Forest Policy and Economics xxx (2010) xxx–xxx

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

Potential impact of carbon trading on forest management in New Zealand

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ARTICLE INFO

Available online xxxx

Keywords:
Carbon price risk
Carbon trading
Forest management

ABSTRACT

The New Zealand Government has enacted an emissions trading scheme (ETS) under which owners of Kyoto-compliant forests will receive/surrender units for increases/decreases in the carbon stocks of their plantations. Each unit represents one tonne of carbon dioxide (CO_2) and can be traded. In this paper we evaluate the potential impact of the ETS on forest management decisions including whether to establish new forest, choice of species and silviculture, and forest rotation length. Criteria used in the analysis are financial return (LEV or NPV) and carbon price risk (cost or percentage of units to be surrendered after harvest). Results show that carbon trading has the potential to increase forest profitability and influence the choice of silviculture. Forest rotation length increases with expected carbon price. However there is considerable risk arising from carbon prices. We develop strategies that hedge against carbon price risk at both the stand level and the forest estate level. The former include growing a valuable crop and trading only a portion of units received. The latter includes managing forest structure via age-class composition. We evaluate trade-offs between financial return and risk in order to identify the opportunity cost of strategies that are robust against future carbon prices.

1. Introduction

In 2008 the New Zealand Government enacted an emissions trading scheme[1] that is "designed to eventually cover all significant greenhouse gases (covered by the Kyoto Protocol) and involve all sectors in New Zealand. The primary unit of trade will be the New Zealand Unit (NZU). One NZU represents one tonne of carbon dioxide (CO_2) either released to the atmosphere (emissions) or removed from the atmosphere (removals)" (MAF, 2008).

Unlike the existing European Union ETS, the New Zealand ETS allows CO_2 credits to be obtained from sinks. Owners of Kyoto-compliant plantations (afforestation since 1 January 1990) will be able to opt into the ETS and receive units for carbon sequestered. Conversely, they will be required to surrender units when carbon stocks decrease. Pools included in the calculation of carbon stocks are above-ground live biomass, below-ground live biomass, coarse woody debris and fine litter. Soil carbon is not included because changes in soil carbon are generally small and difficult to measure at reasonable cost (MAF, 2008). Carbon stocks are to be determined either by (i) a look-up table approach or (ii) a field measurement approach.[2] Participants will be able to claim units for the annual change in carbon stocks.

The ETS adopts the current Kyoto Protocol rule that harvested carbon (ie, logs extracted from the forest) is emitted at the time of harvest; ie, the ETS excludes harvested wood products. Obligations under the ETS go with the land and apply indefinitely until a participant exits from the ETS at which time they must meet any liabilities.

Carbon trading, through the provision of early cashflows, has the potential to change the economics of plantation forestry in New Zealand. Consequently, the Ministry of Agriculture and Forestry (MAF) commissioned the New Zealand School of Forestry to undertake a study to evaluate the likely impact of the ETS on:

- forest profitability,
- choice of species,
- choice of silviculture, and
- rotation length.

This study was carried out by the final year Bachelor of Forestry Science students supervised by the authors of this paper. Results were

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[1] The ETS was one of the final pieces of legislation passed in 2008 by the Government prior to a General Election. At this election on 8 November, a new Government was elected. It has subsequently reviewed the ETS and, although some changes have been made, an ETS that allows carbon trading for Kyoto-compliant plantations has been retained.

[2] The latter approach is mandatory for projects over 50 ha.

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doi:10.1016/j.forpol.2010.01.001

presented to MAF[3] and summarised in Maclaren and Manley (2008). They confirmed that the ETS could have a major impact on forest profitability and forest management. Subsequently there have been concerns expressed about the potential risk from (i) future carbon price uncertainty; and (ii) an unexpected event (eg, wind, fire, pests and disease) that will require early surrender of units and create cashflow problems for the owner. In this paper we extend the original analysis and develop strategies to mitigate the first type of risk. The second type of risk is not addressed here. We start by reviewing key results from the initial study. We then evaluate strategies that hedge against carbon price risk at both the stand level and the forest estate level.

We note that although the paper deals with the specifics of the New Zealand ETS the results will have applicability to other situations where forest carbon offset credits can be obtained. It deals with the potential returns and risks from forestry carbon trading and how carbon price risk can be managed.

