Ministry for Primary Industries
Manatū Ahu Matua

Impacts of carbon prices on forest management

MPI Technical Paper No: 2019/13

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ISBN No: 978-1-99-000842- (online)
ISSN No: 2253-3923 (online)

September 2019

New Zealand Government

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Contents

		Page
1	**Executive Summary**	**1**
2	**Introduction**	**3**
3	**Approach**	**5**
3.1	Afforestation	5
3.2	Forest management	7
3.3	Deforestation	9
3.4	Wood availability scenarios	10
3.5	Limitations	11
4	**Findings**	**12**
4.1	Afforestation	12
4.2	Forest management	15
4.3	Deforestation	28
4.4	Wood availability scenarios	28
5	**Concluding remarks**	**31**
6	**References**	**32**
7	**Appendix**	**33**

1 Executive Summary

- MPI has requested an analysis of the impact of alternative ETS accounting proposals under different carbon prices on:
- Afforestation rate
- Rotation length
- Deforestation

Further it has asked for wood availability forecasts showing the combined effects of the impact of carbon price on these activities.

The alternative ETS accounting approaches evaluated are:
- The status quo with the following strategies:
  - Selling all carbon
  - Selling only safe carbon
- Averaging based on:
  - Nominated rotation length (i.e. carbon is received and sold up to the average for the intended rotation age). This is not an option under consideration by MPI but was included to provide a basis of comparison.
  - Realised rotation length (i.e. carbon is sold up to the average for the intended rotation age up to age 28 but carbon is only received up to the average for older ages after the age is attained).
  - Realised rotation length but with 5 year bands
  - Fixed 28 year rotation length (i.e. regardless of harvest age carbon is calculated using the average for 28 years).

The base afforestation model developed by Manley (2017a) was tested against new planting data for 2016 to 2018. New planting in 2017 and 2018 has been at about 60% of that forecast by the model. Consequently forecasts were made assuming both 100% of afforestation model estimates and 60% of afforestation model estimates. A feedback loop was included into the model to allow for forestry being a land price-setter rather than a price-taker.

The forecast afforestation rate is very sensitive to carbon price as well as log price and land price, which were set to the average for the last two years (i.e. 2017 and 2018). At carbon prices beyond $10/NZU, it is estimated that averaging will result in at least 50% more afforestation than current ETS settings.

The impact of carbon price on optimum rotation age was evaluated for pruned and unpruned regimes across nine combinations of site quality (high, medium, low) and harvest difficulty (easy, moderate, hard). It was found that:
- Optimum rotation age is particularly sensitive to carbon price under the sawtooth and average (nominated) approaches. The maximum modelled rotation age of 70 years is reached sooner on the worst site and later on the best site.
- Average (realised) and average (realised) with 5-year bands have similar relationships between optimum rotation age and carbon price. Results for the safe approach are generally similar to these two approaches.
- Using a fixed average for 28 years makes optimum rotation age insensitive to carbon price.

Further analysis found that the impact of carbon price on rotation age is most pronounced:
- On hard harvesting sites.
- At low log prices.
- At low discount rates.

Deforestation estimates were derived from the results of an earlier survey (Manley 2018). Although replanting is already intended in most cases under a safe carbon trading approach, the expectation is that averaging will reinforce the likelihood of replanting following harvesting because deforestation under averaging will require the surrender of more units.

Wood availability forecasts for radiata pine at different carbon prices showed:

- Safe approach – an increase in carbon price causes an increase in afforestation and a delay in harvest.
- Average (nominated) approach – although an increase in carbon prices causes an increase in afforestation the key feature is the delay in harvest caused by the increase in optimum rotation age.
- Average (realised) approach – although similar in general pattern to the safe approach, the level of afforestation is higher.
- Fixed average for 28 years – this has the same level of afforestation as the average (realised) approach but with no delay in harvest as carbon price increases.

2 Introduction

Background
A review of the New Zealand Emissions Trading Scheme (ETS) concluded in the middle of 2017. The major forestry issues identified in that review were that financial risk, reporting requirements and complex calculations associated with accounting for emissions at harvest, reduce incentives to enter the ETS and establish new forests. From 2021 onwards the current ETS forestry approach will also not align with the "averaging" accounting approach used to determine the contribution New Zealand forests make towards our 2030 target. Ongoing significant misalignment could undermine the ability of the ETS to help New Zealand meet its climate change targets.

In September 2018, the Government concluded consultation on a suite of ETS forestry proposals to address these issues. The ETS forestry accounting proposals include introducing an "averaging" accounting approach into the ETS for production forestry, accounting for the carbon stored in harvested wood products, enabling participants to undertake "offset planting", and removing the need to surrender emissions units for a temporary reduction in carbon due to an adverse event.

Description
This analysis is required to help inform the Government's ETS forestry averaging accounting decisions. The Government's averaging proposal has many aspects. For some parts of the proposal, the Government has not yet expressed a preference. For example the Government is considering the implications of whether to make the average fixed (default ages based on forest type) or to introduce "age bands" (ages based on forest type and rotation length). This research could help agencies and the Government to come to a preference for this set of proposals.

One of the objectives of the recently concluded ETS review was to ensure the New Zealand economy is well-prepared for a strengthening international response to climate change, and potentially higher carbon prices. This analysis aims to determine the impacts of ETS forestry accounting proposals under different carbon price scenarios, including whether there are any "thresholds" where different behaviour would be expected to occur.

The analysis and report will:

1. Assess the impact of the ETS forestry accounting proposals under different carbon prices on the following activities:
    a. Afforestation rate.
    b. Forest management in particular the impact on rotation length.
    c. Deforestation.
2. Forecast wood availability under the combined effects of 1a, 1b, and 1c. This will allow the government to assess the impacts of forest owners extending harvest to maximise carbon return and the implications this may have on wood supply.
3. Clearly define the barriers to new forest establishment. This will then help the government assess the economic and non-economic barriers to new forest establishment.
4. Clearly set out all the data, assumptions and methodologies used.
5. Carry out sensitivity analysis and provide the limitations.

The analysis will consider

a. Carbon prices of $0, $25, $50, $75, $100, $150, $200 and any price thresholds at which behaviour changes.
b. Current and potential ETS forestry accounting approaches including:
    i. The status quo with the following strategies:
        - Selling all carbon.
        - Selling only safe carbon.
    ii. Averaging with:
        - Variation based on nominated rotation length (i.e. carbon is received and sold up to the average for the intended rotation age). This is not an option under consideration by MPI but was included to provide a basis of comparison.

- Variation for realised rotation length (i.e. carbon is sold up to the average for the intended rotation age up to age 28 but carbon is only received up to the average for older ages after that age is attained).
- Variation for realised rotation length but with 5 year bands (i.e. rotation ages of 21 to 25 years get the average value for 23 years; rotation ages of 26 to 30 years get the average value for 28 years; rotation ages of 31 to 35 years get the average value for age 33 years. For rotation ages beyond 30 years, carbon is received up to the average for age 28, with additional carbon received only as older bands are attained.)
- No variation for rotation length (i.e. regardless of harvest age carbon is calculated using the average for 28 years).

3 Approach

3.1 AFFORESTATION

The base afforestation model (Model 1, Table 1) was developed by Manley (2017a) and used for the 2017 MPI project "Potential impacts of NZ ETS accounting rule changes for forestry - averaging and harvested wood products":

Afforestation rate = a + b * (LEV – d * LMV) + c (LEV – d * LMV) ^{2} (Model 1)

Where $LEV = LEV_{logs} + k * LEV_{carbon}$

LMV = cost of land (from Beef+Lamb New Zealand Economic Service) calculated as the weighted average of North Island Hard Hill land (weight of 2) and South Island Hill land (weight of 1) over the previous two years. The relative weights reflect the proportion of afforestation that has occurred in the two islands since 1996.

LEV_{logs} is the net present value at an 8% discount rate of future forestry costs and revenues in perpetuity. Revenues come from the sale of logs at the time of harvest while costs come from establishing, tending, maintaining, harvesting and managing the tree crop. Log prices are the average for the two years preceding March of the planting year.

LEV_{carbon} is the net present value at an 8% discount rate of future carbon costs and revenues in perpetuity. Revenues come from annual NZU sales while costs come from joining the ETS, compliance costs and harvesting liabilities. Carbon prices are the average for the two years preceding March of the planting year. All property and forest management/maintenance costs are included in LEV_{logs}.

LEV_{carbon} assumes the annual sale of NZUs received up to the 'safe' level of carbon (i.e. the minimum level of carbon that occurs after harvesting when replanting is assumed) with any further NZUs retained to meet surrender obligations at the time of harvesting. This assumption was adopted because it is evident that, to date, the majority of NZ ETS participants have adopted a conservative carbon trading strategy. Although some have a more aggressive strategy and are selling more units, most participants are only selling units that they do not envisage having to repurchase and surrender (Manley 2017b).

The afforestation model quantifies the relationship between the combined afforestation rate of all exotic species and land affordability, calculated as forestry profitability (LEV) adjusted by land value. LEV is calculated for:

- a standard regime,
- radiata pine grown on an average New Zealand ex-farm site (site index = 30.2 m, 300 Index = 29 m3/ha/year),
- with standard costs,
- with carbon stock derived from the Look-up Table for Hawke's Bay/Southern North island, and
- harvested at age 28 years.

The model is essentially a relationship between afforestation rate and log price, carbon price and land value. It was developed using afforestation rate, log price and land value from 1996 to 2015 and carbon price from 2009 to 2015. All inputs to the model are in real $March 2015.

Table 1: Model 1 coefficients fit to data from 1996 to 2015.

Model coefficient	Estimate	p value
a	8.747	0.02
b	0.005580	0.0003
c	1.293e-06	<<0.001
d	0.4343	0.05
k	0.8300	<<0.001

The initial step was to test (and if necessary adjust) the model using data from 2016 to 2018. The model is then be used to estimate afforestation for:

- Carbon prices between $0 and $50.
- Status quo ETS selling only safe carbon (this is the base assumption for the model) and Averaging.

For the averaging approach, carbon is assumed to be claimed until the average carbon stock is reached for the given rotation age. The average calculated is the long-term asymptotic average, here calculated as the average carbon stock for the second rotation.

As a subsequent step the impact of including harvested wood products (HWP) in the calculation of the average level is evaluated. It was assumed that HWP decayed linearly over the 20 years following harvesting. This means that the long-term asymptotic average carbon stock could also be calculated as the average carbon stock for the second rotation but with HWP included.

3.2 FOREST MANAGEMENT

The focus is on the impact of carbon prices on optimum rotation length.

Silvicultural regimes

The base regime is an unpruned regime:

- Plant 1000 stems/ha
- Waste thin to 800 stems/ha at Mean crop height of 8m
- Waste thin to 500 stems/ha at Mean crop height of 14m

A pruned regime is also evaluated:

- Plant 1000 stems/ha
- Prune to 3m at mean crop height 6m
- Waste thin to 800 stems/ha at Mean crop height of 8m
- Prune to 5.5m at mean crop height 11m
- Waste thin to 375 stems/ha at Mean crop height of 14m

Site quality

Three levels of site quality are evaluated (Table 2). The medium site is based on the mean values in the Index Table of the Radiata Pine Calculator for an ex-farm site.

Table 2. Site productivity measures for the three levels of site quality evaluated.

	Low	Medium	High
300 Index	25.8	29	32.6
Site Index	26.3	30.2	32.6
Look-up Table	C/W	BOP	HB/SNI

The sites are not necessarily in the regions indicated by the look-up tables. A low, medium and high look-up table have been chosen and matched with the appropriate site quality. Note that the low and high sites are not extreme sites. Rather they are representative of land with lower and higher site quality.

Harvesting costs

Three different levels of harvest difficulty are evaluated (Table 3).

Table 3. Characteristics of the three levels of harvesting difficulty evaluated.

	Easy	Moderate	Hard
Logging system	Ground-based easy	Ground-based hard	Cable
Roading cost ($/ha)	3000	5000	7000
Distance to public road (km)	5	5	5
Distance to port (km)	75	100	110
Overhead ($/m^3)	5	5	5

The logging costs are derived using the functions provided by Visser (2017) in 'Benchmarking harvesting cost and productivity – 2016 update'. Transport costs are calculated using the Visser Costing Model.

As an example, delivered wood costs (DWC) at age 28 for the unpruned regime on medium site quality are presented in Table 4.

Table 4. Delivered wood cost components at age 28 for the unpruned regime on medium site quality.

	Easy	Moderate	Hard
Logging ($/m^3)	20.69	24.41	37.30
Roading ($/m^3)	3.58	5.97	8.35
Transport ($/m^3)	23.9	29.78	32.13
Overhead ($/m^3)	5.00	5.00	5.00
DWC ($/m^3)	53.17	65.15	82.78

Log Yields
Volume by log grade is estimated for ages 20 to 70 years using the Radiata Pine Calculator.

