MARLBOROUGH RESEARCH CENTRE
Te Rito Hiranga o Wairau

Funded by

Agriculture & Investment Services
Ministry for Primary Industries
Manatū Ahu Matua

Marlborough's Future is Durable

A regional development case study on the potential for a durable hardwood industry

Part Two: Individual property case studies

MPI SLMACC 406896 Report No: 3.2

Ministry for Primary Industries Technical Paper No: 2024/15

Prepared for Ministry for Primary Industries

Authors: Paul Millen, Euan Mason and Harriet Palmer

ISBN No: 978-1-991308-31-3 (online)
ISSN No: 2253-3923 (online)




1st August 2024

Te Kāwanatanga o Aotearoa
New Zealand Government

Disclaimer

The Authors

- **Paul Millen** is General Manager, New Zealand Dryland Forests Innovation (NZDFI).
- **Professor Euan Mason** leads silviculture and modelling research and teaching at the University of Canterbury School of Forestry.
- **Harriet Palmer** is communications consultant to NZDFI.

Acknowledgements

The authors thank the following people for their contributions to this report and to the SLMACC project:

1. **University of Canterbury School of Forestry**
   Dr Cong (Vega) Xu, Dr Ning Ye, Associate Professor Clemens Altaner, Dr Monika Sharma, Meike Holzenkampfer, Alex Chamberlain, James Burns, Thomas Copeland, Seb Lallemant, Christophe Robert and Georgia Kennedy
2. **Marlborough Research Centre – staff and contractors**
   Gerald Hope, Susan Foster, Kevan Buck, Ruth McConnochie, Roger May, Ash Millen, Tony Pruden
3. **Bioenergy Association**
   Brian Cox
4. **NZDFI case study landowners and trial site hosts**
   Fraser and Shelley Avery, the Dillon family, Gary Fleming, Robert Holdaway, Andrew and Ngaire Lawson, Rob Martin, Robb Macbeth, Marlborough District Council, Marlborough Regional Forests (Phil Woodward)
5. **Marlborough District Council**
   Pere Hawes
6. **Ministry for Primary Industries**
   Sonya Hunt, James Gorrie
7. **Energy Efficiency and Conservation Authority**
   Oliver Howitt

Photos

The front cover photos show the four individual properties featured in this case study:

Top left:	*Lawson*	*Top right:*	*Avery*
Bottom left:	*Pukaka Forest*	*Bottom right:*	*Holdaway*

Contents

Table of tables

Table of maps

1 Introduction

This report is Part Two of the Marlborough regional case study on the regional development potential for a durable hardwood industry that could produce over $90 million in gross domestic product (GDP) based on 5,000 ha of sustainably managed eucalypt forests established between 2025 and 2055.

New Zealand Dryland Forests Innovation (NZDFI) has undertaken this study to promote a new regional hardwood forestry and wood processing supply chain that could diversify the forest industry and generate new investment and employment. This would improve long-term environmental and economic sustainability and resilience for Marlborough's grape growers, farmers and forest growers.

The case study authors investigated:

a. the potential for a sustainable regional supply of naturally durable posts for vineyards; other timber products and markets; and the overall economic contribution to the regional economy, that growing and processing durable eucalypts in Marlborough could generate.
b. the woody biomass residues that could be recovered from harvesting and processing operations to supply solid biofuel to major energy users in Marlborough, including the wine sector, as they switch away from using fossil fuels.
c. greenhouse gas emissions (GHG) that could be saved by fuel-switching, and that could be offset through carbon sequestration by new eucalypt forests
d. current national and regional policy and regulations associated with forest growing and hardwood processing relevant to case study
e. potential economic and environmental implications of growing durable eucalypts to supply a new industry on four individual Marlborough case study properties.

This report covers 'e' in the above list - the four individual property case studies undertaken to assess the potential of each property to grow and market durable eucalypts based on their land type and proximity to one of the two processing hubs. The extent to which existing and new planting could offset greenhouse gas emissions from their land-based activities and the financial benefits which could be derived under current Emissions Trading Scheme (ETS) rules were also evaluated. The outcomes of the case studies are to inform other landowners in Marlborough.

The completion of the Marlborough regional case study provides a market- and science-based pathway for developing a sustainable durable hardwood industry and supply chains. The results highlight that developing a durable eucalypt supply chain will require long term regional planning, collaboration and investment in landowners planting genetically improved trees through to processors marketing durable hardwood products. The study provides evidence that a durable hardwood industry could diversify the region's economy; deliver financial and environmental outcomes to farmers, forest owners, grape growers and wine makers; and create new employment in the forestry and wood processing sectors.

2 Summary of individual property case study outcomes

Individual property case studies were completed by working with four NZDFI landowners with environmentally contrasting but typical Marlborough farm/forest sites. All four are already growing *Eucalyptus bosistoana* and *E. globoidea* in trials and/or in small commercial plantations. These case studies inform the landowners about the potential economic and environmental value of establishing new durable eucalypt plantations. The values identified included:

- assessing the potential to supply a new regional industry producing durable hardwood for sawn timber, posts and biomass
- assessing the current carbon sequestration by the existing *E. bosistoana* and *E. globoidea* trials on each property and identifying the extent to which new planting could contribute to reducing properties' GHG emissions
- assessing any financial benefits which could be derived from new planting under current ETS criteria.

For each property, suitable species and a durable eucalypt forestry regime has been identified based on supplying one of the regional hubs for processing into posts, timber, veneer and woody biomass.

2.1 Potential durable eucalypt forest productivity

The model simulations produced predictions of forest productivity for each property quantified the significant north/south sub-regional productivity difference.

Table 1 summarises the predicted productivity for total stem volume; stem heartwood volume and above-ground biomass (AGB) for the potential durable eucalypt forestry regime identified at each of the four individual case study properties.

More details are provided in Section 3 of this report. These predictions provide the basis for 'broad brush' regional case study projections of forest growth and yield for both species under the two regimes described in the Part One Marlborough regional case study report.

Table 1: Individual property case studies – regimes, species, nearest processing hub/s and model outputs for stem volumes and total biomass.

