervals, because a greater
quantity of units per hectare would need to be surrendered
as the harvest-age increased.

If the grower does decide to opt in, it would be wise
to review the intended rotation age as the optimum may
be substantially later than originally intended. A series
of harvesting coups may be a better option than a single
clearfelling operation - but this would need to be costed out in
local detail, in view of the minimum economic harvest size.

**Limitations**

One obvious limitation of this study is the restricted
number of species investigated. The main reason for this is
the difficulty in acquiring hard data for alternative species
on growth, costs and prices, and in modelling that data.
Mostly this is because the information is simply unavailable:
domestic timber supply in New Zealand is totally dominated
by radiata pine and to a lesser extent Douglas-fir. Good cost
and price data for alternative species are non-existent and
growth models are still at a primitive stage. The discovery
that carbon stocks from alternative species can be modelled,
provided that a reliable yield table has been developed, has
led to the use of *E. nitens* in this study.

Where indigenous sequestration was assessed the
assumption used in the draft ETS regulations of 3 tCO2
per hectare per year were copied, but this is obviously an
unsatisfactory approximation or simplification.

The absence of a clear policy environment has
complicated this technical study and made conclusions less
robust than might have been the case. At time of writing, we
cannot be sure how the ETS will survive the New Zealand
election, let alone the post-2012 international negotiations.
There may, for example, be a considerable premium paid for
carbon sequestration of a certain vintage whereby an emitter
who releases carbon in a given year must sequester it in that
year. If this philosophy becomes widespread, it may totally
alter the ability of a grower to “bank” carbon credits and
smooth over periods of negative growth in carbon stocks,
thus greatly increasing the risk factor.

**Recommendations**

It would be very useful for similar studies in future
years to employ a standardised “carbon calculator”. This
would be similar to the existing radiata pine and Douglas-fir
calculators, but simplified and custom-designed for carbon
(many of the current inputs and outputs have no relevance
to this type of analysis and might serve only to bewilder
those unfamiliar with the software). A user would merely
have to input a yield table in a suitable format for any new
species, and read off the results.

To provide such yield tables, considerably
more work is required in mensuration and modelling of
alternative species.

Even for the two dominant species, there is a scarcity
of information for very young ages (Douglas-fir, and radiata
pine on poor sites) and there is an absence of data for over-
mature stands. A good case could be made for the establishment
of permanent sample plots in a representative range of very
old stands - with some agreement that these stands would be
allowed to remain standing until they have collapsed of natural
causes. Only then can we hope to model the consequences of
the “no harvest” strategy considered here.

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