Carbon stock
For the Measurement (i.e. FMA) approach, carbon stock is estimated using the Radiata Pine Calculator.

For the Look-up Table approach, MPI look-up tables were extended from age 50 to age 70 using an asymptotic curve (Figure 1) based on the assumption that the rate of increase would equal zero at age 100 years.

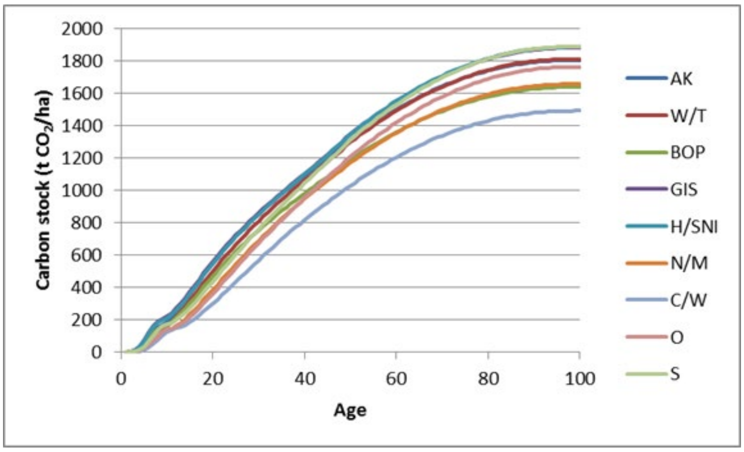

Figure 1. Extended look-up table curves used in this analysis. The existing MPI Look-Up Table provides values for ages 1 to 50. Values for years 51 to 100 are asymptotic extensions of the MPI curves and not based on any additional data. Only values for ages up to 70 years are used in the analysis.

Log prices
Average AgriHQ log prices over the last 12 months are used as the base. Figure 2 shows that current prices are at the high end of prices over the last 6 years. The low points are about 80% of the current prices.

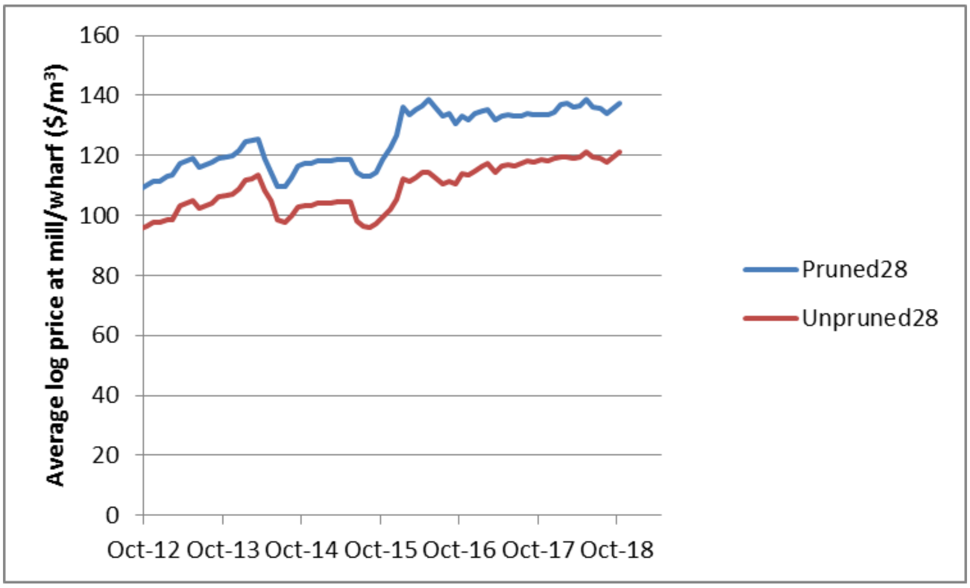

Figure 2. Weighted average log price at age 28 for pruned and unpruned regimes using real ($ Sept 2018) AgriHQ log prices.

3.3 DEFORESTATION

Manley (2018) carried out a survey of the intentions of forest owners following harvest of post-1989 forests. The survey was carried out at a time when carbon price was in the range $20-22/NZU. Overall results (Table 5) indicate that 2.6% of owners intend to convert while another 6.6% plan to sell land in cutover state following harvest, return land to its owner, or are unsure about what they will do. Results were differentiated for ETS participants and non-ETS participants (Tables 6 and 7). ETS participants are more likely to replant and intend replanting 95.2% of area.

Table 5. Summary of intentions after harvesting for all owners [Table 14 of Manley (2018)]

	<40 ha	40-99 ha	100-999 ha	>1000 ha	Total
Replant/ mānuka /regenerate	81.2	81.1	90.9	97.2	90.8
Convert	8.3	5.1	2.0	0.3	2.6
Return/Sell/Unknown	10.5	13.8	7.1	2.5	6.6
Total	100.0	100.0	100.0	100.0	100.0

Table 6. Summary of intentions after harvesting for ETS participants [Table 15 of Manley (2018)]

	<40 ha	40-99 ha	100-999 ha	>1000 ha	Total
Plant/ mānuka /regenerate	88.4	89.4	89.7	100.0	95.2
Convert	1.8	4.0	2.9	0.0	1.4
Return/Sell/Unknown	9.8	6.6	7.4	0.0	3.4
Total	100.0	100.0	100.0	100.0	100.0

Table 7. Summary of intentions after harvesting for non-ETS participants [Table 16 of Manley (2018)]

	<40 ha	40-99 ha	100-999 ha	>1000 ha	Total
Plant/ mānuka /regenerate	79.1	73.3	91.8	90.9	86.5
Convert	10.2	6.0	1.3	0.9	3.9
Return/Sell/Unknown	10.7	20.7	6.9	8.2	9.6
Total	100.0	100.0	100.0	100.0	100.0

An earlier study by Manley (2017b) concluded that "the majority of NZ ETS participants have adopted a conservative carbon trading strategy. Although some have a more aggressive strategy and are selling more units, most participants are only selling units that they do not envisage having to repurchase and surrender." Although replanting is already intended in most cases under a safe carbon trading approach, the expectation is that averaging will reinforce the likelihood of replanting following harvesting (rather than deforestation). Deforestation under averaging will require the surrender of more units than is required if only safe carbon is traded.

Consequently, the assumptions made for deforestation are:

- For a carbon price of $0/NZU a rate of 8.7% is used. This is equal to the convert percentage (3.9%) for non-ETS participants together with half of the return/sell/unknown percentage (half of 9.6%).
- For the safe approach and a carbon price of $25/NZU, a rate of 3.1% is used. This is equal to the convert percentage (1.4%) for ETS participants together with half of the return/sell/unknown percentage (half of 3.4%). For carbon price of $50/NZU and above, a deforestation rate of 1.4% is assumed; i.e. the convert percentage for ETS participants.
- Under the averaging approaches, for carbon price of $25/NZU a deforestation rate of 1.5% is assumed while at carbon prices of $50/NZU and above a rate of 0.7% is used. These rates were calculated as half of the rates used for the safe approach.

3.4 WOOD AVAILABILITY SCENARIOS

The scenarios are for radiata pine only. The ETS has a total of around 236,700 ha of radiata pine. It has a bimodal distribution with the major peak in the mid-1990s and a minor peak in 2011-2012 (Figure 3)

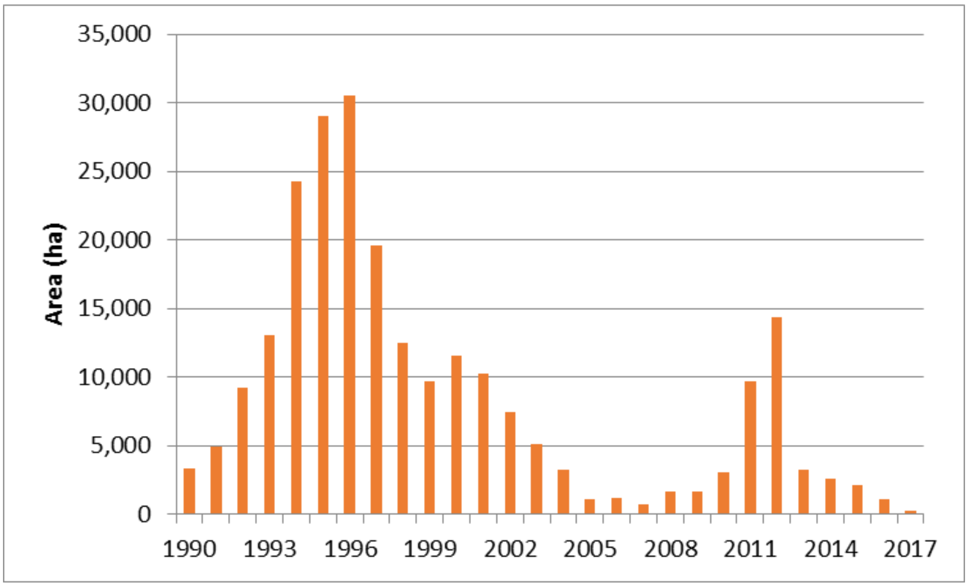

Figure 3. Age-class distribution for radiata pine area entered in the ETS.

Table 8: Percentage of post-1989 area that is not intended for harvest. [Table 16 of Manley (2018)]

	<40 ha	40-99 ha	100-999 ha	>1000 ha	Total
ETS participants	4.1	4.1	2.4	16.6	10.5
Non-ETS participants	1.6	0.3	2.8	1.3	1.9
Total	**2.2**	**2.2**	**2.6**	**11.9**	**6.1**

Manley (2018) found that overall some 6.1% of post-1989 forest is not intended (or is not economic) to be harvested. However, for ETS participants the percentage is higher at 10.5%. This is predominantly area of permanent forest managed for carbon sequestration. Consequently, for wood availability forecasting the ETS radiata pine area was scaled down by 10.5% leaving an area of 211,847 ha. Other assumptions are:

- The existing area is assumed to be 71% pruned and 29% unpruned based on the results of the Manley (2018) survey.
- Replanting is assumed to be 50% into the pruned regime and 50% into the unpruned regime. Again this split is based on the results of the Manley (2018) survey.
- Area is assumed to all be on the medium site quality; i.e. the medium yield tables were used for all area.
- All existing area that has passed the average for a medium site (age 17; i.e. planted in 2000 or earlier) will continue to be harvested at the "Business as Usual" rotation age (i.e. as for the safe approach) because this area has already received more than the average carbon and there is little incentive for a change to averaging. This area will also have the deforestation rate for the safe approach applied to it.
- No existing post-1989 area that is not already entered in the ETS will be entered into the ETS because of the same reason.
- The same general assumptions as used in the MPI/NEFD Wood Availability Forecasts were used. Non-declining yield (total recoverable volume) constraints are applied from 2018 (year 1) to 2034 (year17) and again from 2039 (year 22) on. Yield can reduce by up to 10% per year between 2034 and 2039. For models where optimum rotation age is substantially increased the initial non-declining yield constraint was only applied for the first 14 years; i.e. it was applied to the older stands planted in 2000 or earlier.
- The afforestation model estimates new planting for all exotic species combined. It is assumed that 81% of this area will be radiata pine, the percentage of exotic plantation area in the ETS that is radiata pine.

- Afforestation occurs at the forecast rate for the first 25 years of the forecast period.

3.5 LIMITATIONS

3.5.1 Model extrapolation

Models are used to project the impact of carbon price well beyond the range of historical carbon prices. For example the afforestation model was developed from carbon price data for 2009 to 2015 that had a maximum price (in $2015) of $21.68/NZU.

3.5.2 Land category

It is assumed that there are nine categories of land made up from 3 site qualities (high, medium, low) and 3 harvest difficulties (easy, moderate, hard). Further, when weighted averages are calculated, it is assumed that each of the nine combinations represents an equal proportion of land.

3.5.3 Sawtooth approach

The sawtooth approach is evaluated for its impact on rotation length compared to other options. However the afforestation model forecasts the same new planting for the sawtooth option as for the safe option. Both are options under the current ETS; the status quo. However it is evident (see for example Manley 2017b) that most ETS participants are not adopting it.

3.5.4 Interactions in wood availability forecasting

In generating wood availability forecasts there are interactions between constraints, such as the non-declining yield constraints used, afforestation rate and clearfell age. Consequently the volumes generated are very sensitive to the constraints that are applied.

4 Findings

4.1 AFFORESTATION

4.1.1 Testing afforestation model performance

Table 9 shows the comparison between MPI estimates and afforestation model predictions for 2016 to 2018. MPI estimates have been derived from published results for 2016 and 2017. The 2018 MPI estimate is not an official figure. The Nursery Survey is not complete – the estimates below assume that seedlings planted in 2018 are 10 to 15% higher than 2017 with replanting staying at 44,700 ha.