Property	Regime and species	Processing hub and distance	Stem total volume m^3/ha	Stem heartwood vol m^3/ha	Above ground biomass (AGB) tonnes/ha dry weight
Lawson	20-25 year post regime *E. bosistoana / E. cladocalyx*	Riverlands 31 km	79.8 (age 20)*	14.8 (age 20)	61.1 (age 20)
Avery	20-25 year post regime *E. globoidea*	Riverlands 35km	163.5 (age 25)	78.0 (age 25)	140 (age 25)
Holdaway	Insufficient land area within vineyard property. On separate (Wairau Valley) site, 20-25 year post regime *E. bosistoana*	Riverlands 65km Kaituna 55km	N/A	N/A	N/A – trees too young at measurement for meaningful growth simulation
MRF Pukaka Forest	20-25 year post regime *E. bosistoana* 28-32 year sawlog regime *E. globoidea*	Kaituna 27km	165 (age 19) 467 (age 25)	37 (age 19) 343 (age 25)	*E. bosistoana* 177 (age 19) *E. globoidea* 255 (age 25)

* Specified age in all cases is the maximum age the model predictions extend to.

2.2 Tree/stand model development and productivity predictions

The University of Canterbury School of Forestry (UCSoF) developed two new tree-level models of stem wood volume, heartwood content and biomass by destructive sampling of 79 *E. bosistoana* and 33 *E. globoidea* trees to collect the necessary data (a Technical Report with full details of model development is available[1]).

By comparison, regional plot(stand) level models developed for use in these case studies are based on data from measurement of permanent sample plots (PSPs) that extend from Northland to north

[1] *Details of growth and carbon sequestration modelling can be found in the accompanying document: Individual Tree Biomass Sampling of Durable Eucalypts* – MPI SLMACC 406896 Technical Paper 02.

Canterbury. Repeated measurement of PSPs over the rotation of a forest is necessary to fully capture and understand the site characteristics that influence species' performance.

However, there are no New Zealand data sets for *E. bosistoana* or *E. globoidea* PSPs that have been fully measured over a rotation. Therefore, the datasets used to develop the case study regional plot level model for *E. globoidea* were measured in 23 Scion-managed PSPs (mostly located in North Island semi-mature and mature stands) and 97 NZDFI PSPs located in early to mid-rotation age trials. There are no older Scion PSPs of *E. bosistoana* as the species was rarely planted in New Zealand until NZDFI commenced research in 2008. Hence, the datasets used for the regional plot level model came from 130 NZDFI PSPs, nearly all of these under 12 years at time of measurement.

While, the PSPs are located in different age classes of forest and across a diversity of site types with varying management, by combining these national datasets, it has been possible to develop Marlborough regional models for both species of plot (stand) growth and yield by predicting over time the increases in mean top height, basal area/ha, and natural mortality by reducing stems/ha.

For each of the four individual case study properties, re-measurement of existing *E. bosistoana* or *E. globoidea* NZDFI PSPs located within various trial blocks was completed as a part of the 2022/23 summer field work. The new tree-level models of stem wood volume, heartwood content and biomass were applied to each measurement of individual trees in PSPs, and relationships between plot-level estimates of these variables with mean top height, basal area, and stand density index were developed to simulate growth (and natural tree mortality) so as to predict annual increases in total stem volume; heartwood volume; CO2 sequestration; stem biomass and branch biomass. The simulation predictions for plot-level modelling of each site are presented in section 3 of this report.

These predictions by the plot level model are limited to 20 years for *E. bosistoana* and 25 years for *E. globoidea* as these have been developed using only data from young and semi mature stands. Even at these ages, projections are provisional because they are based just a few permanent sample plots. The model will become more consistent and accurate as new data are obtained.

However, while growth and yield models can be built with data from just permanent sample plots (PSPs), they are more secure if they are informed by analyses from designed experiments. Designed experiments enable developing precision silvicultural strategies and provide growers confidence to apply site specific management.

Stand density is the extent to which trees occupy a site. Different eucalypt species can differ in their response to stand density and stand density management. Stand density index (SDI) can be used to guide thinning strategies if the maximum stand density index for a species is known on the site where the trees are growing. Therefore, accurate stand density measurement is required to extend the stand level models to precision silviculture models for *E. globoidea* and *E. bosistoana.*

In order to do this a network of silvicultural trials needs to be planted for long term measurement and further model development. These trials would inform on optimizing silviculture through learning about:

- Effects of genotypes in delivering gain
- Effects of spacing on branching
- Implications for pruning for clearwood and value
- Wood durability and heartwood
- Impacts of spacing on yield by log grade
- Financial outcomes of various regimes

2.3 Heartwood productivity predictions and genetic improvement

The simulation outputs also confirm that *E. bosistoana* produces less heartwood than *E. globoidea* at a similar age, regardless of site. As a result, the model predictions at the two case study properties with *E. bosistoana* indicate that the actual stem heartwood volume at harvest is low. However, heartwood development in older trees could increase at a faster rate than the heartwood volumes predicted by the model. There is no published work about eucalypt heartwood formation during tree maturation so this variation between the species can only be studied by further measurement, coring and destructive sampling as the NZDFI trials get older.

Future productivity from any new planting of NZDFI's first generation improved seedlings is difficult to predict. This is because growth models have been developed using data from unimproved stands and therefore do not take into account the genetic gain achieved by breeding.

NZDFI has calculated the improvement for diameter growth and heartwood as 12.2% and 31.1% respectively by breeding and selection of *E. globoidea*. For *E. bosistoana* the improvement is 11.4% for diameter growth and 22.6% for heartwood ratio.

Top performing families have already been grafted and established in clonal seed orchards by Proseed NZ that are producing XyloGene branded seedlots. These genetic gains from NZDFI breeding programme will increase productivity and heartwood percentage over the unimproved trees that have provided the data sets for the models.

Having a secure supply of genetically improved seed makes it possible for these gains to be available for landowners to secure improved seedlings for commercial scale planting. The seed and seedlings are sold under the XyloGene® brand and a NZDFI royalty charge is collected from nurseries on their seedling sales.