2. Method

We evaluated three different species: radiata pine, Douglas fir and *Eucalyptus nitens*. For radiata pine we assumed an average New Zealand ex-farm site of site index[4] 30.2 m and 300 Index[5] of 29 m^3/ha/year. We evaluated three different silvicultural regimes:

- Clearwood (plant 800 stems/ha, prune to 5.5 m in 2 lifts, thin to 250 stems/ha at age 8 years).
- Framing (plant 800 stems/ha, thin to 375 stems/ha at age 8 years).
- No thin (plant 800 stems/ha, no thinning).

The Douglas fir site is an average New Zealand site with a site index[6] of 31.3 m and a 500 Index[7] of 18.4 m^3/ha/year. The silvicultural regime is plant 1650 stems/ha, thin to 500 stems/ha at age 15 years.

The *Eucalyptus nitens* site has site index[8] 25.6 m. The silvicultural regime is plant 900 stems/ha with no thinning.

We estimated log and carbon yields using the Radiata Pine and Douglas fir Calculators (NZTG 2003) and, in the case of *Eucalyptus nitens*, the Forest Carbon Predictor implementation of C_Change (Beets et al. 1999).

Financial criteria used are Land Expectation Value (LEV) and Net Present Value (NPV) at an 8% real discount rate[9] (Manley 2007). Current log prices were used — in the case of radiata pine published MAF[10] 12-quarter average prices. Industry average costs were used. A range of carbon prices was used with \$30/t CO_2 as a base case — 2008 prices for secondary Certified Emission Reduction (CER) units were around this level.[11] A fixed cost (\$60/ha/year) was assumed for the costs of measurement, auditing, registration associated with carbon trading. For the estate-level analysis it was assumed (based on information from forest managers) that new land for afforestation could be purchased for \$3000/ha. All prices and costs are in New Zealand dollars.

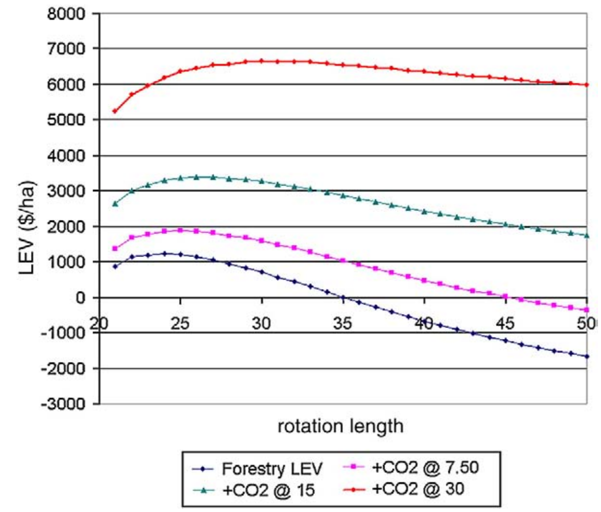

Fig. 1. LEV of radiata pine clearwood regime when revenues come (i) from log sales only (Forestry LEV); and (ii) log sales and carbon trading with carbon prices of \$7.50, \$15 and \$30/t CO_2.

3. Results

3.1. Impact of the ETS on forest profitability

Initial analysis compared (Fig. 1) the profitability of the radiata pine clearwood regime when revenues come (i) from log sales only; and (ii) log sales and carbon trading with carbon prices (per tonne CO_2) at fixed levels of \$7.50, \$15 and \$30. With traditional forestry the maximum LEV of \$1223/ha occurs at age 24. With carbon trading the LEV and rotation age increases with increasing carbon price. At a carbon price of \$30/t CO_2 the maximum LEV of \$6647/ha occurs at age 30.

The increase in forest profitability with carbon trading is explained by Figs. 2 and 3. Fig. 2 shows the carbon stock over time for the radiata pine clearwood regime while Fig. 3 gives the consequent net cashflow from carbon trading with a carbon price of \$30/t CO_2. The financial benefit of carbon trading arises because:

- of the time value of money — units are received during the rotation and do not have to be surrendered until harvest
- not all units have to be surrendered. Biomass left on site after harvesting decays only gradually. The minimum level of carbon stock after harvest is 250 t CO_2/ha. Consequently of the 1002 units received only 752 units have to be surrendered.

