Evaluation of alternative carbon accounting categories for forestry in Gisborne District under the Emissions Trading Scheme

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Abstract

In 2022, as part of Management Case Study, final-year Bachelor of Forestry Science students at the University of Canterbury re-mapped the small-scale forest estate in Gisborne District, estimated the delivered wood cost (DWC) at the time of harvesting and assessed the likelihood of harvesting. They also evaluated the profitability of afforestation under different carbon accounting approaches and categories.

It was found that the mapped area of the small-scale estate in Gisborne District is 68,810 ha compared to the National Exotic Forest Description (NEFD) estimate of 77,382 ha. Comparison of the distribution of DWC with weighted average log price over the 10 years to March 2022 indicates that at least 98% of this area will be profitable to harvest.

The carbon trading opportunity has a major impact on land affordability for land that is eligible to be registered in the New Zealand Emissions Trading Scheme (ETS). At a carbon price of $75/NZU, Land Expectation Value (LEV at a 7% required rate of return) increases from an average of $1,500/ha without carbon to $18,000/ha for averaging with look-up table carbon and $26,500/ha with measured carbon. The optimum rotation age under the averaging approach remains the same as that for forestry without carbon, although it does increase with harvest difficulty. Some 94% of sampled area has optimum rotation age in the range 25 to 35 years. Of the balance of 6% with an optimum rotation age in excess of 35 years, only half (3% of all the sampled area) has an optimum rotation age of 40 years or more.

At a carbon price of $75/tonne, permanent forestry in radiata pine gives a higher LEV than averaging for 96% of sampled area with look-up table carbon and 100% of sampled area with measured carbon. Production forestry (with averaging and look-up table carbon) is preferred (for land that is ETS-eligible) only for the 4% of sampled area with a DWC (at age 28) of less than $48/tonne.

The long rotation averaging category, put forward by the Ministry for Primary Industries (MPI) in 2022, is preferred to averaging for most blocks at a carbon price of $75/NZU. This category would have a minimum rotation age of 40 years and would allow carbon to be earned for 21 years rather than 16 years for averaging. Although this category was proposed for remote and marginal land, the extra five years of carbon mean that the longer rotation is preferred to averaging for 89% of sampled area with look-up table carbon and 99% of sampled area with measured carbon.

Introduction

Since 2015, Management Case Study, the capstone course taken by all final-year Bachelor of Forestry Science students at the University of Canterbury, has focused on improving our knowledge of the small-scale forest estate. A result of this effort has been the development of a map of the small-scale forest estate in New Zealand (Manley et al., 2021).

In 2022, Management Case Study focused on the East Coast Wood Supply Region (i.e. Gisborne District) and updated the analysis carried out in 2018 to answer key questions including:

1. What is the area of the small-scale estate in Gisborne District?
2. What proportion of this area is likely to be harvested?
3. What is the likelihood of afforestation?
4. What are the implications of findings on future wood availability?

This paper presents summary results for the first two questions but focuses on the third question. The fourth question will be covered in a subsequent paper. In considering the likelihood of afforestation the intent was to evaluate the impact of carbon trading under the New Zealand Emissions Trading Scheme (ETS). Specifically, the intention was to compare:

- Averaging accounting, the new carbon accounting method that will be used for newly registered production forests from 1 January 2023

- Stock change accounting, the standard method of carbon accounting until 31 December 2022
- 'Safe' accounting, a variation of stock change accounting under which the only units traded are those that do not have to be surrendered following harvesting, provided that replanting occurs
- Permanent forestry with forests registered in the permanent post-1989 forest category and stock change accounting.

At the commencement of Management Case Study, MPI released the discussion document 'Managing Exotic Afforestation Incentives' (MPI, 2022). It put forward options that would remove or limit the eligibility of exotic forests for the permanent post-1989 forest category.

The discussion document also described a long rotation category under averaging accounting for radiata pine forests which are not profitable to harvest at age 28 years. This category 'recognises *Pinus radiata* grown on remote and marginal land is likely to be harvested later than other production forests, so will probably store more carbon' (MPI, 2022). The assumed rotation age for this category is 40 years with forests earning carbon units until an age of 21 years. This long rotation averaging category was also included in the evaluation.

Methods

Small-scale forest area mapping

Orthorectified aerial photography (resolution 30 cm) collected in the summers of 2017–2019 was primarily used for forest boundary mapping. All aerial photos were downloaded from the Land Information New Zealand Data Service. Sentinel imagery acquired in the summers of 2021–2022 was provided by the Ministry for the Environment and used to update the status of forests (i.e. whether it was still stocked or harvested).

A mask was applied to the study areas to exclude large-scale plantation forests. These boundaries were provided by forest owners – being the same set of large-scale owners used for the MPI Wood Availability Forecast for East Coast (MPI, 2021a). Small-scale forests on all land outside this mask, including harvested area awaiting restocking, were systematically mapped in ArcGIS using the map developed in 2018 as a starting point.

Small-scale forest sampling

The 26 students worked in nine groups with each group working on a sub-region of Gisborne District. Although they re-mapped all stands in their sub-region, subsequent analysis was done on the 100–150 oldest stands in their sub-region with age estimated using a model developed from LiDAR data. In total, 1,226 stands were included in the analysis.

Harvest volume estimation

Summary statistics were provided for the region by MPI based on the ETS Field Measurement Approach (FMA) plots. For radiata pine these included:

- Mean site index of 33 m
- Mean 300 index of 32 m^3/ha/year
- Mean final crop stocking of 335 stems/ha for pruned stands and 470 stems/ha for unpruned stands
- 67% of area has been pruned. (In subsequent analysis the area in each sample block was assumed to be pruned/unpruned in the proportion indicated by the FMA plots in the region. Analysis on the likelihood of area being harvested was undertaken for both the pruned and unpruned portion with results weighted by the relative pruned/unpruned area.)