2.4 Potential for carbon sequestration to offset greenhouse gas emissions and for earning NZUs under the Emissions Trading Scheme

The total CO2e sequestered for the potential durable eucalypt forestry regime identified at each of the four properties included in the case study are summarised in Table 2. These can be compared to predicted outputs for total above ground biomass (AGB) shown in Table 1.

Table 2 provides further comparison with the total GHG emissions estimated for each property using a Ministry for the Environment (MfE) on-line calculator[2] and industry published methods, and potential NZUs that could be earned under Te Uru Rākau ETS look-up tables[3]. More information on these is included in section 3 of this report.

The MfE on-line calculator is a freely available tool that has been used to estimate gross GHG emissions from the three agricultural-based properties while published reports on forestry GHG emissions have been used to estimate the emissions by forestry activities.

There are significant differences between the MfE Calculator outputs, the ETS NZU look-up tables, when compared to the estimates produced by the SoF model. The results indicate that both the MfE calculator and the Te Uru Rākau look-up tables over-estimate the growth rates i.e. the carbon sequestration rates of these durable eucalypts on dryland sites.

These differences highlight the difficulty to offer robust scientific advice to our case study landowners on how to utilise additional planting of durable eucalypts that will effectively contribute to offsetting their emissions.

[2] https://environment.govt.nz/what-you-can-do/agricultural-emissions-calculator/
[3] https://www.mpi.govt.nz/forestry/forestry-in-the-emissions-trading-scheme/emissions-returns-and-carbon-units-nzus-for-forestry/calculating-the-amount-of-carbon-in-your-forest-land/carbon-tables-for-calculating-carbon/

Table 2: Individual property case studies: total biomass, heartwood and carbon estimates based on modelling and calculations done as part of the case study.

Property	Species	Modelled average annual carbon sequestered by planted eucalypts t CO2e/ha/yr	Total property annual carbon emissions tCO2e/yr	NZU allocation under current ETS rules
Lawson	*E. bosistoana / E. cladocalyx*	9.3 (to age 20)	-179.2*	320 NZUs/ha (total 12-year averaging allocation)
Avery	*E. globoidea*	13.9 (to age 25)	- 4,315.1*	320 NZUs/ha (total 12-year averaging allocation)
Holdaway	*E. bosistoana*	N/A – trees too young at measurement for meaningful carbon simulation	- 217.7**	Planting at the Wairau Valley forestry block likely to require measurement under ETS FMA rules for plantations over 100ha
MRF Pukaka Forest	*E. bosistoana* *E. globoidea*	18.2 (to age 19) 28.4 (to age 25)	-37.75 *** (roading and harvesting operations estimate)	Pre 1990 forest land - ineligible for ETS

* MfE calculator

** Industry average estimates for vineyard and winery

*** Carbon footprint of forest harvesting operations in New Zealand: FGR Technical Report H060, 2023[4].

Farmers wanting to directly offset their livestock emissions by planting trees cannot currently do this within the ETS. One purpose of He Waka Eke Noa was to find a way for farmers to be able to include existing woodlots and regenerating areas, or new tree plantings, in their emissions accounting, thereby reducing liabilities from livestock emissions if and when agriculture is brought into the ETS or a new carbon accounting mechanism is established.

3 Individual property case studies and NZDFI trials

Selection of the case study sites was based on ensuring a diversity of property types along with the landowner hosting at least one NZDFI trial of either *E. globoidea* or *E. bosistoana.* Details of the case study properties and durable eucalypt trials that were measured for the case study are shown in Table 10 and Map 4. The four properties comprise:

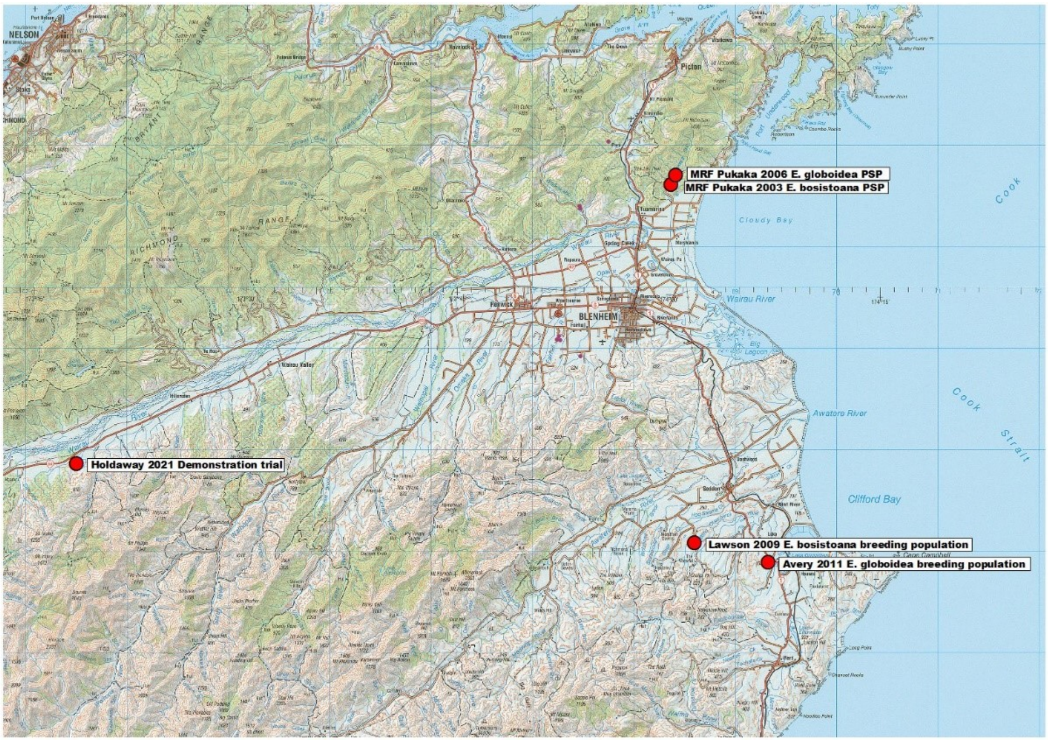
- The Lawson property (Andrew and Ngaire Lawson) – vineyard owner and small-scale beef and sheep farm in Awatere Valley. This property includes a 2.87 ha trial of *E. bosistoana* planted in 2009.
- The Avery property (Fraser and Shelley Avery) – large-scale beef and sheep and cropping farm in Grassmere Valley. This property includes a 6.3 ha trial of *E. globoidea* and *E. tricarpa* planted in 2011.
- Lowlands vineyard and winery – (Alfa Lea Horticulture including Birch Hill Forestry Ltd) – Holdaway family vineyard and commercial pine forests in Wairau Valley. This property includes stands/trials of *E. bosistoana* and *E. globoidea*, both planted in 2021.
- Marlborough Regional Forests Pukaka Forest – regional government-owned commercial forest in Pukaka Valley. There are two trial sites in this forest. One of these is a small roadside