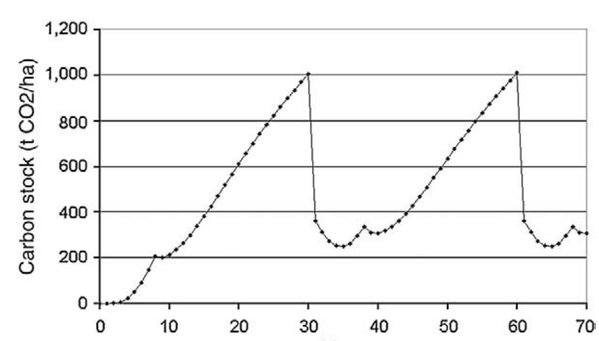

Fig. 2. Carbon stock for radiata pine clearwood regime grown on a 30 year rotation.

[3] http://www.maf.govt.nz/climatechange/slm/grants/research/2007-08/2008-10-obj1-summary.htm.
[4] Mean top height of 100 largest stems/ha at age 20 years.
[5] 300 Index is an index of volume productivity. It is the stem volume mean annual increment at age 30 years for a defined silvicultural regime of 300 stems/ha (Kimberley et al. 2005).
[6] Mean top height of 100 largest stems/ha at age 40 years.
[7] 500 Index is the stem volume mean annual increment at age 50 years for a defined silvicultural regime of 500 stems/ha (Knowles 2005).
[8] Mean top height of 100 largest stems/ha at age 15 years.
[9] All cashflows, whether they arise from traditional forestry or from carbon trading, are discounted at this rate. Graphs are presented of undiscounted carbon stocks versus age or time to compare alternative strategies. However we concur with Boyland (2006) that carbon needs to be discounted to "give reasonably interpretable economic results". Hence we use LEV and NPV as the financial criteria.
[10] http://www.maf.govt.nz/forestry/statistics/logprices/.
[11] http://www.ecx.eu/EUA-CER-Daily-Futures.

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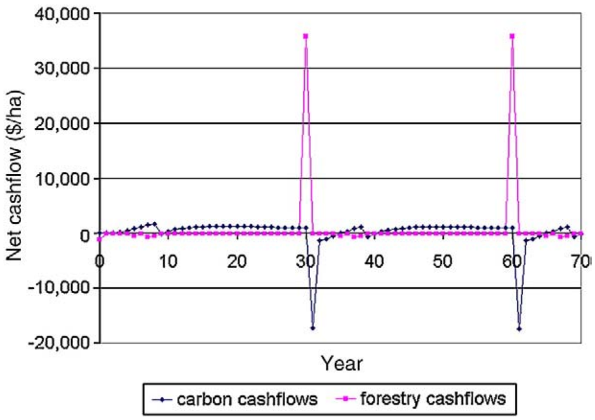

Fig. 3. Net cashflow from carbon trading for radiata pine clearwood regime grown on a 30 year rotation. Carbon price is assumed to be constant at $30/t CO_2. The net cashflow from forestry is also shown.

3.2. Impact of the ETS on forest management

Without carbon trading, the LEVs of all three radiata pine regimes exceed those of *Eucalyptus nitens* and Douglas fir (Fig. 4). The ranking of different species changes little with carbon trading. Only at high carbon prices does *Eucalyptus nitens* start to match radiata pine.

However the ranking of the three radiata pine silvicultural regimes changes as carbon price increases. The no thin regime goes from least to most preferred while the clearwood regime does the opposite.

The relativity of the different species/regimes is largely explained by the relative carbon stock profiles (Fig. 5). As carbon prices increase (and log prices are held constant) the production of biomass is favoured relative to the production of logs. Consequently, species/regimes with high carbon stocks are favoured as carbon price increases. The relative financial performance of *Eucalyptus nitens* does not match its relative carbon stocks because logs are sold only for pulpwood.

As carbon price increases optimum rotation increases. Fig. 6 shows the impact for the three radiata pine regimes – the effect is most pronounced for the no thin regime. The different effect reflects the relative value of log products compared to that of carbon for each regime. Increasing carbon price has least effect on the clearwood regime – this produces the highest value log products and hence stumpage revenues.