These values were input into the Radiata Pine Calculator (Knowles, 2003) in order to generate volume by market log grades.

Estimation of delivered wood cost (DWC)

The Visser Cost Model (VCM) was used to estimate the delivery cost ($/tonne) for each sample block at ages 20 to 50 years, broken down into the three main cost components: harvesting, roading and log transportation to market. The VCM is based on empirical cost data from operations throughout New Zealand, as well as experience. It uses physical factors of the site and stand to estimate the cost components. For details on model inputs see Park et al. (2012). Key inputs of slope, distance to public road and distance to port were estimated for each sample block using ArcGIS. An additional cost of $5/tonne was included for the cost of log sales administration and marketing.

Log prices

Monthly AgriHQ log prices for each grade from April 2012 to March 2022, converted to real $December 2021, were used to provide context to the DWC results. For financial analysis, average real prices for the 10-year period were used.

Financial analysis

The financial criterion used was LEV (Land Expectation Value) calculated using a 7% real discount rate. This was estimated for an unpruned regime using current costs for silvicultural operations.

In order to assess the likelihood of afforestation, the sample blocks were used to estimate the LEV that would be achieved if an adjacent area of non-forest land (that was eligible to be registered in the ETS) was afforested.

Carbon accounting

Carbon accounting methods/categories evaluated for radiata pine afforestation were:

- Stock change method for production forestry with a maximum rotation age of 50 years. NZUs are earned (and sold) as carbon stocks increase and surrendered (and purchased) when carbon stocks decrease after harvest. Replanting is assumed

- Safe method with units only traded until the safe limit is reached (i.e. the minimum level of carbon stocks after harvest of the first rotation assuming that replanting occurs)
- Averaging method with units earned only for the first 16 years of the rotation. Replanting is assumed
- Long rotation averaging with units earned for the first 21 years of the rotation. A minimum harvest age of 40 years is assumed together with replanting
- Permanent forestry assuming that the permanent post-1989 forestry category is available for post-1989 forests, including exotic forests, that will not be clearfelled for at least 50 years after they are registered in the ETS.

Under permanent post-1989 forestry, when the 50-year non-clearfell period expires the participant has three options:

- Sign up for another 25 years and continue to earn units on the stock change approach. This choice will occur again every 25 years after that date
- Transition to averaging accounting and surrender some units back down to the average age for the forest type. Harvesting is permitted as long as there is replanting
- Remove the forest from the ETS and surrender the carbon unit balance for the area removed.

Because of the level of carbon units that would need to be surrendered, the second and third options have considerable carbon price risk. In contrast, the first option does not require units to be surrendered. Consequently, it provides a better basis for comparison with production forestry under the averaging approach.

The assumptions made for permanent forestry were:

- The same unpruned radiata pine silvicultural regime as for production forestry (final crop stocking of 470 stems/ha)
- Carbon is earned for 50 years
- No carbon is earned or surrendered after 50 years.

The assumption of a 50-year limit on earning carbon reflects the limit in the look-up tables. Although additional carbon may be able to be earned beyond this, the impact on LEV will be small given the 7% discount rate used.

Carbon stock estimation

For all carbon accounting methods/categories, carbon stock was estimated both from the:

- Look-up table for radiata pine in Gisborne, and
- Radiata Pine Calculator based on site productivity and silviculture (this modelling was done to mimic the carbon that would be measured under the FMA).

Two estimates were made for all blocks because the 100 ha limit that determines whether look-up tables or FMA are required is based on a participant's total forest area rather than individual block size.

Carbon price

For initial analysis a carbon price of $75/NZU was assumed.

Results

Small-scale forest area

The total mapped area (Figure 1) for the small-scale estate is 68,810 ha compared to the National Exotic Forest Description (NEFD) (MPI, 2021b) estimate of 77,382 ha (Table 1). LCDB (Land Cover Database v5.0 as at December 2018) and LUCAS (Land-use and Carbon Analysis System NZ Land Use Map v011) estimates are higher.

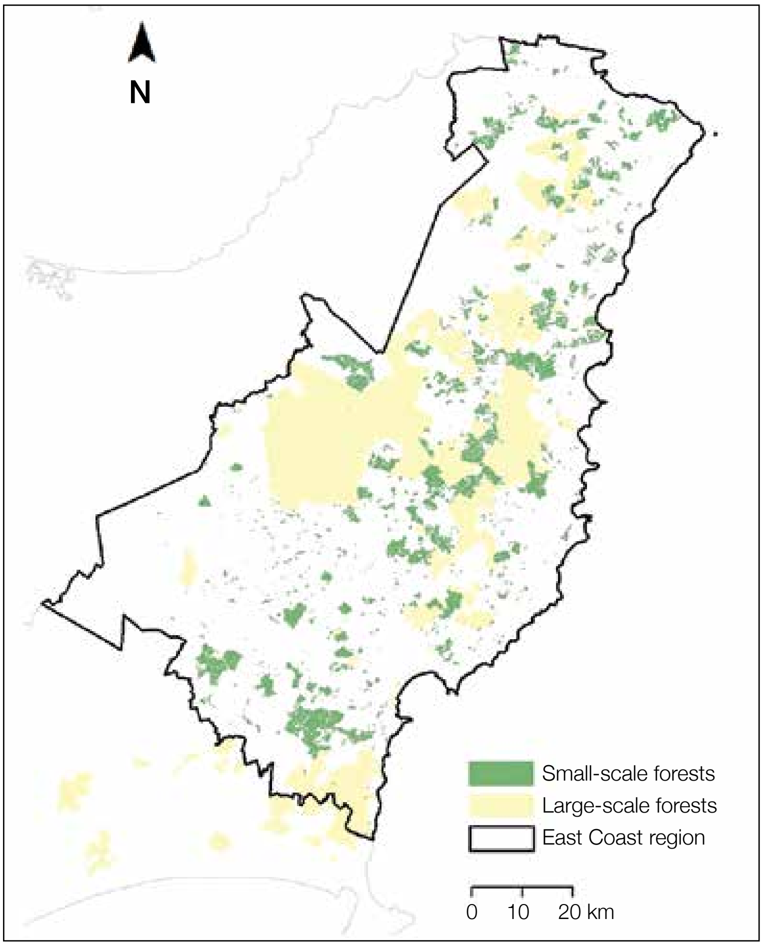

Figure 1: Mapped small-scale forests in Gisborne District (also shown are the legal boundaries of large-scale forests). As the small-scale forests are small and scattered their boundaries have been enhanced so that they are visible on the map