[4] https://fgr.nz/documents/download/10587?161537090

0.19 ha stand of *E. bosistoana* planted in 2003. The second is a steep pine cutover site planted with pine in early 1970's and harvested in 2005. When replanted in 2006 a 0.92 ha mixed species trial was established with a surround of predominantly *E. globoidea.*

Table 3: Case study landowner trial site information.

Property	Elevation (m a.s.l)	Temperature (°C)		Total Annual rainfall (mm)	Species	Year planted	No. of Permanent Sample Plots
		Winter minimum	Summer max				
Lawson	117 - 177	1.9	22.3	727	*E. bosistoana*	2009	4
Avery	8 - 87	3.4	21.6	632	*E. globoidea*	2011	2
Holdaway	287 – 340	- 0.5	22.8	1114	*E. bosistoana* *E. globoidea*	2021	1 of each
MRF Pukaka	22 - 115	3.2	22.0	1183	*E. bosistoana* *E. globoidea*	2003 2006	1 1



Map 1: Location of case study sites in Marlborough.

The NZDFI trials assessed within each of the case study sites were not homogenous either in their initial planting layout or the number of stems planted per hectare (SPH). Also thinning to waste has been undertaken at different ages to reduce within stand competition and the current stems per hectare varies between all trials. This variation is due to the trials having been planted and managed for different objectives. Therefore, the model outputs for each property need to be interpreted as indicative only and this limits direct comparison between the sites.

Ground based measurement of PSPs was completed in the eucalypt trials on the case study properties in mid-summer 2022-23. Data collected for each PSP was used to calculate the mean top height, average stem diameter, basal area and stocking at the time of measurement. These values were then applied to the stand level models to predict future growth and productivity. The model simulations are included in Section 3 below.

3.1 Scope of net emissions calculations for the individual property case studies

New Zealand guidance around Greenhouse Gas (GHG) measurement and reporting is provided by the Ministry for the Environment[5]. The guidance itself is extracted from international frameworks for GHG reporting. The GHG Protocol separates emissions based on their source into the following categories[6]:

- **Scope 1:** direct GHG emissions (and removals) from sources owned or controlled by the landowner or company (i.e., within the organisational boundary) - for example, emissions from livestock production on-farm, from fuel-use by vehicles owned or controlled by the company; also, emissions removals – for example by forests owned by the company
- **Scope 2:** indirect GHG emissions from the generation of purchased energy (in the form of electricity, heat, or steam) that the organisation uses –for example, heat and power used in on-farm/winery processing
- **Scope 3:** other indirect GHG emissions because of the activities of the organisation but generated from sources it does not own or control (e.g., air travel).

Almost all GHG reporting is based on estimates and emissions conversion factors. In all the following case studies, Scope 1 emissions are estimated. In the Holdaway case study, Scope 2 emissions from the Lowlands winery are also estimated. All estimates are expressed in terms of tonnes CO_2-e/year.

3.2 Sources of information and tools used

There are various free sources of information and tools available for landowners wishing to better understand their greenhouse gas emissions profile. Consultants offer carbon-related services which are not freely available, but which are likely to take a far more detailed approach than has been taken in this report.

The following resources have been used:

- The MfE publication: *Measuring Emissions: A guide for organisations 2022* provides detailed guidance on how to calculate greenhouse gas emissions in all NZ's main industry sectors, along with relevant data and conversion factors[7]

- MfE Agricultural Emissions Calculator[8] - a simple, freely available interactive calculator which utilises the data and conversion factors in the above MfE report and calculates broad-brush emissions based on average annual livestock numbers and fertiliser use in any calendar year. This very easy-to-use calculator enables livestock farmers to generate ball-park estimates of annual emissions from various categories of livestock and fertiliser use. It also has a facility for estimating carbon storage (or loss if trees are harvested or otherwise removed) by planted forests, pre 1990 tall forest, pre 1990 regenerating forest and post 1989 regenerating forest. The 'planted forest' category makes no distinction between species, age of trees, or growth rates, so is a very blunt tool.

- Te Uru Rākau's ETS look-up tables were used to calculate the current emissions/sequestration profile of Pukaka Forest and to estimate the averaging allocations for the Lawson and Avery properties[9].

---

[5] MfE, (2021). Carbon Neutral Government Programme: A guide to measuring and reporting greenhouse gas emissions. Ministry for the Environment. New Zealand Government.
[6] WBCSD. (2001). The Greenhouse Gas Protocol. World Business Council for Sustainable Development & World Resources Institute. Reed Business Education.
and delivered to MPI.
[7] https://environment.govt.nz/assets/publications/Measuring-emissions-guidance-August-2022/Detailed-guide-PDF-Measuring-emissions-guidance-August-2022.pdf

[8] https://environment.govt.nz/what-you-can-do/agricultural-emissions-calculator/
[9] https://www.mpi.govt.nz/forestry/forestry-in-the-emissions-trading-scheme/emissions-returns-and-carbon-units-nzus-for-forestry/calculating-the-amount-of-carbon-in-your-forest-land/carbon-tables-for-calculating-carbon/

- Sustainable Winegrowing New Zealand's *National Greenhouse Gas Emissions and Energy Use Report* [10]- this is a detailed industry bench-marking report, derived from data collected from surveys of members.