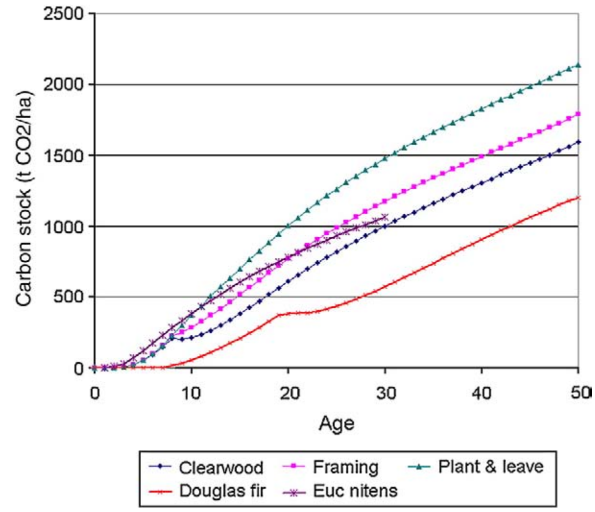

Fig. 5. Carbon stock by age for different species/silviculture. (The clearwood, framing and no thin regimes are for radiata pine.)

Sensitivity analysis was also carried out for discount rate. As expected, LEV and optimum rotation age decrease as discount rate increases. However, the ranking of different species/regimes stays much the same.

3.3. Cashflow risk

The profile of cashflows from carbon trading (early revenues, cost at time of harvest) complements that from forestry (early costs, revenue at time of harvest). However a concern of potential forestry investors is their ability to have the cashflow necessary to purchase the units that have to be surrendered at the time of harvest; ie, whether they will be able to afford to harvest.

To illustrate this we evaluated a series of scenarios in which carbon price starts at $30/t CO_2 and changes at a constant percentage from year to year. This was done for the radiata pine clearwood regime assuming a 30 year rotation. Fig. 7 shows that although LEV consistently increases as the percentage change in carbon price increases, so does the cost of the carbon units that need to be surrendered. Although this cost is factored into the LEV it does create a cashflow risk. At the time of harvest, stumpage revenues of $37,000/

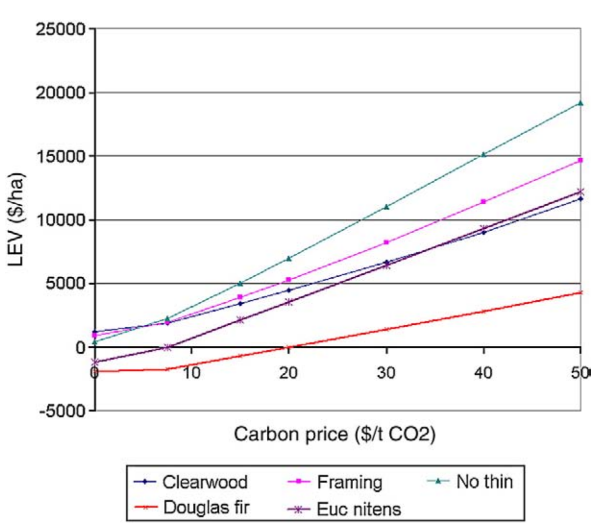

Fig. 4. Effect of carbon price on the LEV of different species/silviculture. (The clearwood, framing and no thin regimes are for radiata pine.)

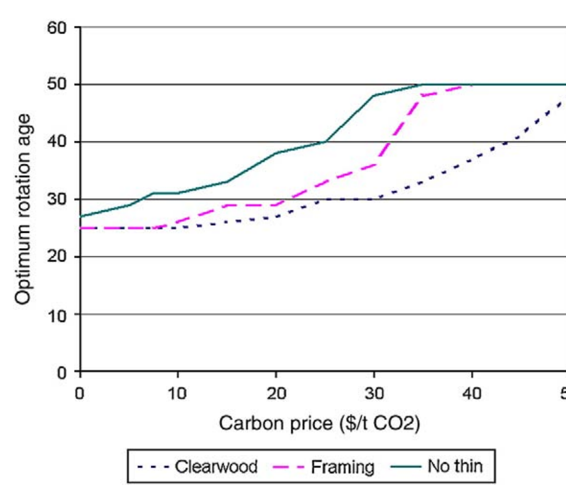

Fig. 6. Effect of carbon price on optimal rotation age for three radiata pine silvicultural regimes. (As the maximum rotation age evaluated is 50 years, the upper asymptote is artificial).