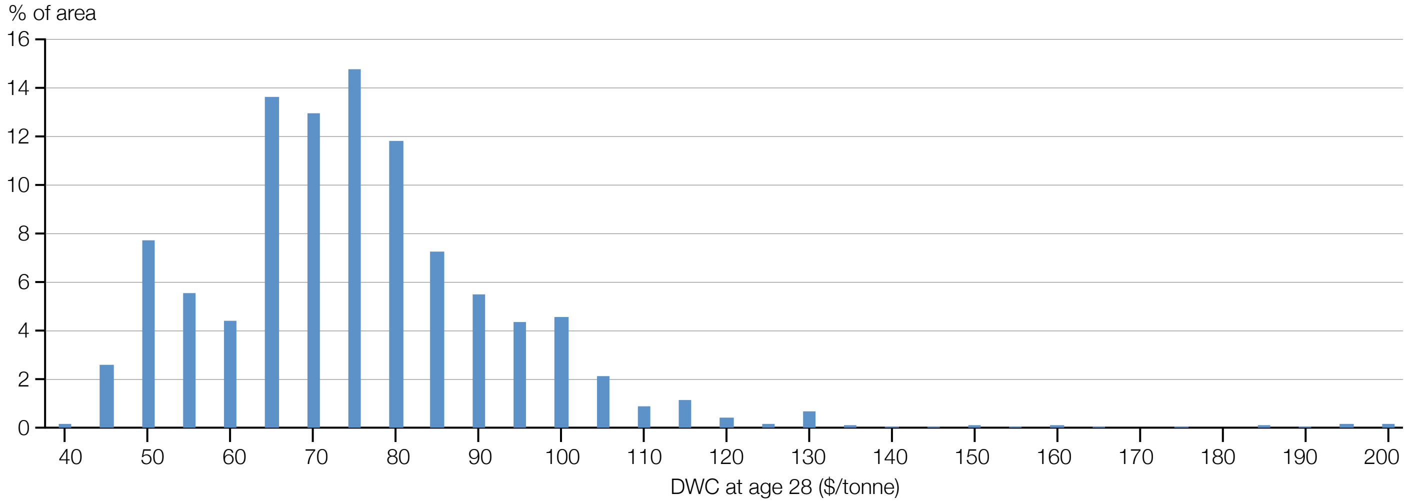

Figure 2: Estimated delivered wood costs for unpruned regime at age 28 years

Table 1: Small-scale plantation forest area comparison

Area (ha)	Small-scale forest	*Pinus radiata*	Other species
LCDB	77,505		
LUCAS	84,324		
NEFD	77,382	74,716	2,666
Case study	68,810	66,836	1,974

Likelihood of area being harvested

DWC at age 28 years (Figure 2) for the unpruned regime varies because of:

- Block size, which influences harvesting and roading costs
- Slope, which influences harvesting costs
- Distance to nearest public road, which influences roading cost
- Distance to nearest port, which influences transport cost.

DWC for the pruned regime was higher by $4/tonne on average because of the lower total recoverable volume resulting from the lower final crop stocking.

The average log price (real $Dec 2021) for the unpruned regime over the 10-year period is $120/tonne with a minimum of $78/tonne and a maximum of $152/tonne (Figure 3). Only 1.9% of the small-scale area has a DWC at age 28 that exceeds the average log price of $120/tonne and, of this area, 0.5% has a DWC that exceeds the maximum log price of $152/tonne. The percentages are even lower for the pruned regime given that the weighted average log price is $15/tonne higher than for the unpruned regime with average DWC being only $4/tonne higher.

Likelihood of afforestation

Figure 4 highlights the impact of carbon on the affordability of land for afforestation, assuming a carbon price of $75/NZU. LEV (at a required rate of return of 7%) for forestry only (i.e. without carbon) varies around $1,500/ha. The area with a negative LEV indicates land

Figure 3: Weighted average log price (at port) for pruned and unpruned regime. It is calculated from real ($Dec 2021) AgriHQ log grade prices multiplied by the proportion of the age 28 total recoverable volume made up by each grade

on which forestry is earning a lower real rate of return than 7%. LEV for averaging is intermediate to the LEV under the safe approach and the LEV under the stock change approach. With look-up table carbon, the LEV under averaging varies around $18,000/ha and around $26,500/ha with measurement carbon.

The distribution of LEV under the stock change approach is narrow. At a carbon price of $75/NZU, the optimum rotation age calculated under this approach for virtually all blocks was 50 years, the maximum set in the financial model that was developed.

In contrast, the optimum rotation age under the averaging approach remained the same as that for forestry without carbon. However, it does increase with harvest difficulty (Figure 5). Some 94% of sampled area has optimum rotation age in the range 25 to 35 years. Of the balance of 6% with an optimum rotation age in excess of 35 years, only half (3% of all the sampled area) has an optimum rotation age of 40 years or more.

Averaging vs long rotation averaging vs permanent forestry

Under carbon accounting with measurement and a carbon price of $75/NZU, permanent forestry has a greater LEV than both averaging and long rotation averaging regardless of harvest difficulty (Figure 6). Long rotation averaging has a higher LEV than averaging when DWC at age 28 years exceeds $48/tonne.