- For the Pukaka Forest case study, data on the carbon footprint of harvesting operations have been used – these are found in Forest Growers Research Technical Report H060: *Carbon footprint of harvesting operations in New Zealand*[11].

In addition, a 2022 report by the Parliamentary Commissioner for the Environment (PCE): *How much forestry would be needed to offset warming from agricultural methane?*[12] was consulted. This report emphasises that different calculation methodologies can be used for estimating the longevity and warming effect of methane derived from livestock, and that there is not necessarily consensus between different groups on the best way to evaluate livestock emissions.

3.3 Benefits of new planting on Marlborough case study properties under current ETS rules

Any new plantings of durable eucalypts on eligible (post-1989) land could be entered into the ETS as long as qualifying criteria are able to be met.

If the total area of ETS-registered forest on the property remains less than 100 hectares, then Te Uru Rākau's look-up tables would be used to calculate the carbon accumulated by the new plantings and allocate NZUs to the owner accordingly.

If the total area is over 100 hectares, a system called the Field Measurement Approach (FMA) is used, where 'participant-specific tables' are produced following measurement of sample plots in the forest.

All new plantings entered into the ETS are now assessed using 'Averaging' rules, where the average amount of carbon stored by the trees over infinite rotations is used to allocate NZUs to owners. In the case of eucalypts, this average has been set at age 12, (the total amount of carbon accumulated in years 1-12) according to the look-up tables. This means owners of any new eucalypt forests planted from now onwards and which are entered into the ETS receive a total allocation of 320 NZUs/ha. These NZUs do not carry any liabilities (unless the forest is felled and not replanted) and can be exchanged for cash. There is no further allocation of carbon.

Therefore, the value of the allocation for durable eucalypts per hectare is 320 x the $/NZU value upon sale. The current price (May 2024) is around $47/NZU, giving a gross income of around $15,000/ha over a total of 12 years from planting.

If any sizeable new planting were to occur on the Lawson and Avery properties, registering for the ETS and using the Te Uru Rākau look-up tables to confirm their averaging allocation is the most likely scenario. Growers considering entering the ETS need to first learn about the costs associated with joining the scheme, submitting carbon returns and selling carbon, and ensure it is worthwhile to join.

The Holdaways could plant more durable eucalypts on their large forestry property where it is likely the Forest Measurement System (FMA) is applied, and participant-specific tables are used. The existing eucalypt blocks and any new planting will be measured within any compulsory emissions return period, and an additional participant-specific table showing the annual carbon sequestered by the eucalypts produced.

The Marlborough Regional Forests estate is on pre-1990 land, which is ineligible for the ETS.

[10] https://www.nzwine.com/media/22253/nz-winegrowers-sustainability-report-2022.pdf
[11] https://fgr.nz/documents/download/10587?161537090
[12] https://pce.parliament.nz/publications/how-much-forestry-would-be-needed-to-offset-warming-from-agricultural-methane/

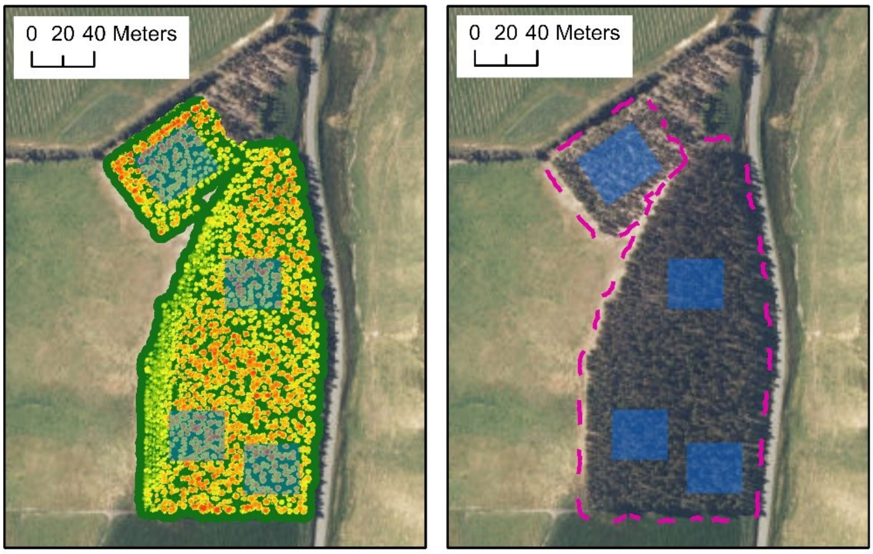
4 Individual property case study outcomes

4.1 The Lawson property

The Lawson property is an approximately 80-hectare farm running a low-intensity beef cattle operation. There is also a small radiata pine plantation, some spaced poplars and willows, and a 2.87ha NZDFI *E. bosistoana* breeding trial planted in 2009 (Map 2). This includes four PSPs that were re-measured in summer 2022/23.

MPI SLMACC 406896

Landowner Case Study Biomass Sampling Site 051 Lawson
2009 Eucalypt Breeding Trial Total Area 2.87 ha
E. bosistoana, 3x 0.1117 ha PSPs and 1x 0.155 ha PSP's measured highlighted in blue



Map 2: Lawson property eucalypt trial area. Left: LiDAR image Right: Drone based aerial image

The farm topography is easy to moderate slope hill slopes and the soils derived from sedimentary conglomerate with loess overlying some slopes. The average annual rainfall is 727mm with average July minimum temperature of 1.9 degrees.

The property is 31 km by road from the proposed Riverlands hub.

4.1.1 Plot level model simulation outputs – Lawson property

This *E. bosistoana* breeding trial was planted in 2009 on a moderately sloping, north and east facing grassed hill. It was laid out in 150 single-tree-plots with 30 trees per plot in a 1.8m x 2.4m spacing which is 2315 stems per hectare.(spha). The first height assessment was undertaken at age 3 and 98.5% survival was recorded. A second assessment at age 5 included measurement and some thinning to collect early wood samples for analysis. A third assessment at age 7 included collection of core samples followed by thinning to reduce the stocking to around 1200 spha. A fourth assessment at age 10 was followed by thinning the trial to the current stocking of around 600-700 spha. No further thinning is planned. The most recent measurement PSP data has been used to undertake growth modelling with the average values shown in Table 4.