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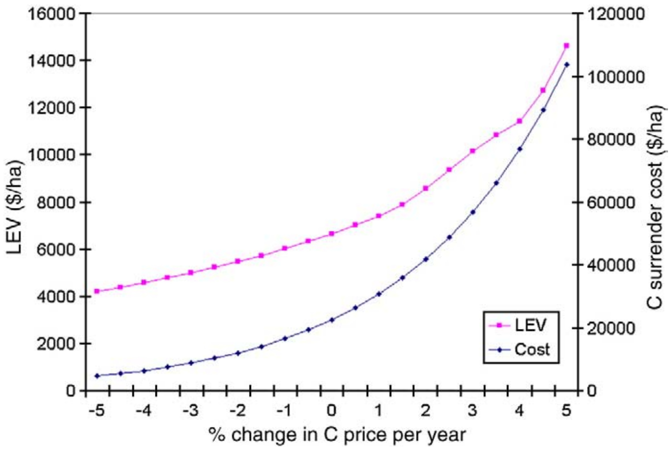

Fig. 7. Impact of changing carbon price on LEV and cost of carbon units to surrender at time of harvest. Radiata pine clearwood regime with initial carbon price of $30/t CO_2 and a constant percentage change from year to year.

ha are expected — these only partially cover the cost of units if carbon prices at the time of harvest increase beyond $49/t CO_2.

3.4. Stand-level strategies to hedge carbon price risk

One strategy to partially mitigate the carbon price risk is to grow a valuable crop; ie, to produce a crop that will give a stumpage revenue high enough to offset the cost of carbon units to be surrendered. Fig. 8 shows that the radiata pine clearwood regime and Douglas fir are relatively low risk in this regard — at a carbon price of $30/t CO_2 stumpage revenues exceed the carbon unit surrender cost (ie, less than 100%). Conversely *Eucalyptus nitens* is high risk.

Trading only a portion of the units received is another way to manage for carbon price risk. The ETS units do not expire; ie, they do not have to be traded in the year in which they are earned. Rather they can be banked in the owner's account at the New Zealand Emissions Unit Registry and surrendered at the time of harvest.

The optimum LEV of $6647/ha for the clearwood regime assumes that all units received are traded (for a price of $30/t CO_2). Fig. 9 shows the trade-off between the percentage of units traded and the LEV. The point at the bottom-left of the curve involves trading of only 250 units. This is low risk — no carbon units need to be surrendered because the level of carbon stock in the stand does not subsequently fall beneath 250 t CO_2/ha. However the opportunity cost is the reduction in LEV to $3808/ha.

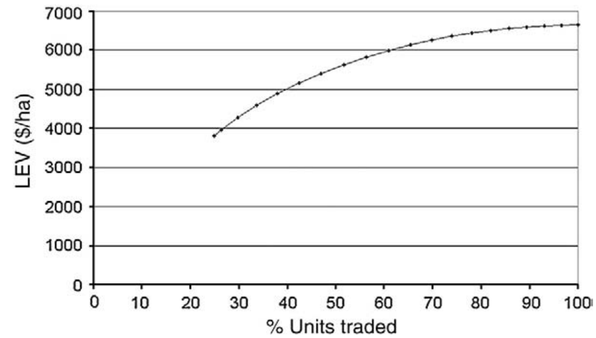

Fig. 9. Trade-off between percentage of carbon units received that are traded and LEV. Radiata pine clearwood regime with a 30 year rotation.

3.5. Estate-level strategies to hedge carbon price risk

We evaluated a range of different estate establishment, silviculture and harvesting strategies for a 1200 ha property that is currently bare of trees. To illustrate key points, here we present the results of four alternatives that include only radiata pine grown under the clearwood regime (and a fixed carbon price of $30/t CO_2). The alternatives differ in terms of when the land is planted and harvested in the first rotation (all have a rotation age of 30 years in the second and subsequent rotations):

1. Plant 1200 ha this year and harvest at age 30 years.
2. Plant 1200 ha this year and harvest 40 ha per year at ages 21 to 50.
3. Plant 600 ha this year and 600 ha in 15 years time. For both blocks harvest 40 ha per year between ages 25 and 39 years.
4. Plant 40 ha per year and harvest at age 30 years.