Table 9: Comparison of model estimates of new land planting in 2006 to 2008 with MPI estimates.

	MPI estimate (000ha)	Model forecast (000ha)
2016	3.5	3.7
2017	4.3	7.0
2018	9 to 11[1]	16.7

It appears that the model is over-predicting afforestation. Reasons for this could be that potential forest growers are:

- awaiting the conclusion of the current ETS review so that they have certainty about the new rules,
- more risk averse regarding the ETS than they were in 2009 to 2011,
- facing constraints on available seedlings, labour and land (as described in section 5),
- transitioning towards the rate of afforestation modelled, rather than there being a sudden shift.

Regarding the second point - in reviewing the afforestation model Manley (2017a) noted that "for the short-term, the model forecast could be optimistic. Some investors who purchased land for afforestation based on the high carbon prices in 2009 to 2011 did not complete their projects when carbon prices subsequently fell. There was concern that the Government did nothing to stop emitters use lower cost Kyoto Protocol units meet their ETS obligations. Given their experience, many forest growers are adopting a degree of 'once-bitten twice-shy scepticism' and waiting to see how carbon prices evolve before committing to additional afforestation."

For subsequent analysis, forecasts were made assuming both:

- 100% of afforestation model estimates; and
- 60% of afforestation model estimates (i.e. calibrated to estimated actual new planting).

The afforestation model was developed using data for which the maximum carbon price was $21.68/NZU ($March 2015). In order to use it to extrapolate the afforestation rate at higher carbon prices it is necessary to allow for forestry becoming a land price-setter rather than a price-taker. Consequently a feedback loop/constraint was developed so that when the combined LEV exceeds the LMV, the value of LMV is increased to the value of the combined LEV. This causes a lower level of afforestation to be forecast at higher carbon prices than that forecast by the unadjusted model.

4.1.2 Afforestation model projections

The forecast afforestation rate is very sensitive to carbon price (Figure 4) as well as log price and land price, which were set to the average for the last two years (i.e. 2017 and 2018). At carbon prices beyond $10/NZU, it is estimated that averaging will result in at least 50% more afforestation than current ETS settings. The afforestation model assumes a 28 year rotation. Consequently it does not differentiate averaging based on realised age and averaging based on nominated rotation age. All four averaging approaches follow the same carbon claiming trajectory for the first 28 years.

[1] Range for 2018 is an estimate using the incomplete information currently available.

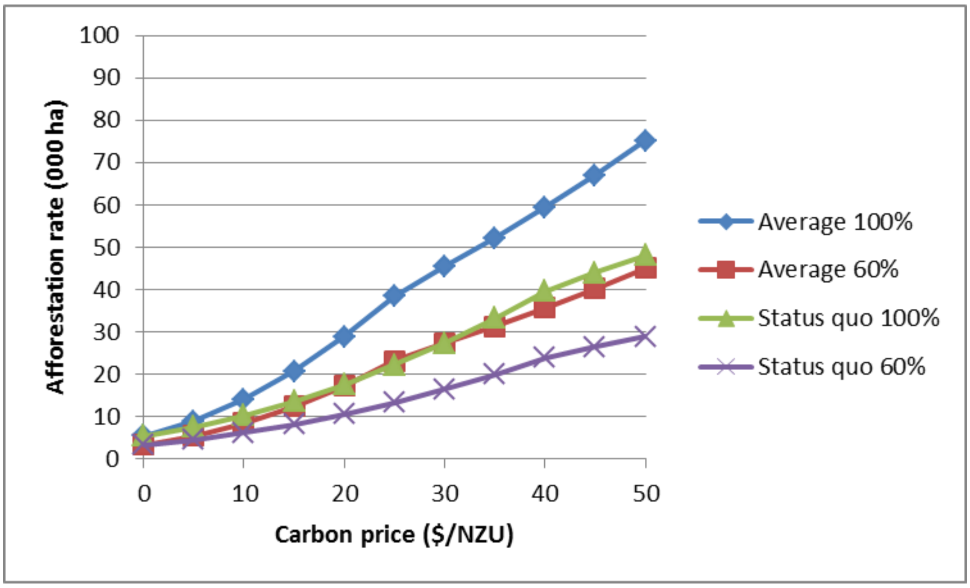

Figure 4. Afforestation rate projections for different carbon prices. Model estimates (100%) and reduced estimates (60%) are presented for the status quo and averaging. Model inputs include average log prices and land price for 2017 and 2018.

4.1.3 Inclusion of harvested wood products

The long-term average varies with the HWP decay function adopted as well as the number of rotations considered. Here, the asymptotic long-term average for a 20-year linear decay function is assumed. The long-term average of 578 t CO_2/ha is reached at age 21 years compared to the situation without HWP where the average level of 426 t CO_2/ha is reached at age 17 years. The inclusion of HWP allows an additional 152 t CO_2/ha to be claimed. Two alternative approaches are considered for when the carbon associated with HWP can be claimed:

- As the forest grows; i.e. the additional 152 t CO_2/ha is claimed between ages 17 and 21 years.
- At the time of harvest by a lump sum or one-off ‘top-up’ of the additional 152 t CO_2/ha.

The inclusion of HWP has a moderate impact on afforestation. The effect is reduced at carbon prices of $25/NZU and above because of the assumed increase in land price. The lump sum approach leads to a lower rate of afforestation because the reduction in LEV caused by the delayed claiming of carbon.

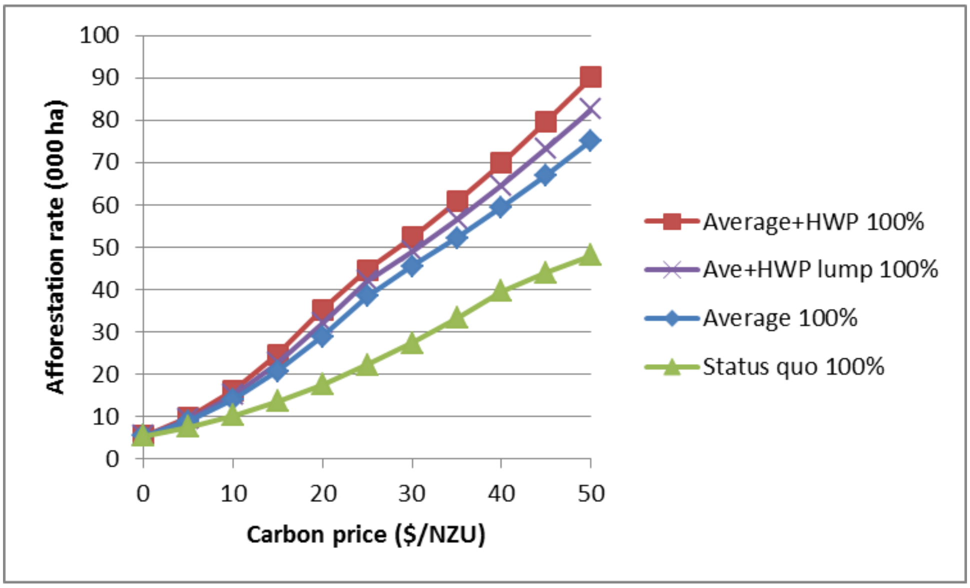

Figure 5. Afforestation rate forecast for different carbon prices. Model estimates (100%) are presented for the status quo, averaging, averaging with HWP, and averaging with HWP as a lump sum at rotation age. Model inputs include average log prices and land price for 2017 and 2018.

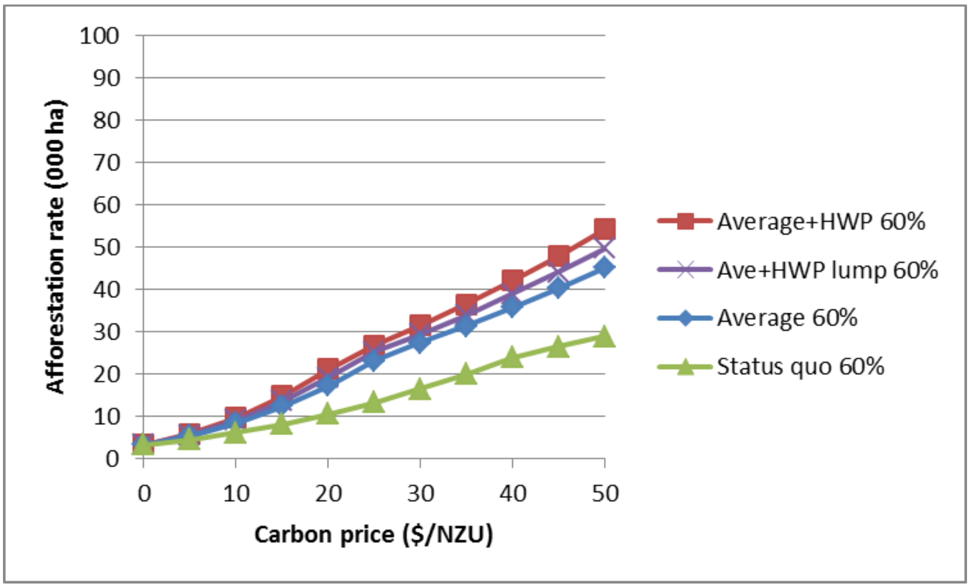

Figure 6. Afforestation rate forecast for different carbon prices. Reduced model estimates (60% of estimates) are presented for the status quo, averaging, averaging with HWP, and averaging with HWP as a lump sum at rotation age. Model inputs include average log prices and land price for 2017 and 2018.

4.2 FOREST MANAGEMENT

4.2.1 Log yields

The combinations of regime and site quality produce a range of Total Recoverable Volume (TRV - Figure 7). Volume at age 28 ranges from 650 m^3/ha for the pruned regime on the low site to 929 m^3/ha for the unpruned regime on the high site.

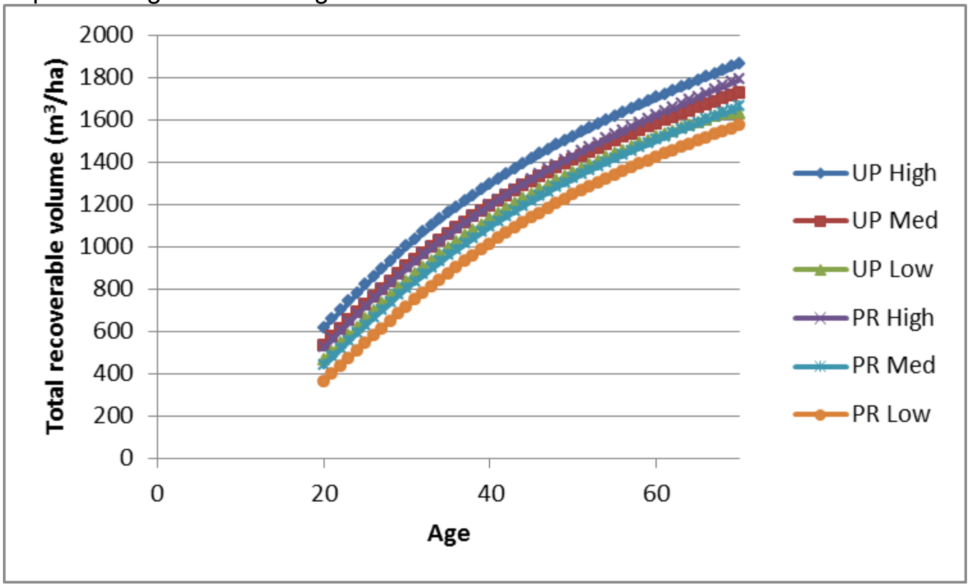

Figure 7. Total recoverable volume for each combination of regime and site quality.

4.2.2 Carbon stock

Carbon stock for each regime/site combination (Figure 8) reflects, as expected, the volume for that combination (Figure 7).

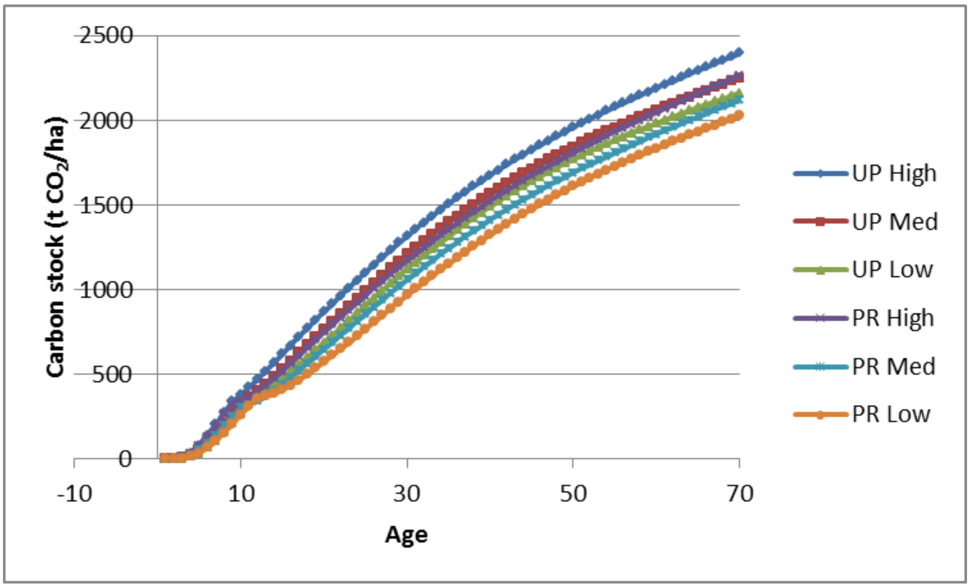

Figure 8. Carbon stock for each combination of regime and site quality.