Plot level simulations predict that a total stem volume of 80m^3/ha could be possible from this *E. bosistoana* trial block by age 20. This is only 4m^3/ha mean annual increment (MAI). Therefore, another 5 years of growth continuing at this rate are needed to reach 100m^3/ha. This low productivity is in part due to high natural mortality predicted by the model with spha declining to around 500 spha by age 20. Natural mortality in low-rainfall regions can occur due to drought and inter tree competition. However, given the model limitations, it is possible that the level of mortality is being over predicted.
There is a low prediction at this stage for the heartwood volume. As the trees get older this could increase at a faster rate than predicted by the model.

Table 4: Model simulations based on average values at age 13 for four E. bosistoana PSPs at the Lawson property. Stem volume is total stem wood volume. Stem biomass is stem biomass inside bark, and branch biomass is total branch biomass including bark.

Age	Mean top height m	Basal area m^2/ha	Stem diameter at breast height cm	Stems/ha	Stem volume m^3/ha	Heartwood vol m^3/ha	CO2-e t/ha	Stem biomass t/ha	Branch biomass t/ha
13	13.1	10.8	14.5	657	35.0	5	96.5	20.5	11.0
14	14.0	12.1	15.4	634	41.5	6.3	111.3	24.3	13.0
15	14.8	13.4	16.1	610	48.8	7.5	126.8	28.0	15.0
16	15.6	14.6	16.9	586	56.0	9.3	142.3	31.8	17.0
17	16.5	15.8	17.5	563	63.8	11.0	157.8	36.0	19.3
18	17.3	17.0	18.2	539	71.8	12.8	173.8	40.3	21.8
19	18.1	18.1	18.8	516	80.0	14.8	190.3	44.5	23.8
20	19.0	19.2	19.4	494	88.8	17.0	205.8	49.0	26.5

Stem volume is total stem wood volume. Stem biomass is stem biomass inside bark, and branch biomass is total branch biomass including bark.

Based on these simulations, the property is suitable for planting additional durable eucalypt forestry areas and managing these under a 25-year post regime. Fertile sheltered lower slopes and wet frosty areas could be planted with *E. bosistoana. Eucalyptus cladocalyx* could be planted on the exposed upper slopes and ridges. The property is also suitable for planting *E. globoidea* forestry areas based on the outputs for the Avery trial block which is only 7 kilometres away (see Map 1 and Section 3.2).

4.1.2 Emissions calculations – Lawson property

To calculate emissions from farming operations, the MfE 'Calculate your agricultural emissions' on-line calculator was used. It is re-emphasised that the MfE calculator is a blunt tool.

Inputs

- 96 cattle (30 cows plus calves to two years)
- 10 sheep
- No fertiliser containing nitrogen; 300 kg lime (impact is minimal)

Outcome:
The MfE calculator generates a figure for the total annual emissions from the Lawsons farming operations of **179.2 tCO_2e.**

The MfE calculator indicates that the Lawson's 2.87 ha of E. bosistoana are sequestering 102.1t CO2e/yr (35.5tCO2e/ha/yr), reducing total annual property emissions to around 77.2t CO2e/yr.

This contrasts with an estimate derived from average amount in the TuR look-up tables of a total of around 76.3t CO2e/yr for 2.87ha of eucalypts (26.6t CO2e/ha/yr).

By comparison, the School of Forestry growth model data predicts a much smaller amount of carbon is being sequestered annually by the 2.87 ha E. bosistoana trial up to age 20:
29.5t CO2e/yr for 2.87 ha (10.3t CO2e/ha/yr)

Table 5: Comparison of E. bosistoana carbon sequestration tCO2e/ha/yr estimates from various sources for the Lawson property.

Estimated carbon sequestration tCO2e/ha/yr to age 12-13		
MfE	TuR	SoF
35.5	26.6	10.3

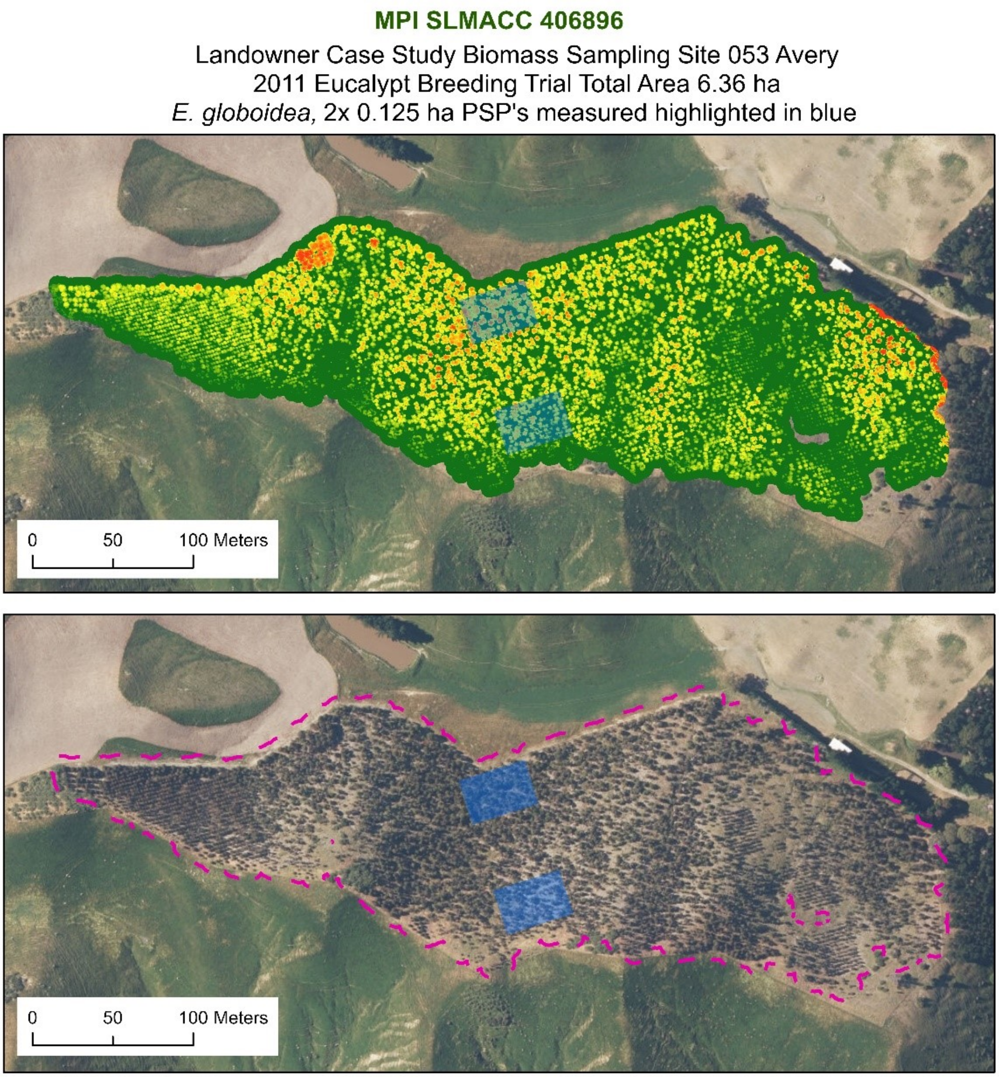
If the additional approx. 2 ha of radiata and 2 ha of poplars and willows are also entered into the MfE calculator, the outcome becomes an overall positive carbon balance for the property of 65.1t CO2e/yr.