Strategy 1 is the stand-level strategy presented in Fig. 2 scaled up by 1200 ha. The other 3 strategies are all alternative ways of developing a normal forest with a target rotation of 30 years. Each strategy provides a different carbon stock profile over time (Fig. 10). Note that it takes two rotations for a steady state of carbon to be reached — carbon stocks are higher during the second rotation as residual carbon from the first rotation is still present, particularly during early stages before it decays.

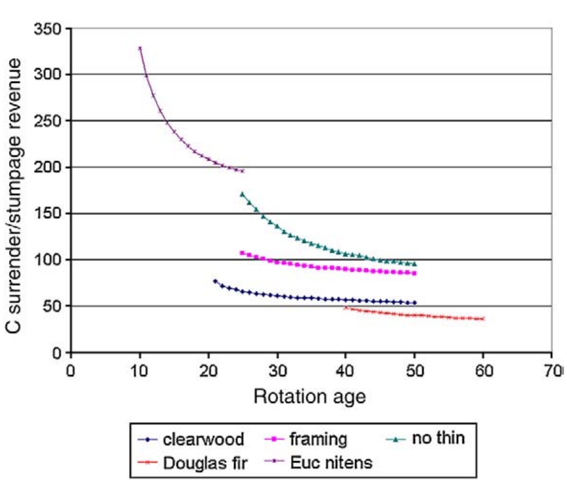

Fig. 8. Cost of carbon units to surrender at time of harvest as a percentage of stumpage revenue for different species/silviculture.

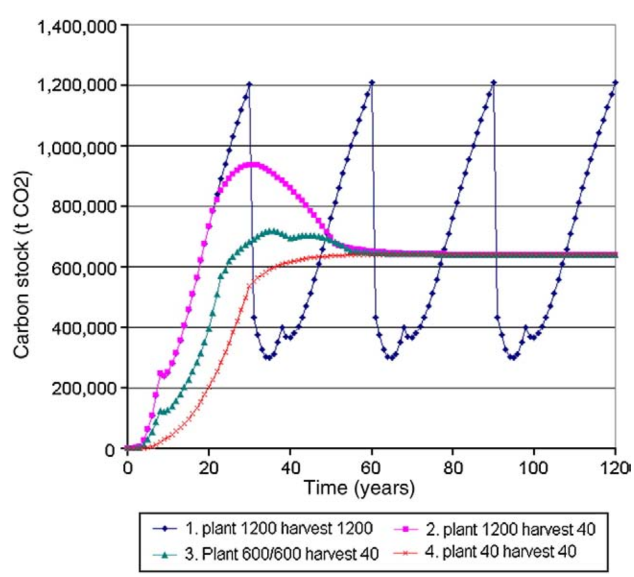

Fig. 10. Carbon stocks for four estate-level strategies.

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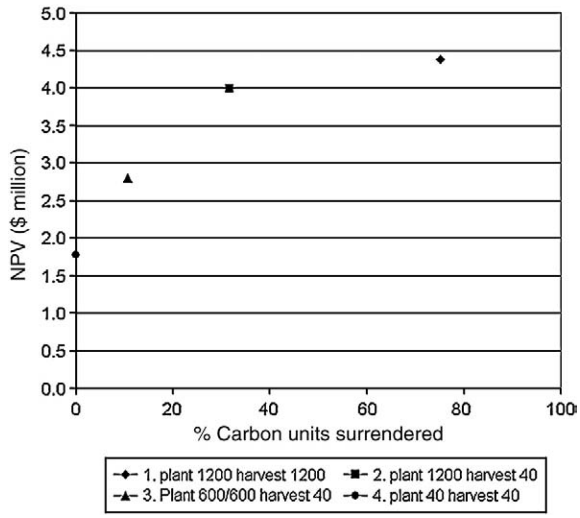

Fig. 11. Trade-off between the percentage of carbon units received that have to be surrendered and NPV of four estate-level strategies.