For a 28 year rotation, the four variations of averaging all follow the same carbon stock trajectory (Figure 9). However differences occur at other rotation ages, particularly older ages. Figure 10 shows how carbon stock trajectories differ for a 40 year rotation. The fluctuation associated with the sawtooth approach is evident in both Figures 9 and 10. Also apparent is the much larger level of carbon earned under averaging compared to the safe approach.

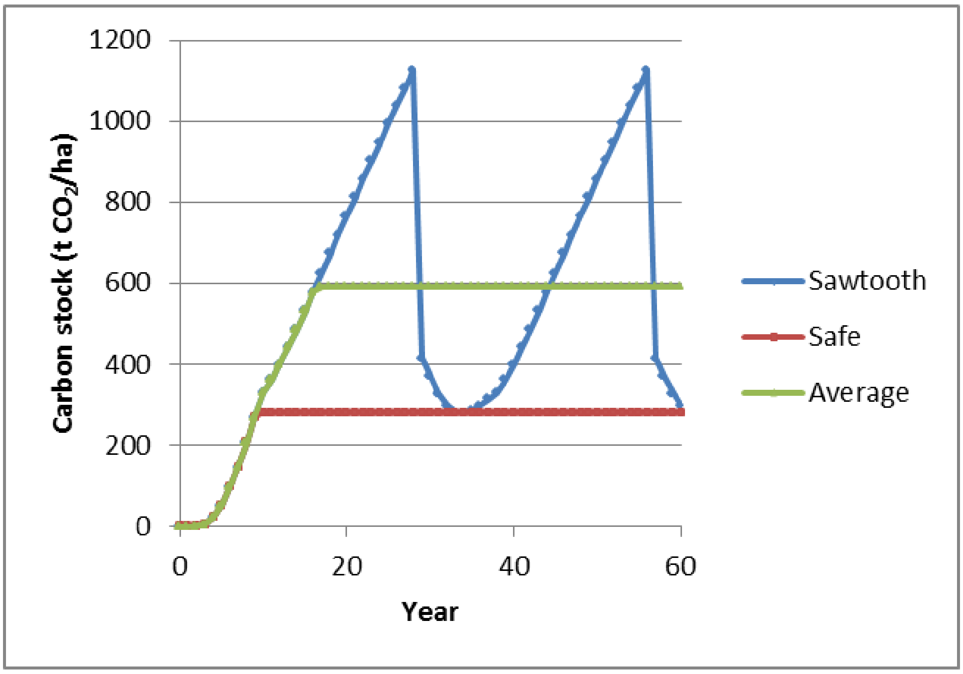

Figure 9. Carbon stock under different ETS accounting approaches for the unpruned regime on a medium site grown on a 28 year rotation.

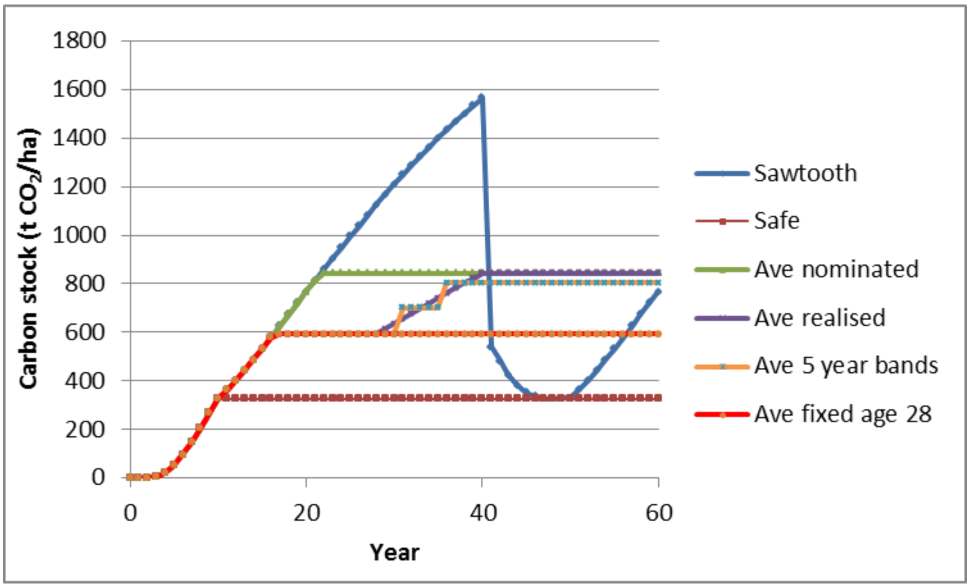

Figure 10. Carbon stock under different ETS accounting approaches for the unpruned regime on a medium site grown on a 40 year rotation.

4.2.3 Optimum rotation age

The impact of carbon price on optimum rotation age is illustrated for the unpruned regime on three different sites:

- High site quality and easy harvesting (Figure 11).
- Medium site quality and moderate harvest difficulty (Figure 12).
- Low site quality and hard harvesting (Figure 13).

Comparison of the three sites illustrates some trends:

- Optimum rotation age is particularly sensitive to carbon price under the sawtooth and average nominated approaches. The maximum rotation age of 70 years is reached sooner on the worst site and later on the best site.
- Average realised and average realised with 5-year bands have similar relationships between optimum rotation age and carbon price. Optimum rotation age increases more on the poorer site.
- The greatest impact for the safe approach is on the median site.
- Using a fixed average for 28 years makes optimum rotation age insensitive to carbon price.

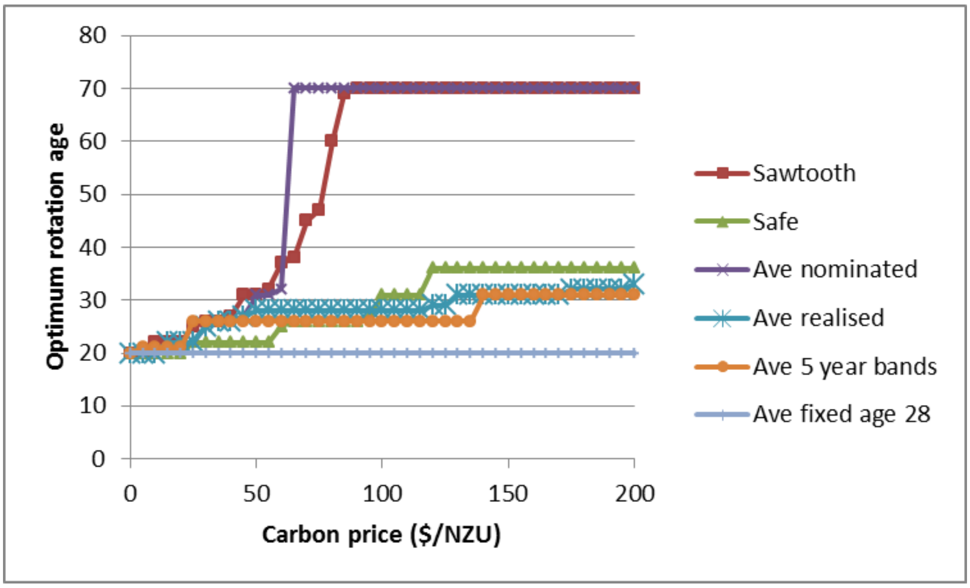

Figure 11. Unpruned regime with high site quality and easy harvesting. Comparison of the impact of carbon price on optimum rotation age for different ETS accounting approaches. Log prices are at 100%; i.e. average for last 12 months.

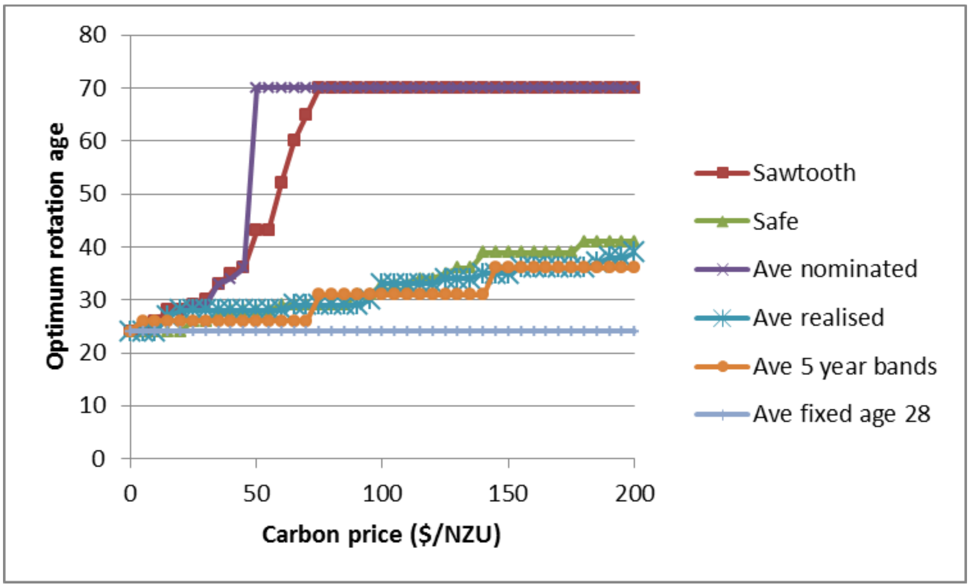

Figure 12. Unpruned regime with medium site quality and moderate harvest difficulty. Comparison of the impact of carbon price on optimum rotation age for different ETS accounting approaches. Log prices are at 100%; i.e. average for last 12 months.

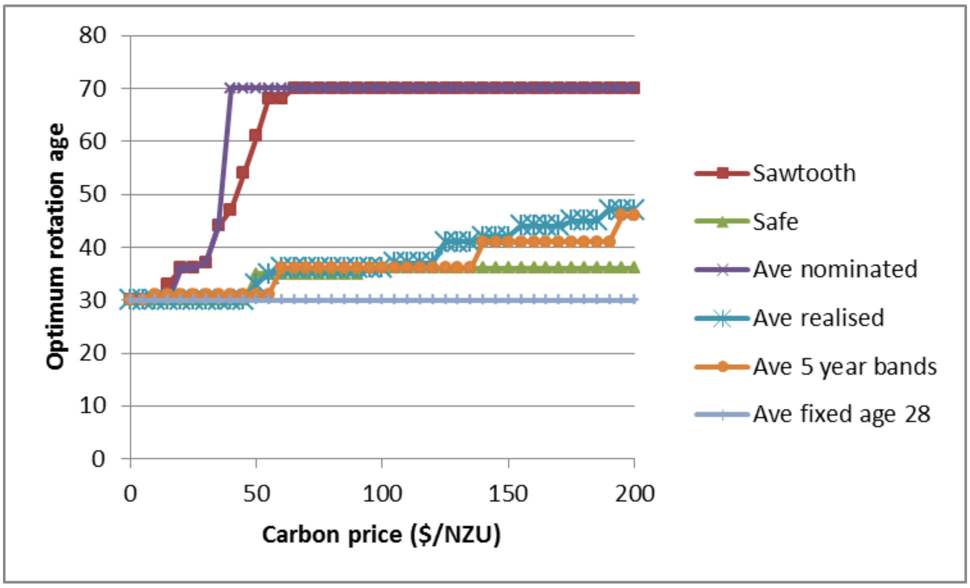

Figure 13. Unpruned regime with low site quality and hard harvesting. Comparison of the impact of carbon price on optimum rotation age for different ETS accounting approaches. Log prices are at 100%; i.e. average for last 12 months.

4.2.4 Effect of log price

Sensitivity to log price is explored by alternatively decreasing and increasing all log prices by 25%. Again results are shown for the unpruned regime on the best (Figure 14), the median (Figure 15) and the worst (Figure 16) of the nine site quality/harvest difficulty combinations.

Reducing log prices causes optimum rotation age to increase faster as carbon price decreases. Conversely increasing log prices causes optimum rotation age to increase slower. The exception is for the fixed 28 year average approach where, as already seen, optimum rotation age is unaffected by carbon price.

A notable feature is the steeper increase in rotation age for the poorer site, compared to the other sites at 75% log prices under the average (realised) and average (realised) 5 year approaches.