Any new eucalypt planting on post-1989 land that is entered into the ETS would be eligible for the averaging allocation of a total of 320 NZU/ha over years 1-12, potentially generating a cash income for the owners.

4.2 The Avery property

The Avery property is around 2,550 ha large scale livestock and cropping property on some of the driest land in Marlborough. There are older farm trees, shelterbelts and pine woodlots on the property as well as some remnant patches of dryland native forest. There is also a 6.3 ha NZDFI *E. globidea* and *E. tricarpa* breeding trial planted in 2011 (Map3).

This includes two PSPs that were re-measured in summer 2022/23. See Map 3 below.



Map 3: The Avery property eucalypt trial area. Top: LiDAR image Bottom: Drone based aerial image.

The farm topography is diverse with flat arable paddocks as well as easy to moderate to steep hill country. The soils are derived from mudstone with loess overlying some slopes. There are areas of tunnel gully and slump erosion. The average annual rainfall is 632mm with average July minimum temperature of 3.4 degrees.

The property is 35km by road from the proposed Riverlands hub.

4.2.1 Plot level model simulation outputs – Avery property

This *E. globoidea* breeding trial was planted in 2011 on a moderate to steep sloping, north facing grassed hill. It was laid out in 298 single-tree-plots with 36 trees per plot in a 1.8m x 2.4m spacing which is 2315 sph. 16 blocks were abandoned following a survival assessment at 18 months with 12 blocks of these replanted with *E. tricarpa* in 2013. There was no assessment until age 9 when this was completed including collecting cores for wood properties analysis. At that stage, overall trial survival for the blocks measured was 62% (38% mortality) although variation in family survival ranged from 96.9% to 20.3%. The trial was thinned at age 10 to the current stocking of around 900-1000 spha. There is significant variability in growth across this trial, reflecting a combination of both genetic and site influences. Optimal growth is in the sheltered gullies and low-mid slopes where one PSP was first measured in 2015. This was re-measured in summer 2022/23 for the case study along with a new second PSP that was established on the upper slopes. The data from the most recent measurement of these two PSPs has been used to undertake growth modelling with the average values shown in Table 7.

Plot level model simulations predict that a total stem volume of 163m^3/ha is possible from this trial block by age 25. This is only 6.5m^3/ha MAI . This low productivity is in part due to a steady prediction of natural mortality due to drought and inter tree competition.

Table 6: Model simulations based on average values at age 11 for two E. globoidea PSPs at the Avery property.

Age	Mean top height /m	Basal area m²/ha	Stem diameter at breast height cm	Stems/ha	Vol m³/ha	Heartwood vol m³/ha	CO2-e t/ha	Stem biomass t/ha	Branch biomass t/ha
11	9.5	13.0	13.0	988.5	30.5	5.5	76.5	14.0	19.5
12	11.0	14.6	13.8	983.0	39.5	8.5	95.5	17.5	23.5
13	12.5	16.1	14.6	977.5	48.5	11.5	115.5	21.5	27.5
14	14.0	17.6	15.3	972.0	58.5	16.0	136.5	26.0	32.0
15	15.4	18.9	15.9	966.5	69.0	21.0	157.5	29.5	35.5
16	16.8	20.2	16.5	961.0	79.0	26.0	178.5	34.5	40.0
17	18.1	21.4	17.0	956.0	89.5	31.0	200.0	39.0	44.0
18	19.3	22.5	17.5	950.5	99.5	37.0	220.5	43.0	48.0
19	20.4	23.5	17.9	945.0	109.5	42.5	241.0	47.5	52.0
20	21.6	24.4	18.3	939.5	119.5	48.5	260.5	51.5	55.0
21	22.6	25.4	18.7	934.5	129.0	54.5	279.0	55.5	58.5
22	23.5	26.2	19.1	929.0	138.0	60.0	297.5	59.5	62.0
23	24.4	27.1	19.4	924.0	147.0	66.5	315.0	63.5	65.0
24	25.2	27.8	19.8	919.0	155.5	72.5	331.0	66.5	67.5
25	25.9	28.5	20.1	913.5	163.5	78.0	346.5	70.0	70.0

Based on these outputs, the property is suitable for planting additional *E. globoidea* forestry areas and managing these under a 25-year post regime. Based on the Lawson trial block outputs which is only seven kilometres away, *E. bosistoana* could also be planted on the fertile sheltered lower slopes or in wet and frosty areas. In addition, there are several small blocks of *E. cladocalyx* already established on the property that demonstrate this species can be grown on exposed upper slopes and ridges.