With look-up table carbon and a carbon price of $75/NZU, permanent forestry has a greater LEV than averaging once DWC at age 28 exceeds $50/tonne. With look-up table carbon, long rotation averaging has a higher LEV than averaging when DWC at age 28 exceeds $56/tonne.

It is instructive to consider the effect of carbon price on LEV under the different approaches for an example block (Figure 7), which has a DWC at age 28 of $70/tonne. It shows:

- Higher LEVs under measurement compared to look-up table carbon
- LEV for permanent forestry starting off lower (at low carbon prices) than the LEV for averaging. The LEVs become equal at a 'breakeven' carbon price before the LEV for permanent forestry becomes greater than the LEV for averaging
- The breakeven carbon price is lower under measurement than under look-up table carbon
- The sensitivity of LEV to carbon price for long rotation averaging is intermediate to that for averaging and permanent forestry.

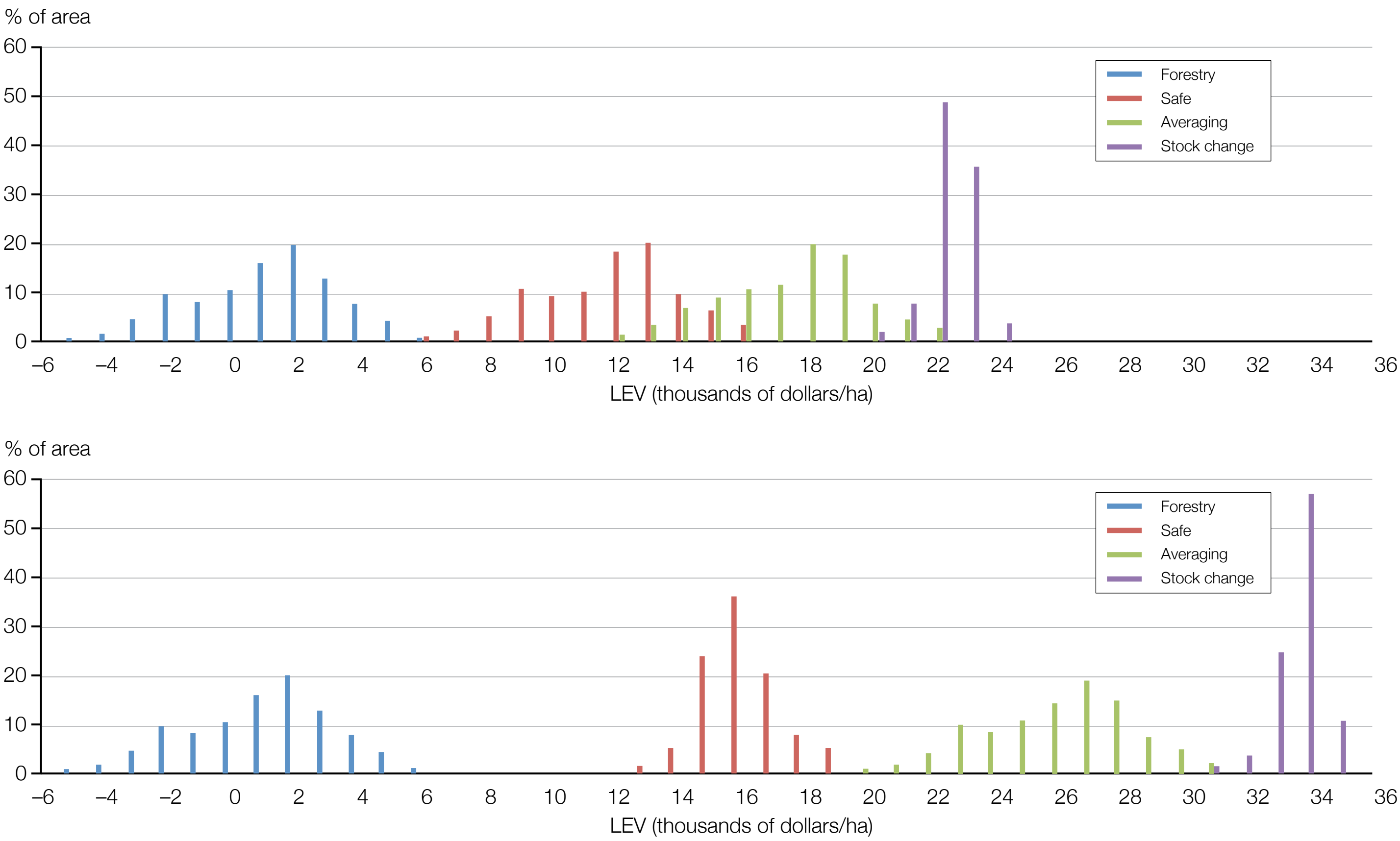

Figure 4: Distribution of LEV (at a 7% real rate of return) under: (a) (upper graph) look-up table carbon; and (b) (lower graph) 'measured' carbon. Results are presented for: (i) forestry only; and forestry with carbon accounting under (ii) safe approach; (iii) averaging approach; and (iv) stock change approach. Assumed carbon price is $75/NZU