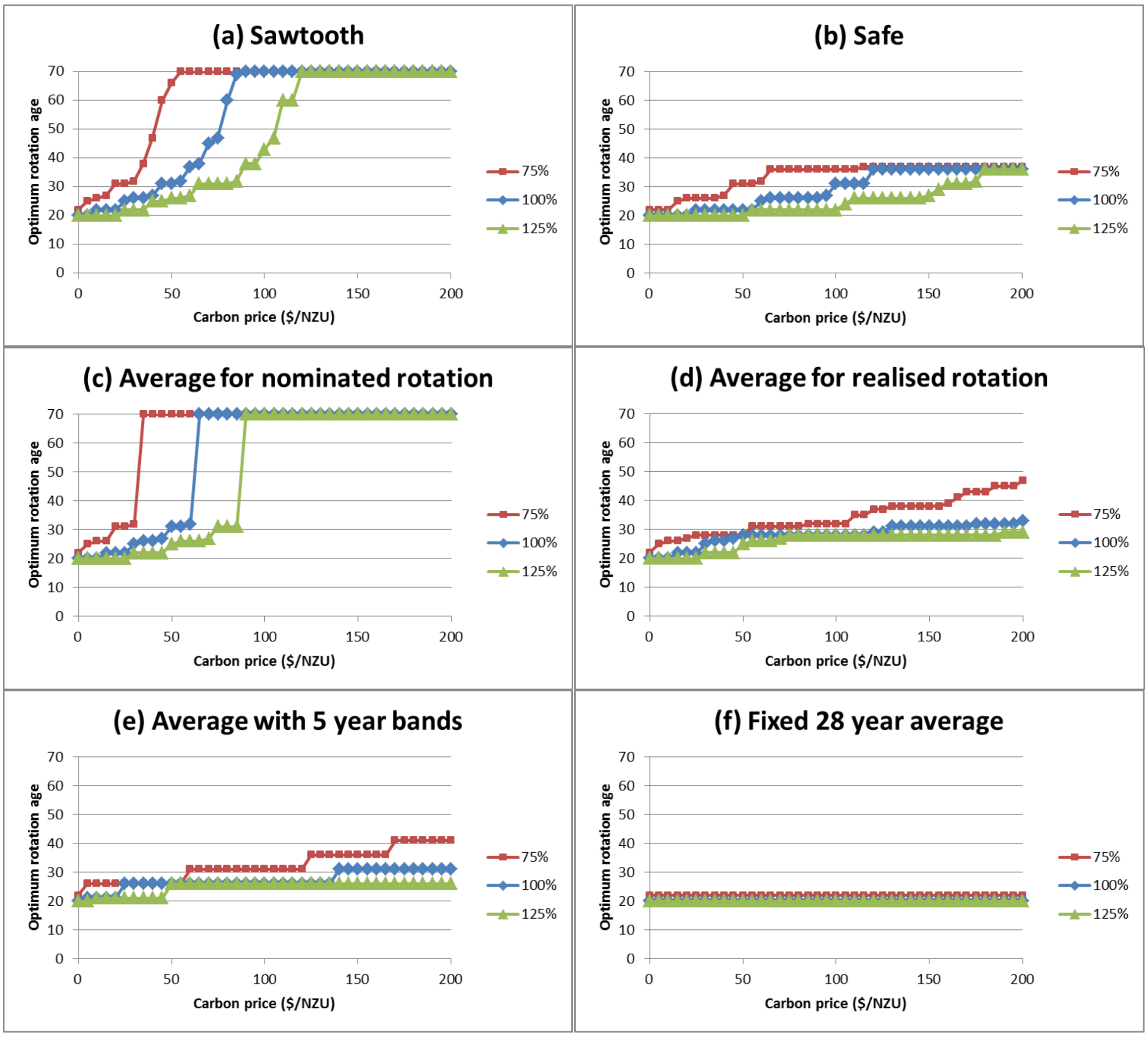

Figure 14. Unpruned regime with high site quality and easy harvesting. Effect of carbon price on optimum rotation age for three different log price levels.

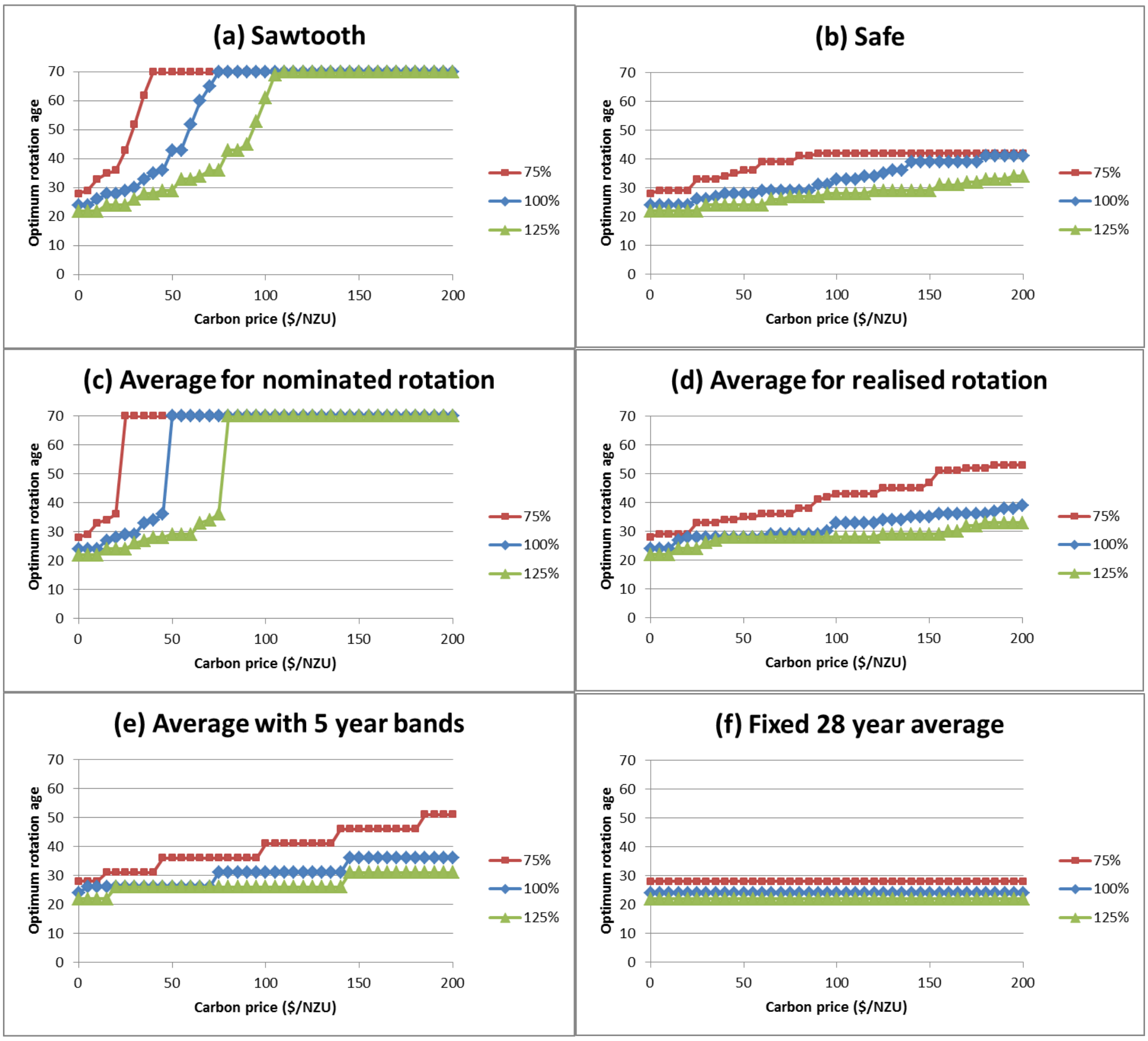

Figure 15. Unpruned regime with medium site quality and moderate harvest difficulty. Effect of carbon price on optimum rotation age for three different log price levels.

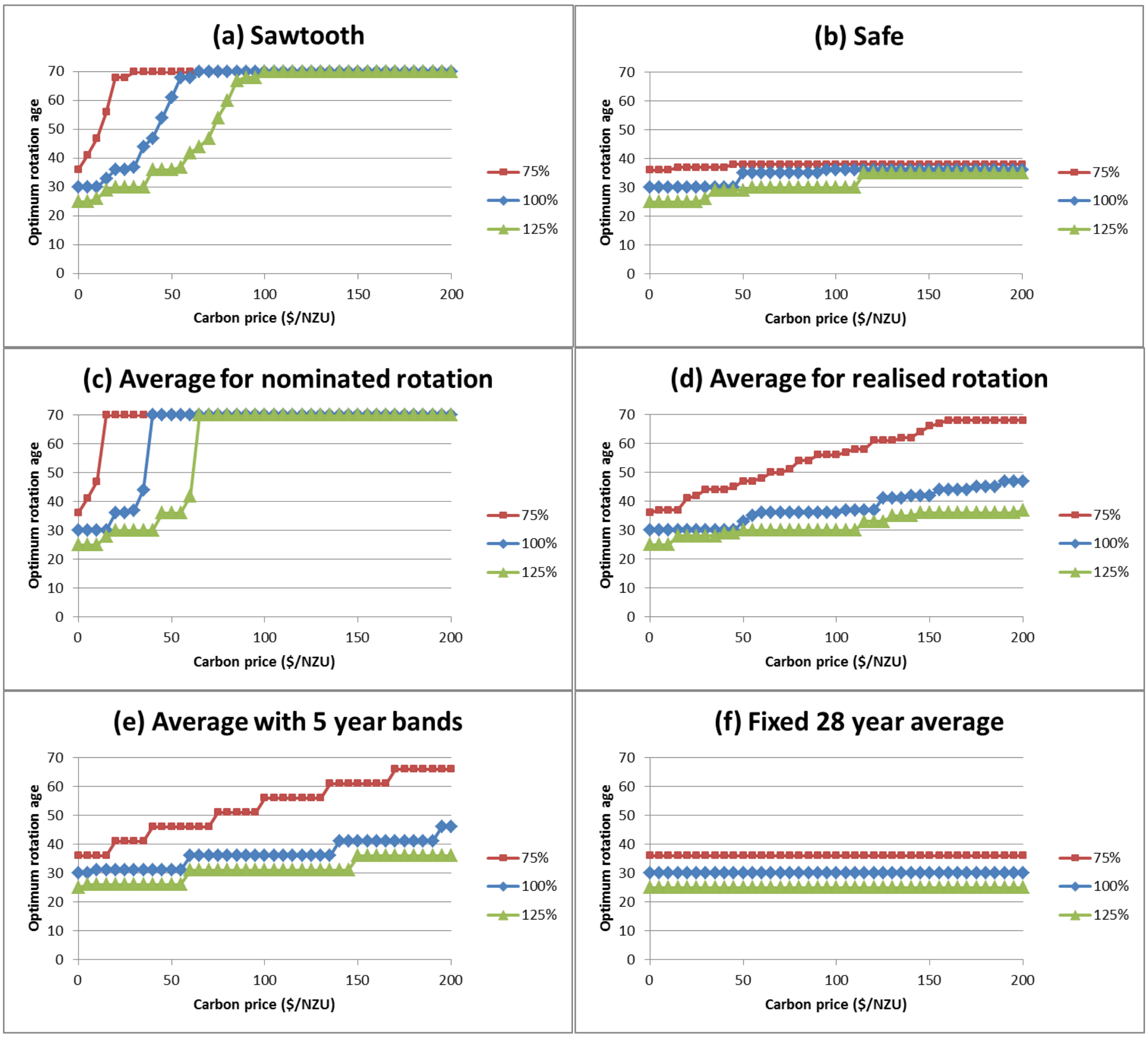

Figure 16. Unpruned regime with low site quality and hard harvesting. Effect of carbon price on optimum rotation age for three different log price levels.

4.2.5 Unpruned regime across all nine site quality/harvest difficulty combinations

Figure 17 shows results together for the unpruned regime on the nine site quality/harvest difficulty combinations. Results are standardised with the y-axis showing the increase in rotation age compared to the "forestry only" (i.e. carbon price = $0/NZU) situation.

Graphs for the safe, average (realised) and average (realised) 5 year approaches show a similar pattern while the sawtooth and average (nominated) approaches also show similar patterns. For these last two approaches there is clustering for the 3 levels of harvest difficulty.