Strategy 1 requires the surrender of 75% of units received while Strategy 4 does not require any units to be surrendered. Fig. 11 shows the trade-off between NPV and the percentage of units that have to be surrendered.

4. Discussion

4.1. Forest profitability

The ETS has the potential to transform the profitability of afforestation in New Zealand. Up to three million ha of agricultural land is available at a cost of less than $7000/ha. Traditional forestry returns make this land unaffordable as is evident by the current low level of afforestation (about 2000 ha in 2007). However carbon trading with prices around $30/t CO_2 increases forestry LEVs to the extent that this land becomes affordable. Although there is no evidence of this yet, in the longer term the ETS might have an impact on land prices.

4.2. Choice of silviculture

The focus of this paper is on the radiata pine clearwood regime — this has been the regime implemented by a majority of small-scale owners responsible for afforestation in the 1990s. Results indicate that less intensive regimes produce higher LEVs than the clearwood regime with carbon trading and prices over $10/t CO_2. As carbon price increases regimes that produce more biomass become preferred and log production becomes relatively less important. However these regimes have increased risk:

- Stumpage revenues are lower and less able to offset the cost of purchasing carbon units for surrender.
- If the carbon market collapses owners will be left with a relatively low value crop.

4.3. Carbon price risk

The cashflow risk associated with the need to purchase carbon units for surrender when carbon stocks decrease has been identified as a deterrent for afforestation. The forest owner's option to defer harvesting until carbon prices are lower may help to reduce this risk. There may also be financing opportunities or the development of financial instruments to hedge this risk although long forestry time horizons may make the cost of these prohibitive.

It could be argued that if carbon prices are high enough then the forest owner may not want to harvest anyway and would instead focus on a no-harvest carbon forestry regime. However there are dangers of excessive stand mortality in over-stocked stands with subsequent reductions in carbon stocks triggering the need to surrender units.

This paper has identified options for managing carbon price risk. For both the stand-level and estate-level analyses we have generated risk-return trade-off curves (Figs. 9 and 11). These show that carbon price risk can be mitigated. However there is a cost in doing so. At the estate level the scenarios that delay planting all area immediately have a high opportunity cost. This arises because the LEV of afforestation greatly exceeds the assumed land cost of $3000/ha.

The estate-level options that target a normal forest effectively use carbon to finance development of a production forest. Once a normal forest is achieved the forest is neither a carbon sink nor a source. Although there is no ongoing revenue from carbon, revenues from logs are received each year from the 40 ha that is harvested.

5. Further work

5.1. Interaction with log prices

Log prices have been treated here as being fixed. More detailed analysis is warranted with variable log prices. In particular the interaction between log prices and carbon prices is important to fully evaluate the risk associated with carbon forestry. Further work is planned to analyse the risk of stumpage revenues not being large enough to offset the cost of carbon units for surrender at the time of harvest. This work will take into account the option that the forest grower has to defer harvest if the conditions in the log and carbon markets are unfavourable.

5.2. Growth of old stands

The maximum rotation age evaluated for radiata pine in this analysis is 50 years. Fig. 6 indicates that the optimum rotation age can exceed 50 years with high carbon prices. The limit of 50 years was used because of concerns about growth model performance beyond this age. The focus of radiata pine growth modelling in New Zealand has been on thinned stands at ages less than 30 to 40 years.

The ETS creates the need for a better understanding of stand dynamics at older ages, particularly for the high stocking stands favoured by the ETS. A database of permanent sample plot data from such stands has been collated and work is proposed to provide a model that would allow growth and mortality, and hence carbon stocks, to be more reliably estimated for stands at ages beyond 50 years. This will allow an evaluation of older rotation ages and also identify the conditions under which stands might never be harvested.

Acknowledgements

The initial work reported here was undertaken by Final Year School of Forestry students: Clare Andrews, Cameron Branch, Rebecca Coles, Blair Cooper, Tim Crone, Joseph Dakin, Hamish Dennis, Leslie Dowling, Cameron Eyre, Sally Haddon, Josh Lee, Jamahl Mannan, William Marshall, Sarah Orton, Daniel Phillips, Lawrie Scott, Aaron Smith, Cong Xu, and Chen Yang.

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