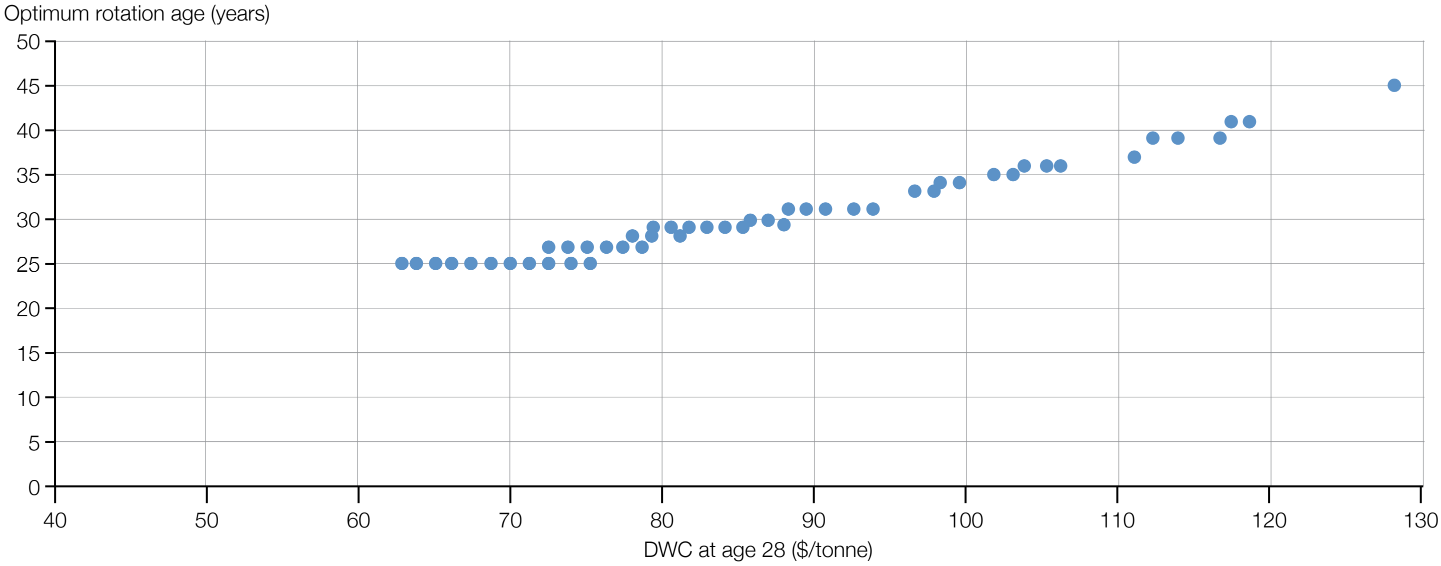

Figure 5: Optimum rotation age for unpruned regime for forestry only (and forestry with carbon under averaging) vs DWC at age 28

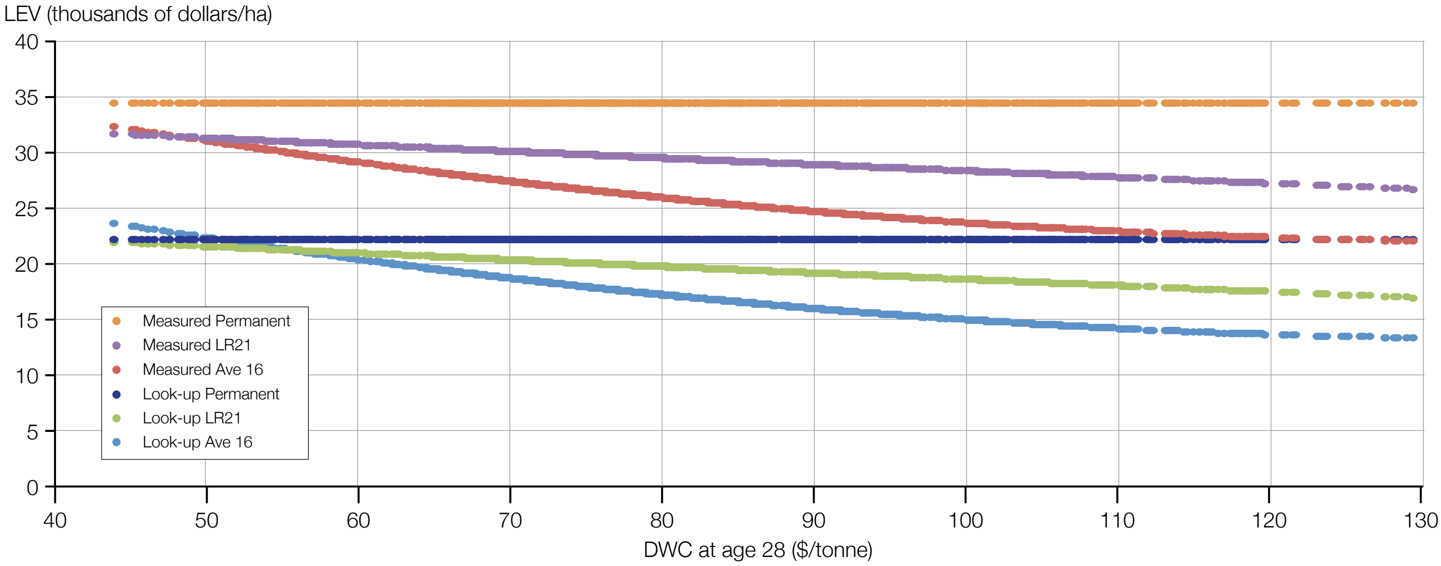

Figure 6: Relationship between LEV and DWC at age 28 under: (a) look-up table carbon; and (b) measured carbon. Results are presented for: (i) averaging; (ii) long rotation averaging; and (iii) permanent forestry. Assumed carbon price is $75/NZU