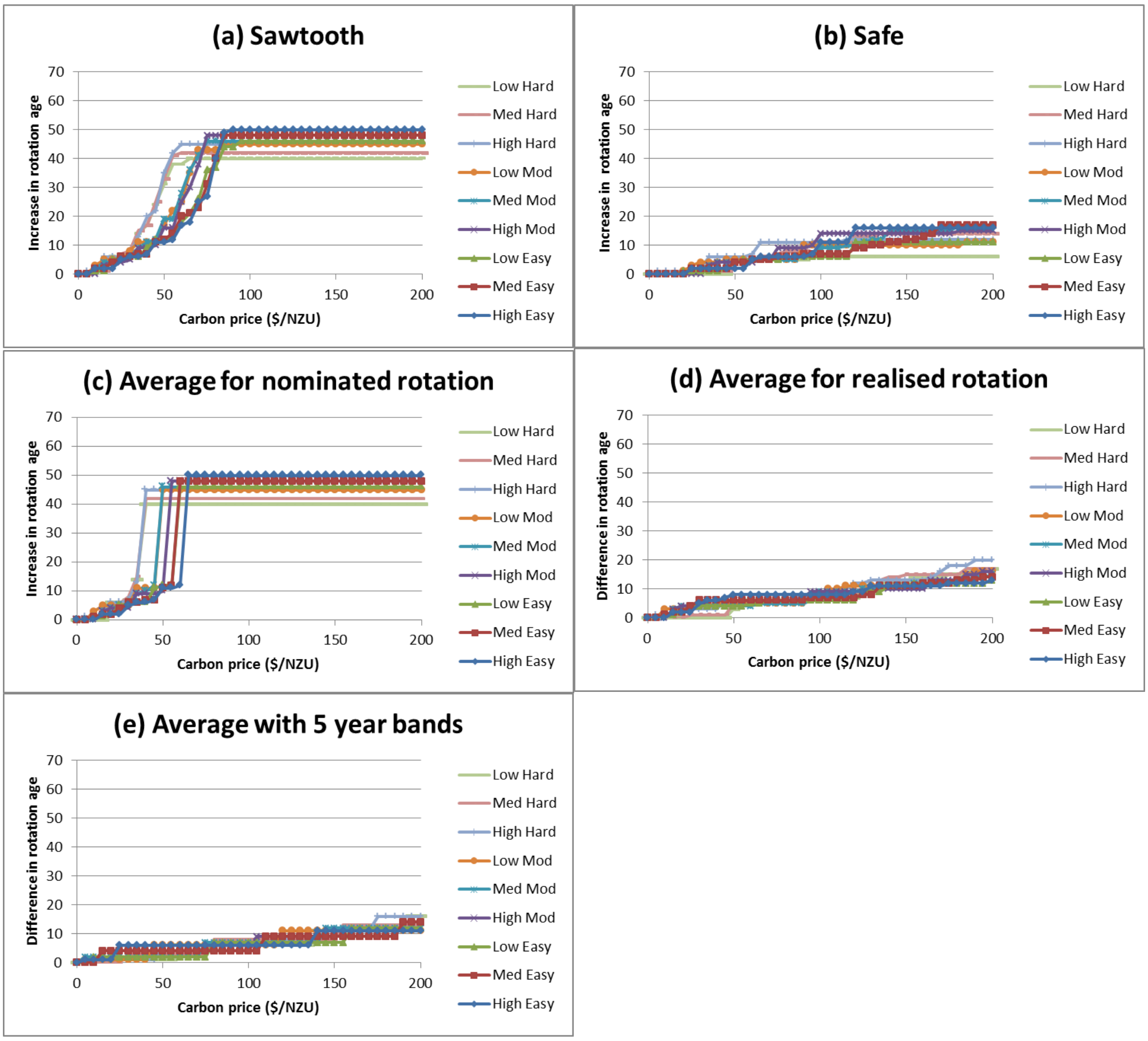

Figure 17. Unpruned regime on nine site quality/harvest difficulty combinations. Increase in rotation age with increasing carbon price for unpruned regime. Log price is at the 100% level (i.e. average for last 12 months).

4.2.6 Pruned regime across all nine site quality/harvest difficulty combinations

Results for the pruned regime (Figure 18) follow a similar pattern to those for the unpruned regime. However for any carbon price, the increase in rotation age is generally less than for the unpruned regime counterpart.

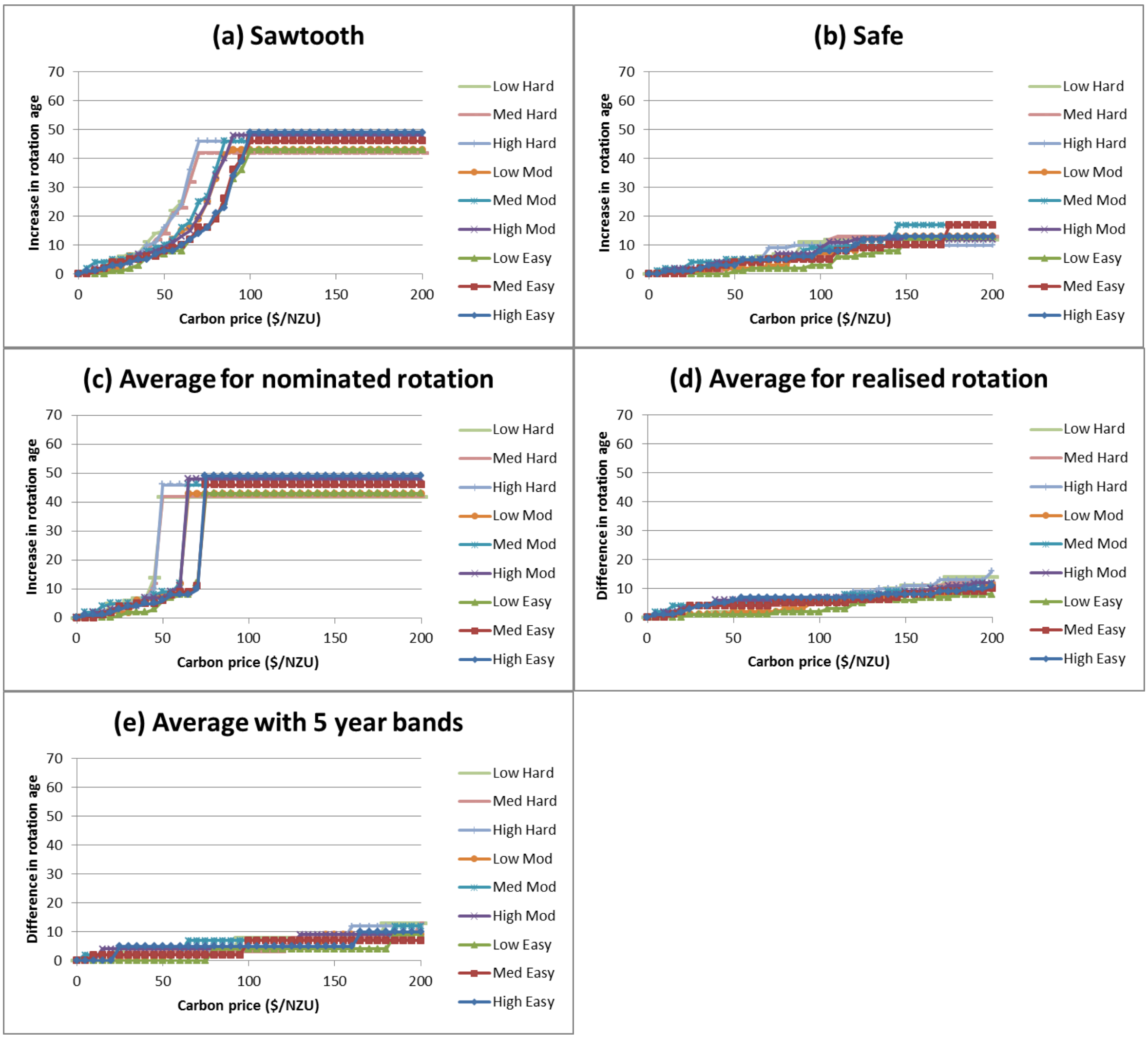

Figure 18. Pruned regime on nine site quality/harvest difficulty combinations. Increase in rotation age with increasing carbon price for unpruned regime. Log price is at the 100% level (i.e. average for last 12 months).

4.2.7 Comparison of different regimes

Overall trends are explored by averaging values across the nine site quality/harvest difficulty combinations (Figure19). Previous results presented have all been under the field measurement approach (FMA). Here results from using look-up tables are also presented. General trends are:

- The increase in optimum rotation age is less when look-up tables are used compared to when the FMA is used.
- Apart from the safe approach, the increase in optimum rotation age is less for the pruned regime compared to the unpruned regime.

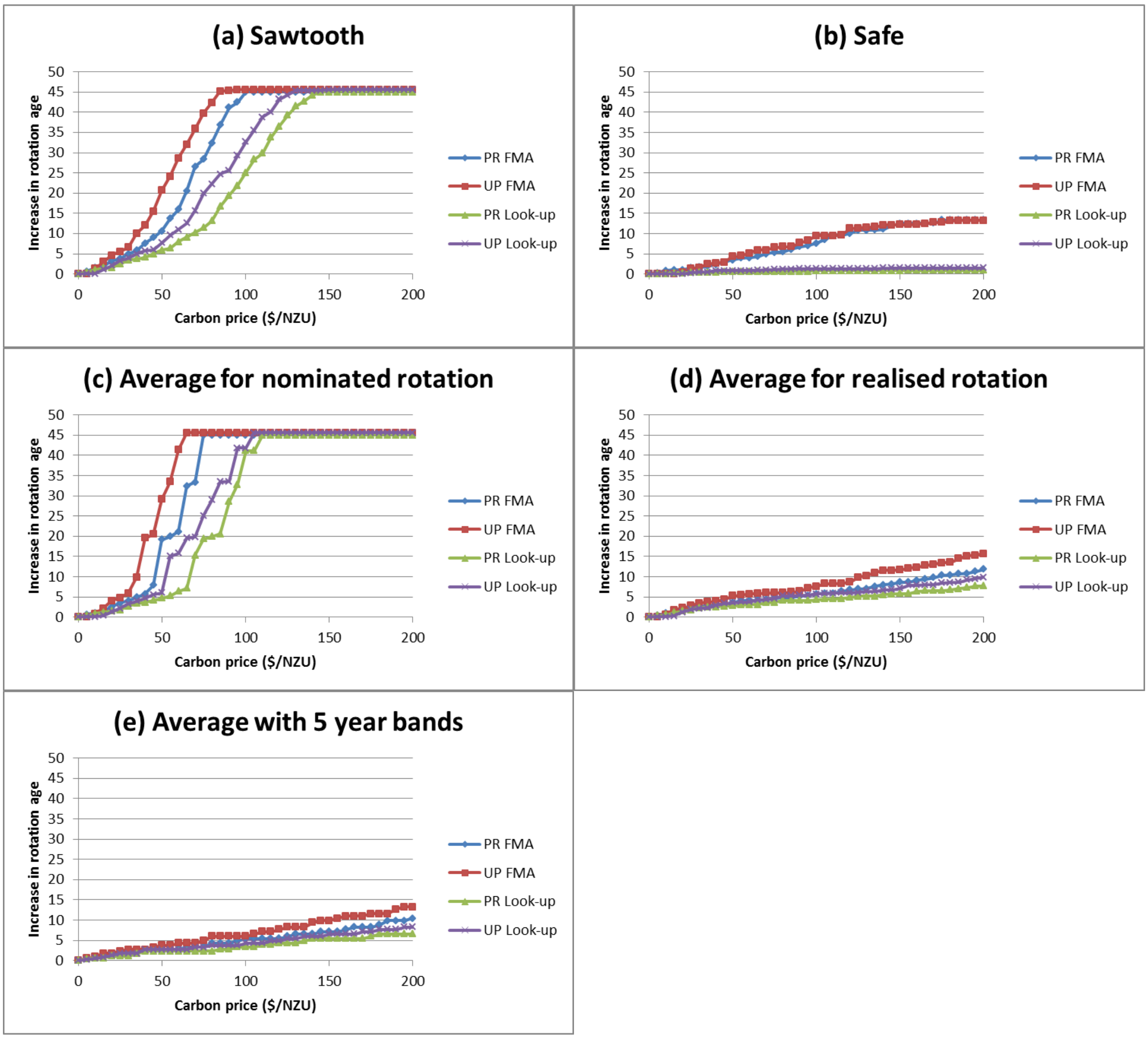

Figure 19. Comparison of results for pruned and unpruned regimes using the FMA and look-up tables. Log price is at the 100% level (i.e. average for last 12 months).

4.2.8 Weighted average

To provide inputs for wood availability forecasting weighted average results are calculated (Figure 20) based on:

- 83% of area in the ETS being accounted under FMA and 17% under look-up tables.
- 50% of future planting being into each of the pruned and unpruned regimes. These are the intentions indicated by the Manley (2018) survey.

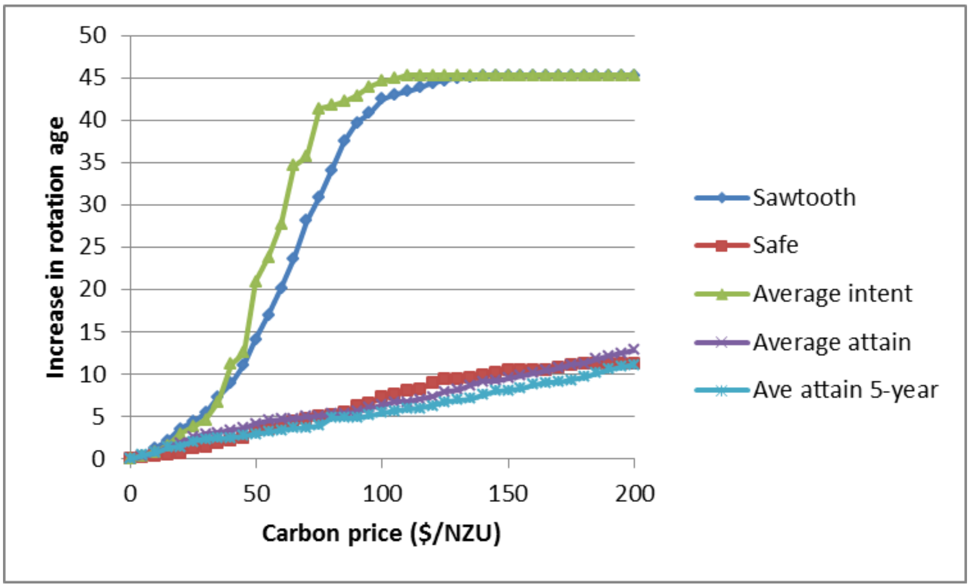

Figure 20: Weighted average results for each ETS accounting approach.

4.2.9 Log price/carbon price interaction

An analysis of the unpruned regime was undertaken to determine, for log prices between 50% and 150% of the current (i.e. last 12 months) price, the carbon price at which optimum rotation age increased by 10 years. Results (Figure 21) confirm that:

- As log price increases, the carbon price required to increase rotation age by 10 years also increases.
- The high sensitivity of rotation age to carbon price for the sawtooth and nominated average approaches.
- The greater sensitivity of rotation age to carbon price on hard harvesting sites.

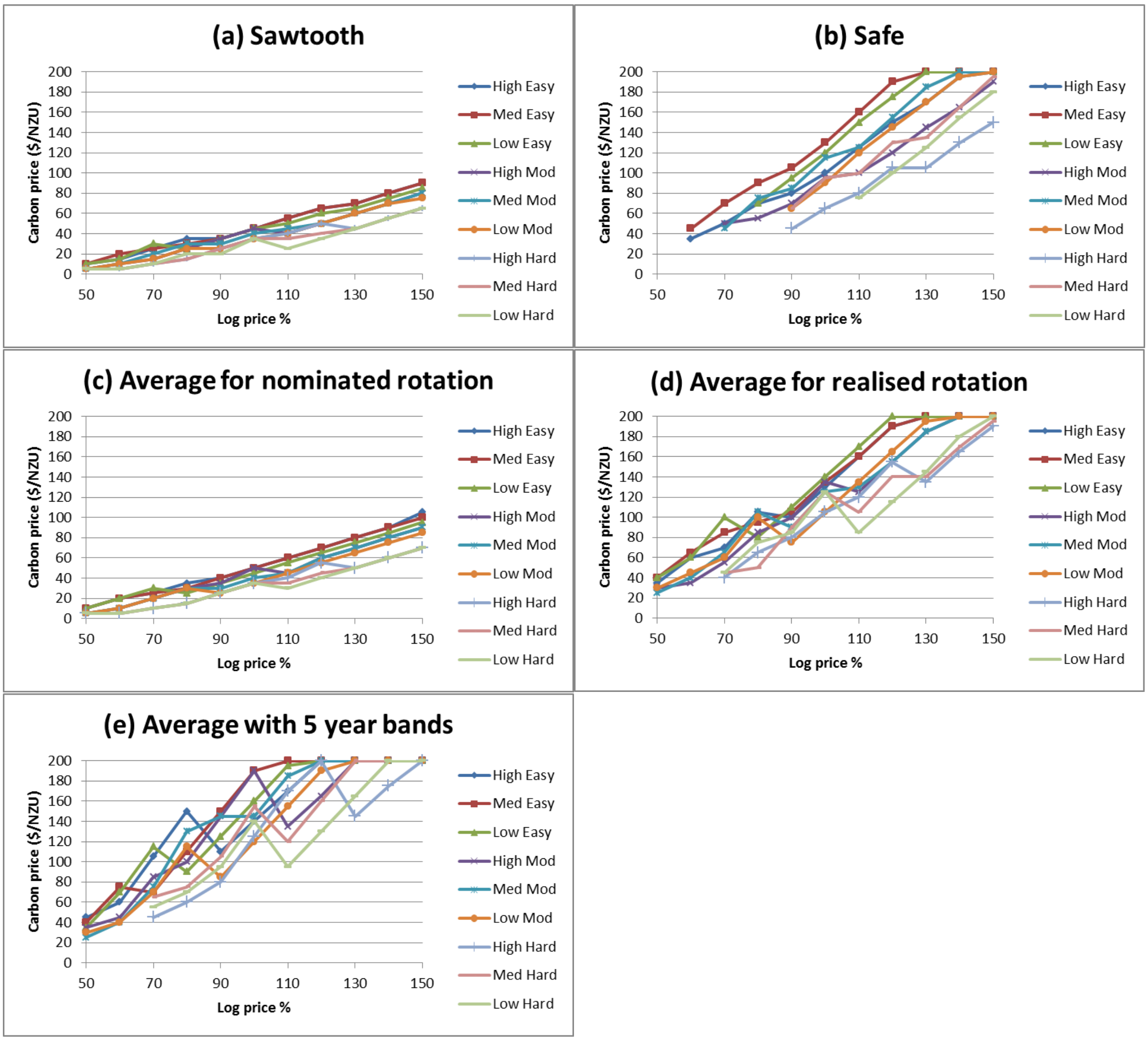

Figure 21. Unpruned regime. Log price/Carbon price combination that causes optimum rotation age to increase by 10 years.

4.10 Sensitivity to discount rate

Sensitivity to discount rate was explored by alternatively increasing and decreasing the base discount rate of 8% by 2% for the unpruned regime with low site quality and hard harvesting; i.e. for the least profitable site. Varying the discount rate had most impact on the average (realised) and average (realised) 5 year accounting approaches (Figure 22).

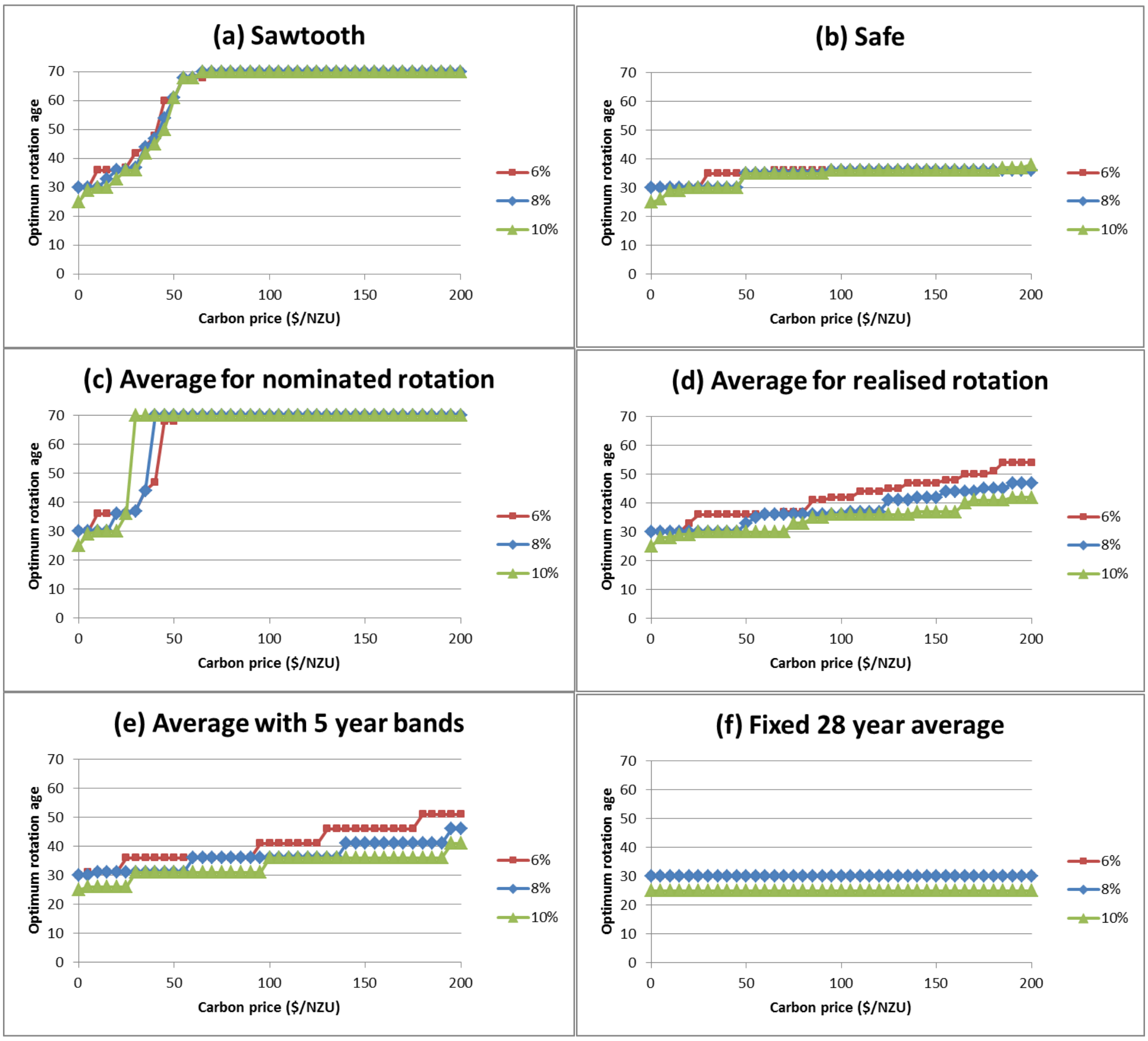

Figure 22. Unpruned regime with low site quality and difficult harvesting. Effect of carbon price on optimum rotation age for three different discount rates. Log price is at the 100% level (i.e. average for last 12 months).

4.3 DEFORESTATION

No modelling was done for deforestation. Rather assumptions were developed for use in the wood availability forecasts. These assumptions were developed in the Approach section 3.3 and are documented below in the Wood Availability Forecasts section 4.4.

4.4 WOOD AVAILABILITY SCENARIOS

The assumptions made for each scenario for radiata pine wood availability forecasting are documented in Table 10. Afforestation is assumed for the first 25 years of the forecast period. The afforestation rates are 60% of that forecast by the afforestation model. Using the 100% afforestation rates form the model would produce similar wood available forecast for the initial 20 to 25 years but with greater volumes in subsequent years.

Table 10. Assumptions made for each scenario for wood availability forecasting (radiata pine only)

Safe							
Carbon price ($/NZU)	0	25	50	75	100	150	200
Afforestation (ha/year)	2600	10800	23400	23400	23400	23400	23400
Deforestation (%)	8.7	3.1	1.4	1.4	1.4	1.4	1.4
Increase in rotation age (years)	0	1	3	5	7	10	11
Age carbon claimed until	17	17	18	19	20	21	22
Average (nominated)							
Carbon price ($/NZU)	0	25	50	75	100	150	200
Afforestation (ha/year)	2600	18700	36500	36500	36500	36500	36500
Deforestation (%)	8.7	1.5	0.7	0.7	0.7	0.7	0.7
Increase in rotation age (years)	0	4	21	41	45	45	45
Age carbon claimed until	17	19	26	33	34	34	34
Average (realised)							
Carbon price ($/NZU)	0	25	50	75	100	150	200
Afforestation 60% (ha/year)	2600	18700	36500	36500	36500	36500	36500
Deforestation (%)	8.7	1.5	0.7	0.7	0.7	0.7	0.7
Increase in rotation age (years)	0	3	4	5	6	10	13
Age carbon claimed until	17	18	19	19	19	21	23
Fixed 28 year average							
Carbon price ($/NZU)	0	25	50	75	100	150	200
Afforestation 60% (ha/year)	2600	18700	36500	36500	36500	36500	36500
Deforestation (%)	8.7	1.5	0.7	0.7	0.7	0.7	0.7
Increase in rotation age (years)	0	0	0	0	0	0	0
Age carbon claimed until	17	17	17	17	17	17	17

The results for each of the four accounting approaches are different:

- Safe approach – an increase carbon price causes an increase in afforestation and a delay in harvest (Figure 23).
- Average (nominated) – although an increase in carbon prices causes an increase in afforestation the key feature is the delay in harvest caused by the increase in optimum rotation age (Figure 24).
- Average (realized) – although similar in general pattern to the safe approach, the level of afforestation is higher (Figure 25).
- Fixed 28 year average – this has the same level of afforestation as the average attain approach but with no delay in harvest as carbon price increases (Figure 26).