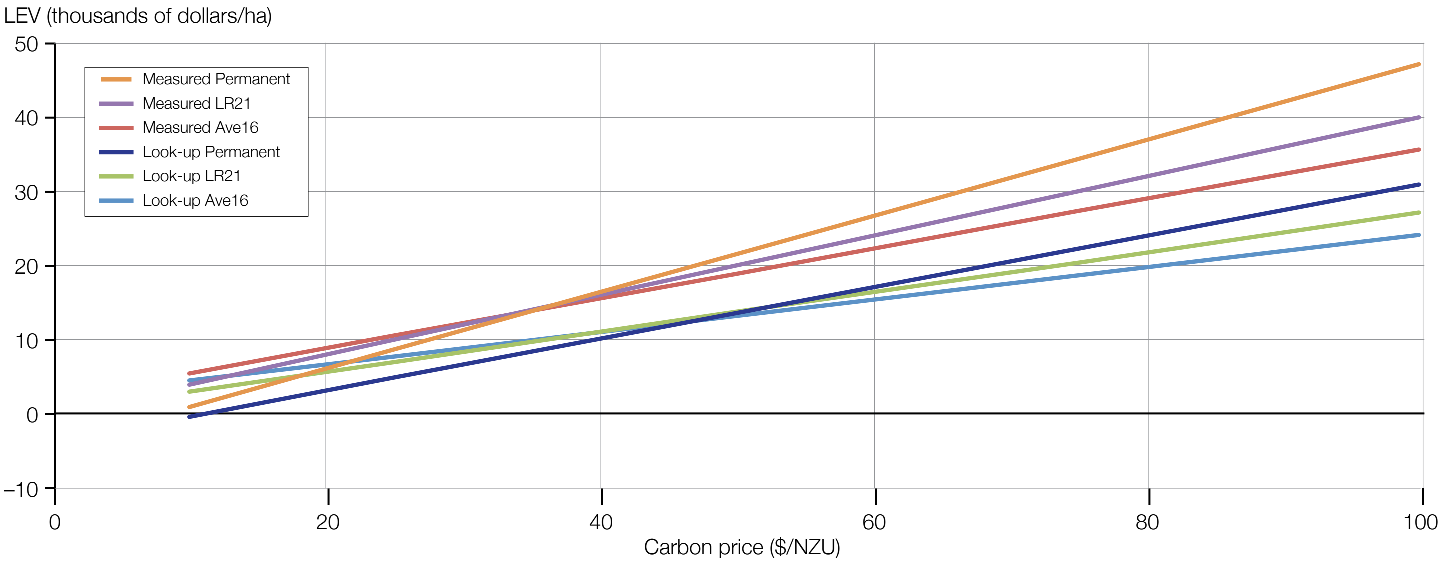

Figure 7: Sensitivity of LEV to carbon price for an example block under: (a) look-up table carbon; and (b) measured carbon. Results are presented for: (i) averaging; (ii) long rotation averaging; and (iii) permanent forestry. DWC at age 28 for the stand is $70/tonne

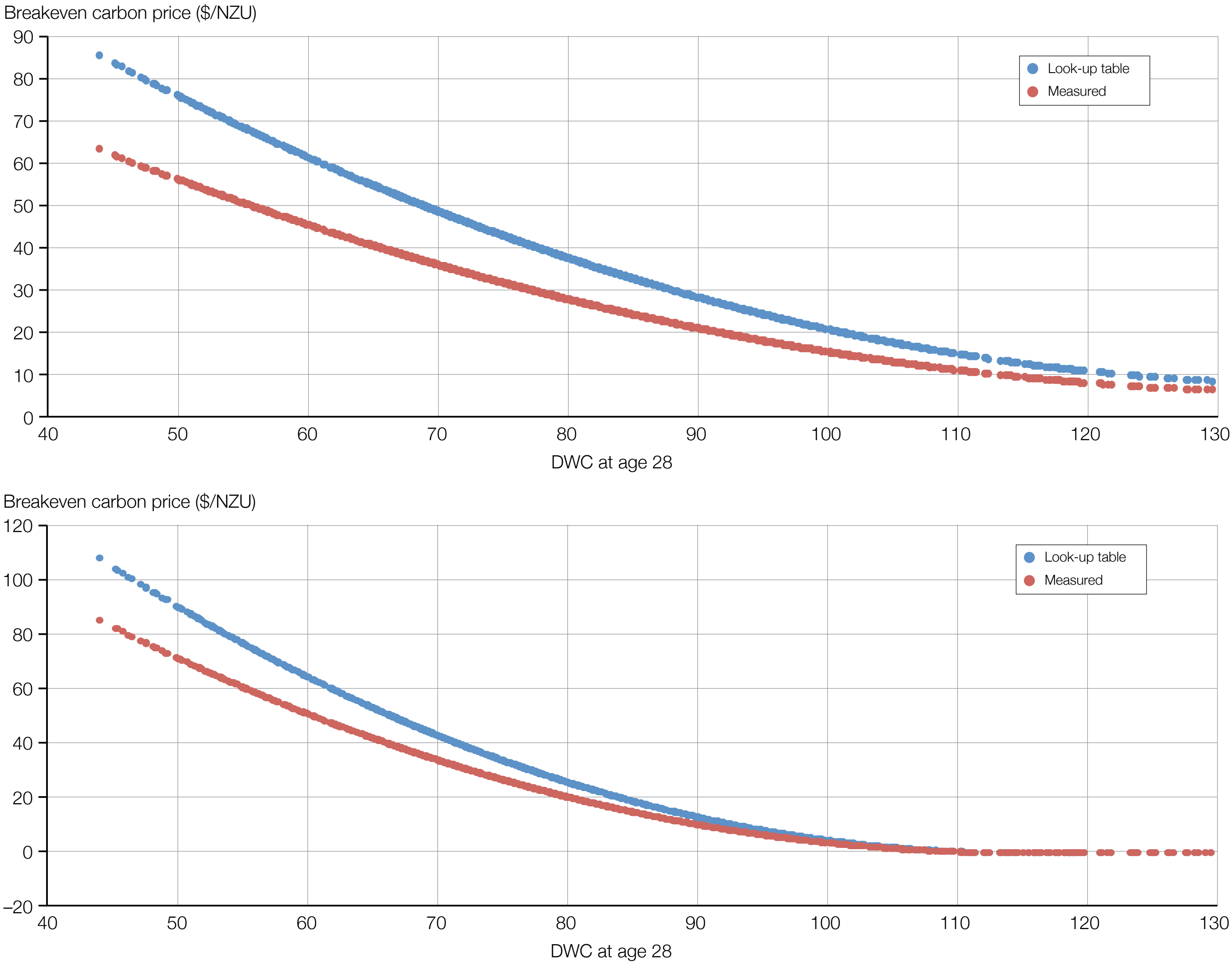

Figure 8: Breakeven carbon price at different levels of harvest difficulty (DWC at age 28) for: (a) (upper graph) averaging vs permanent forestry; and (b) (lower graph) averaging vs long rotation averaging. Results are given for carbon accounting using: (i) look-up tables; and (ii) measurement

Results are generalised, in terms of carbon price, in Figure 8. It shows the breakeven carbon price at which: (a) the LEV of permanent forestry exceeds the LEV of averaging; and (b) the LEV of long rotation averaging exceeds the LEV of averaging. The DWC corresponding to a breakeven carbon price of $75/NZU in Figure 8 confirms the results interpreted from Figure 6.