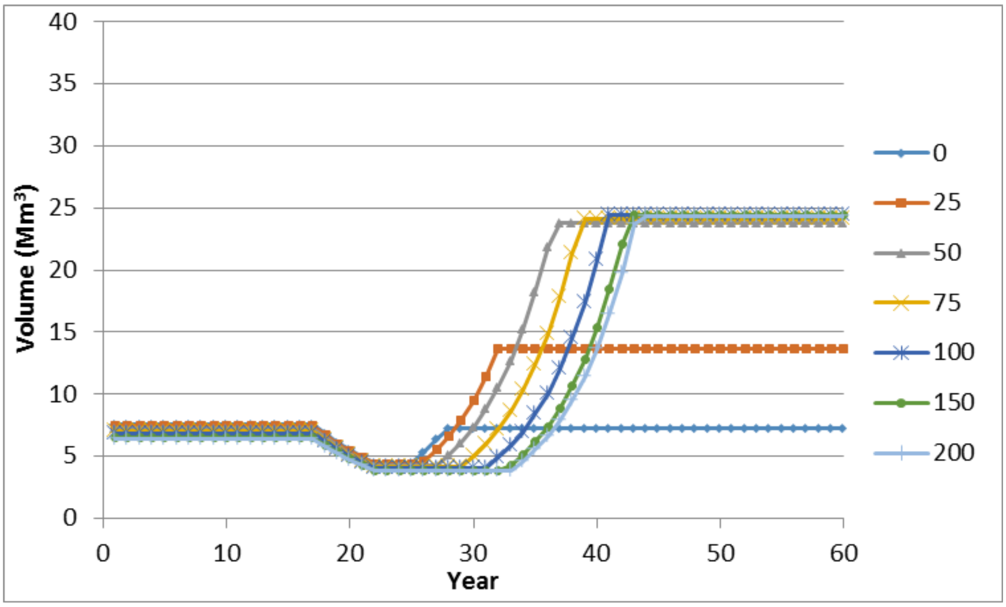

Figure 23. Wood availability forecasts for radiata pine under the safe approach. The legend indicates the carbon price for each scenario.

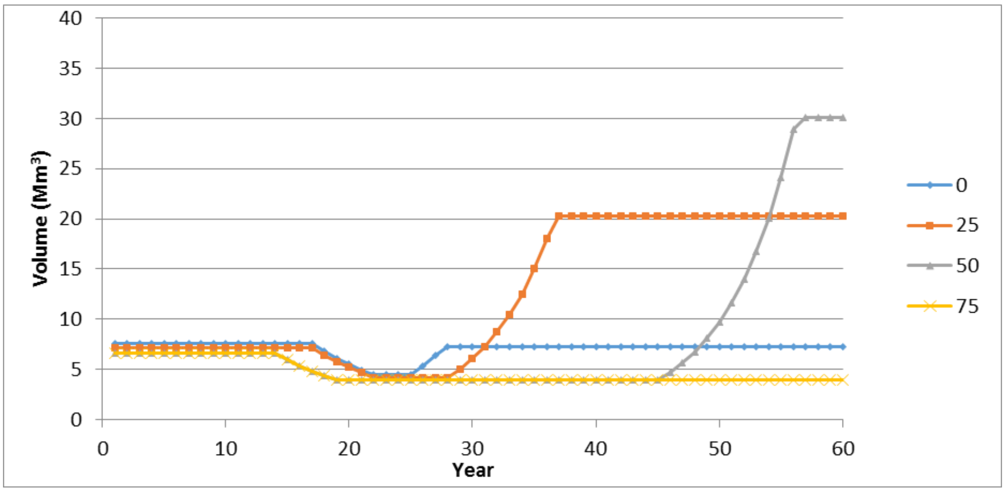

Figure 24. Wood availability forecasts for radiata pine under the average (nominated) approach. The legend indicates the carbon price for each scenario. The result is the same as for $75/NZU with higher carbon prices.

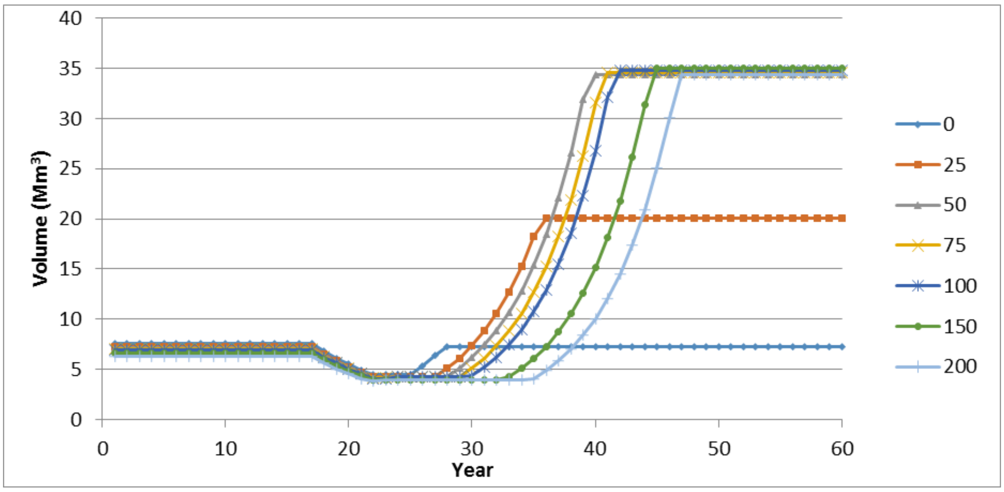

Figure 25. Wood availability forecasts for radiata pine under the average (realised) approach. The legend indicates the carbon price for each scenario.

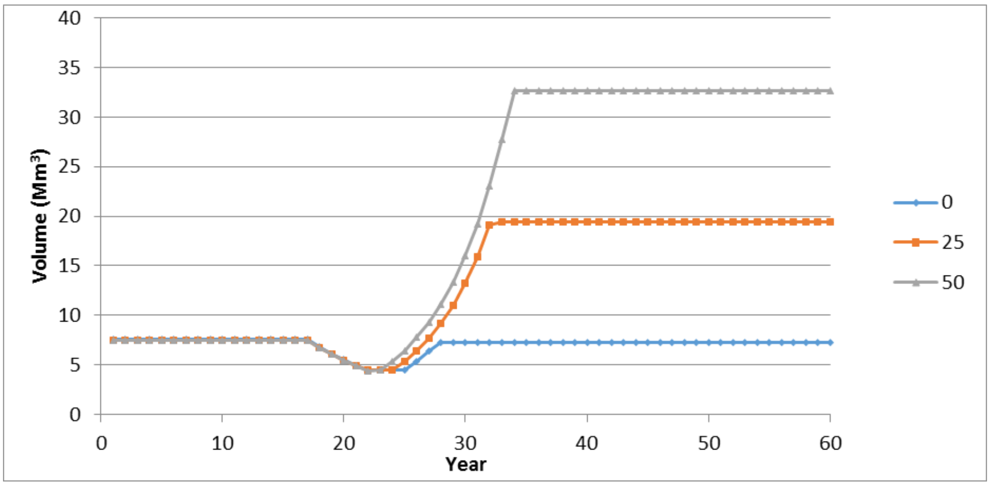

Figure 26. Wood availability forecasts for radiata pine under the fixed 28 year average. The legend indicates the carbon price for each scenario. The result is the same as for $50/NZU with higher carbon prices.

5 Concluding remarks

Barriers to new forest establishment.

The analysis has clearly shown that increasing carbon price provides a strong incentive for afforestation. Even at a carbon price of $25/NZU (and assuming average log prices and land value for the last two years) an afforestation rate of over 13,000 ha/year is estimated under the status quo, increasing to over 23,000 ha/year if the averaging approach is allowed. There are potential barriers to afforestation, in particular the availability of:

- Seed from seed suppliers,
- Seedlings from nurseries,
- Labour (planting crews), and
- Suitable land

Government advice on the area available for planting (September 2018) is that about 2 million hectares is potentially suitable for planting production forest of various species. The issue is the cost of this land.

Provision for offset planting for conversion of post-1989 forest land.

The 2012 amendment to the Climate Change Response Act allowed deforestation liabilities to be avoided when pre-1990 forest land was converted through offset planting a carbon-equivalent area of land. The uptake or interest in a post-1989 offsetting rule would vary depending on the number of units received and safe carbon level.

Assuming crediting of a new forest in the first year established, land conversion under averaging will require the surrender of more units than is required if only safe carbon is traded under current accounting settings. Consider the example of an unpruned stand grown on:

- post-1989 forest land of medium site quality,
- with carbon stock derived from the Look-up Table for Bay of Plenty,
- and harvested at age 28 years.

Land conversion after harvesting under the averaging approach would require the surrender of 592 NZU/ha compared to 282 NZU/ha under the safe approach available within the status quo. The higher level of units that would need to be surrendered under averaging imposes a substantial cost and hence barrier to conversion. Consequently, the implementation of averaging in the ETS will likely ultimately lead to requests for the offset planting provision to be allowed for post-1989 forest land as well as pre-1990 forest land.

However for existing forests registered in the ETS and planted in the 1990s, the cost and benefit for taking up any post-1989 offsetting rule would be different. For the majority of existing ETS registered forests the cost of land purchase and establishment would likely out-weigh the cost of simply surrendering all units received. Given that, in the main, forests planted in the 1990s have nil or little safe carbon and at the point of harvest there is a requirement to surrender a similar number of units whether harvesting or deforesting, there would be no advantage in having a post-1989 offset.

For those forests planted more recently where owners received safe carbon, the option of post-1989 offset planting will have more benefit. However, because the level of safe carbon is less than the level achievable under averaging, post-1989 offset planting would only have limited benefit. Consequently, there is unlikely to be strong demand for a post-1989 offsetting rule until forests for which carbon has been claimed under an averaging approach start to mature.

6 References

Manley, B. 2017a. Forecasting the effect of carbon price and log price on the afforestation rate in New Zealand. Journal of Forest Economics.

Manley, B. 2017b.Potential impacts of NZ ETS accounting rule changes for forestry – averaging and harvested wood products. MPI Technical Paper No. 2017/.

Manley, B. 2018. Intentions of forest owners following harvest of post-1989 forests. MPI Technical Paper No. 2018/55.

Visser, R. 2017. Benchmarking harvesting cost and productivity – 2016 update. Forest Growers Research harvesting Technical Note HTN09-08.

7 Appendix

Government advice on the area available for planting, September 2018

“Mapping analysis by Te Uru Rākau estimates that up to 3.3 million hectares of low-producing pasture land may be suitable for new afforestation, including:

- about 2 million hectares potentially suitable for planting permanent forest or production forest of various species; and
- another 1.3 million hectares that is only suitable for planting new permanent forest, including steep and/or erosion-prone land.

The total amount of this land that could be planted will depend on a number of factors, for instance commercial viability, alternative land use choices, regional and district plan rules, and Emissions Trading Scheme eligibility.

The estimate is based on the physical and climatic attributes of existing farmland, and excludes higher-producing land, existing forest, and land in other established uses including pastoral lease and conservation.

Table A1 shows the results of our analysis. Column A shows the estimated area only suitable for permanent, non-harvested forest, such as plantings for erosion control, biodiversity, carbon farming and amenity. Column B shows the estimated area which is potentially suitable for production forestry (including both exotic and indigenous species) as well as permanent forest.”

Table A1. Wood availability forecasts for radiata pine under the safe approach. The legend indicates the different carbon prices for each scenario

Region	***Potential area only suitable for new permanent forest (ha)***	***Potential area suitable for new production or permanent forest (ha)***	***Total Area (ha)***
Northland	500	20,200	20,700
Auckland	0	12,300	12,300
Waikato	54,300	149,900	204,200
Bay of Plenty	13,800	37,000	50,800
Gisborne	119,900	130,500	250,400
Hawke's Bay	39,100	206,600	245,700
Manawatu-Wanganui	64,000	550,700	614,700
Taranaki	23,100	69,500	92,600
Wellington	12,900	145,100	158,000
Nelson	0	2,000	2,000
Tasman	16,300	22,900	39,200
Marlborough	72,000	86,800	158,800
Canterbury	350,400	272,000	622,400
West Coast	43,900	1,000	44,900
Otago	441,300	220,400	661,700
Southland	48,500	136,600	185,100
Total Area (ha)	***1,300,000***	***2,063,500***	***3,363,500***