Figure 9 confirms that permanent forestry and long rotation average both become preferred, in terms of higher LEV, over averaging as carbon price increases. At a carbon price of $75/tonne, permanent forestry is preferred to averaging for 96% of sampled area with look-up table carbon and 100% of sampled area with measured carbon. At this carbon price, long rotation averaging is preferred to averaging for 89% of sampled area with look-up table carbon and 99% of sampled area with measured carbon.

Discussion

Small-scale forest area

The results presented here confirm the finding of Manley et al. (2021) that, overall, the NEFD over-estimates the area of the small-scale estate. The mapped area of 68,810 ha is 8,572 ha less than the NEFD estimate of 77,382 ha. This difference is less than the difference of 12,615 ha found in the 2018 mapping (Manley et al., 2020). The reduction in the difference is likely to be the 2022 remapping exercise capturing some recent afforestation.

Likelihood of area being harvested

Comparison of the DWC at age 28 with the average log price over the last 10 years indicates that over 98% of the small-scale estate area is likely to be harvested. DWC at age 28 provides a measure of harvest difficulty.

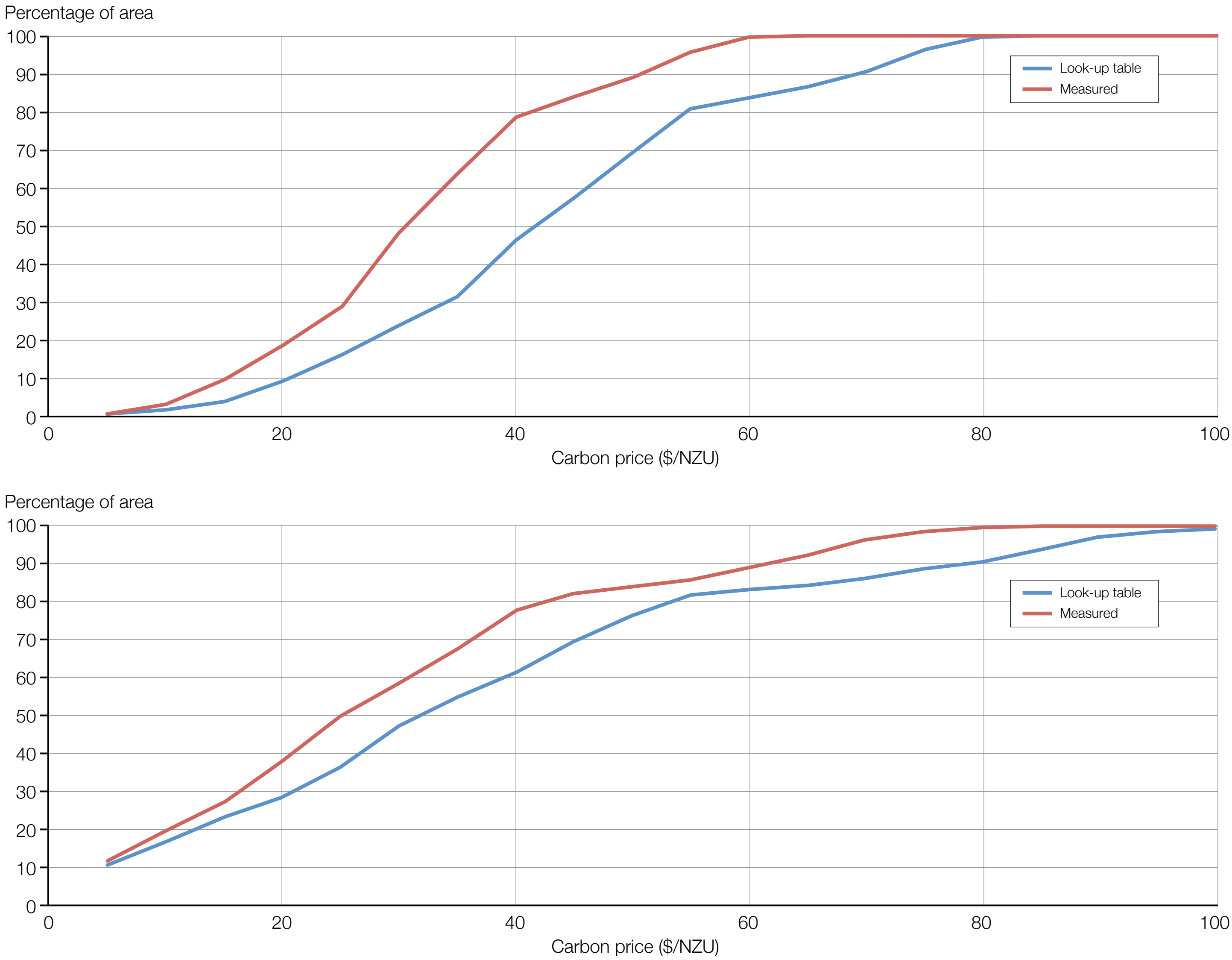

Figure 9: Effect of carbon price on the percentage of area for which: (a) (upper graph) the LEV of permanent forestry exceeds the LEV of averaging; and (b) (lower graph) the LEV of long rotation averaging exceeds the LEV of averaging. Results are given for carbon accounting using: (i) look-up tables; and (ii) measurement

In reality, some blocks will be harvested at younger ages and some at older ages. The greater the level of difficulty, the older the rotation age is likely to be in order for unit harvesting costs to be reduced.

Just because average log price exceeds DWC is no guarantee that a forest grower will wish to harvest at that time. Most will have an expectation of a stumpage margin that provides a rate of return on their historic investment. However, the DWC distribution (Figure 2) is such that only the small proportion of high-cost outliers might not be harvested when production forestry is the goal.

Likelihood of afforestation

The likelihood of afforestation depends on the availability of land and its affordability for afforestation. LEV is a measure of how much a forest grower can afford to pay for land in order to achieve their required rate of return. The results here confirm that the carbon trading opportunity has a major impact on land affordability for land that is ETS-eligible. At a carbon price of $75/NZU, LEV (with a 7% required real rate of return) increases from an average of $1,500/ha without carbon to $18,000/ha for averaging with look-up table carbon and $26,500/ha with measured carbon.

At a carbon price of $75/tonne, permanent forestry in radiata pine gives a higher LEV than averaging for 96% of sampled area with look-up table carbon and 100% of sampled area with measured carbon. Production forestry (with averaging and look-up table carbon) is preferred only for the 4% of sampled area with a DWC (at age 28) of less than $48/tonne. The increasing carbon price indicated by the futures market indicates that permanent forestry in radiata pine will give a higher LEV than production forestry for 100% of sampled area in the near future. Certainly, the findings here confirm the comments in the problem statement of the MPI (2022) discussion document that 'Rising prices in the NZ ETS are expected to drive large-scale permanent exotic afforestation' and 'Permanent exotic forests often provide the highest economic return.'

Long rotation averaging is preferred to averaging for most blocks at a carbon price of $75/NZU. Although it has a minimum rotation age of 40 years, the option, as proposed, would allow carbon to be earned for 21 years rather than 16 years for averaging. Although this option was proposed for remote and marginal land, the extra five years of carbon mean that the longer rotation is preferred to averaging for 89% of sampled area with look-up table carbon and 99% of sampled area with measured carbon.

Limitations

The assumption that all stands have the same site productivity and stocking is a simplification. Although it has helped to make trends apparent, it has resulted in a narrower range of profitability estimates than would be the case if separate estimates had been made for each block. Site productivity for each small-scale block was subsequently obtained using the Watt et al. (2021) surfaces for site index. This indicates that 90% of the small-scale estate has site index (Mean Top Height at age 20) in the range 28.6 to 35 m (i.e. that there is a relatively tight distribution of site productivity and, of particular relevance here, a small proportion of low productivity sites).

In order to assess the likelihood of afforestation, the sample blocks used to assess the likelihood of harvesting were used to estimate the LEV that would be achieved if an adjacent area of non-forest land (that is eligible to be registered in the ETS) was afforested. The implicit assumption is that the existing older blocks are representative of blocks that are available for future afforestation in terms of size, slope and location relative to public road and Gisborne. Although there is unlikely to be an exact match, the key results presented here are so clearcut that they are likely to be robust to this assumption.

Acknowledgements

The basic work reported here was undertaken by final year BForSc students from 2022: Steven Bell, Macey Buri, Dominic Cleary, Olivia Crighton, Harry Dinneen, Tom Forrest, Theodore Fowler, Flynn Green, Robert Hayes, Hannah Humphreys, Aimee Hyland, Will Mace-Cochrane, Nicholas Melvin, Jamila Milne, Caelin Moore, Angus Moulder, Tim Muller, Hannah Munro, Fallon Nish, Robyn Patient, Gracie Perkins, Blake Rapley, Cameron Sclanders, Ham Scown, Max Tweddell and Leah van Boven. Group 9 (Dominic Cleary, Will Mace-Cochrane and Ham Scown) are thanked for doing some supplementary analysis for this paper. The support provided to Management Case Study by MPI, and the guidance provided by Dr Parnell Trost as well as forestry consultant Alan Bell, is gratefully acknowledged.

References

Manley, B., Morgenroth, J. and Xu, C. 2021. Map of the Small-Scale Forest Estate of New Zealand. *New Zealand Journal of Forestry*, 66(1): 33–37.

Manley, B., Morgenroth, J., Xu, C. and final year BForSc students of 2017 and 2018. 2020. Quantifying the Area of the Small-scale Owners' Estate in East Coast, Hawke's Bay and Southern North Island. *New Zealand Journal of Forestry*, 64(4): 18–26.

Ministry for Primary Industries (MPI). 2021a. *Wood Availability Forecast – East Coast 2021*. Wellington, NZ: MPI.

Ministry for Primary Industries (MPI). 2021b. *National Exotic Forest Description as at 1 April 2021*. Wellington, NZ: MPI.

Ministry for Primary Industries (MPI), 2022. *Managing Exotic Afforestation Incentives*. A Discussion Document on Proposals to Change Forestry Settings in the New Zealand Emissions Trading Scheme. MPI Discussion Paper No. 2022/02. Wellington, NZ: MPI.

Knowles, L.J. 2003. Calculators for Radiata Pine and Douglas-fir. *New Zealand Tree Grower*, 24(2): 26.

Park, D., Manley, B., Morgenroth, J. and Visser, R. 2012. What Proportion of the Forest of Small-Scale Owners is Likely to be Harvested: A Whanganui Case Study. *New Zealand Journal of Forestry*, 57(3): 4–11.

Watt, M.S., Palmer, D.J., Leonardo, E.M.C. and Brombrun, M. 2021. Use of Advanced Modelling Methods to Estimate Radiata Pine Productivity Indices. *Forest Ecology and Management*, 479: 118557.

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