4.2.2 Emissions calculations – Avery property

The MfE calculator was again used to estimate the main net carbon balance figures for the property.

Inputs:

- 6653 sheep (average numbers for the given year)
- 1013 beef cattle
- 14010 kg fertiliser (urea with urease inhibitor)

The table below illustrates the output from the MfE calculator for the Avery's farming enterprises.

Table 7: MfE Calculator output for the Avery farming enterprises.

Results

Calculated on 21/11/2023

4264.1 tonnes

CO_2-e emitted per year

4264.1 emitted
due to animals and fertiliser
0 absorbed
by forests
0 emitted
by felled forests

Provide details of your farm above.
Note: Most amounts are expressed in tonnes of CO2 equivalent emitted per year. Very small emissions figures (under 0.1 tonnes) are not shown. Read more about how this is calculated. (https://environment.govt.nz/publications/measuri emissions-a-guide-for-organisations-2022-detailed-guide/)

Yearly emissions breakdown

(tonnes CO_2-e per year)

Source Total tonnes CO_2-e	Methane tonnes CO_2-e	Nitrous oxide tonnes CO_2-e	Carbon dioxide tonnes	Total tonnes CO_2-e
Digestion 3675.7 emitted	3675.7 emitted	None	None	**3675.7** emitted
Manure management 45.1 emitted	45.1 emitted	None	None	**45.1** emitted
Agri soils 512 emitted	None	512 emitted	None	**512** emitted
Fertiliser use 31.4 emitted	None	21 emitted	10.4 emitted	**31.4** emitted
Forests	None	None	None	None
Totals	**3720.7** emitted	**533** emitted	**10.4** emitted	**4264.1** emitted

In addition, Fraser Avery provided figures for total annual fuel use. Fuel is not included in the MfE calculator. The litres of petrol and diesel used can be converted into tCO2e/yr equivalent as follows:

Table 8: Avery property annual fuel use and associated emissions.

Fuel	Annual on-farm use (litres)	Conversion factor [13]	Kg CO2e/yr	t CO2e/yr
Diesel	12,821	x 2.69	34,488	34.5
Petrol	6,653	x 2.48	16,499	16.5
Total				**51.0**

In total, therefore, the estimated annual net carbon emissions for the Avery property for the given year is (4264.1 + 51.0) = **4,315.1 tCO2e/yr**

Using the MfE calculator, the Avery properties existing 6.3 hectares of durable eucalypt trials offset these emissions by around 224t CO2e/yr (35.5t/CO2e/ha/yr). This contrasts with an average estimate derived from the TuR look-up tables of a total for the 6ha of approximately 167.6t CO2e/yr (i.e. around 26.6t CO2e/ha/yr),

By comparison, the School of Forestry growth model data predict a smaller amount of carbon is being sequestered annually by the 6.3ha durable eucalypt block up to age 25: 87.6t CO2e/yr for 6.3 ha (13.9t CO2e/ha/yr).

[13] https://environment.govt.nz/assets/publications/Measuring-emissions-guidance-August-2022/Detailed-guide-PDF-Measuring-emissions-guidance-August-2022.pdf

Table 9: Comparison of annual E. globoidea carbon sequestration tCO2e/ha/yr estimates from various sources for the Avery property.

Annual estimated carbon sequestration tCO2e/ha to age 12		
MfE	TuR	SoF
35.5	26.6	13.9

Over the last ten years there has been significant planting by Fraser Avery that has included durable eucalypts as well as native plants, oaks and other species. These were too extensive to assess within the scope of this case study. Therefore, these areas have not been accounted for under the MfE calculator or under the ETS in the Avery property case study.

Some of these additional planted areas, and any further new eucalypt planting on post-1989 land maybe eligible to be entered into the ETS. All exotic hardwoods will receive a total of 320 NZUs/ha over years 1-12 under the averaging scheme (other species would receive different amounts) potentially generating a cash income.

However, if over 100ha are eventually planted, then the trees will need to be measured and participant-specific tables generated to estimate the averaging allocation. This would result in a much lower allocation of NZUs.

4.3 The Holdaway property: 'Lowlands' vineyards and winery, and Wairau Valley forestry block

The Holdaway property comprises 155-hectares of vineyards in the Wairau Valley, and a winery near Blenheim. There is no scope for production forestry plantations within the vineyards.

However, the Holdaway family also owns a 2500 ha forest property comprising 500 ha of recent plantations and the remainder regenerating native bush, substantial areas of which registered within the ETS. Their plantations include a trial block of 6ha that was planted in 2021 to evaluate a mix of durable eucalypt species. As the Holdaway family has over 100 ha of plantations registered in the ETS they must use the Field Measurement Approach to be allocated NZU's rather than use the TuR look-up tables.

While these forests already offset the total annual emissions of the vineyard and winery business, this isn't possible directly via the ETS. Rather the Holdaway family's interest in planting the durable eucalypt trial was to assess the potential to grow posts for their vineyards.

Their forestry property is moderate to steep hill country with greywacke derived soils. The average annual rainfall is 1114mm with average July minimum temperature of -0.5 degrees. The durable eucalypt trial is on an easy to moderate sloping north facing site.

The forestry property is 65km by road from the proposed Riverlands hub and 55km by road from the proposed Kaituna hub.

Within the NZDFI trial blocks are a mix of both unimproved and early *E. bosistoana* XyloGene seedlots as well as the first clonal trials of this species. There are also trial blocks testing an early *E. globoidea* XyloGene seedlot. There were two PSPs measured, one each of *E. bosistoana* and *E. globoidea*. However, slow early growth rates of the species in this young trial resulted in insufficient data for LiDAR analysis or to simulate in the plot level models.

However, NZDFI has a similar trial in the Waihopai Valley on the Dillon property. This is one of the properties where trees were destructively sampled for the SoF biomass research undertaken as part of this project.

Based on PSP data at the Dillon site, productivity at the Holdaway forest property is expected to be low and a 25-year post rotation for clearfell harvest is likely. However, there are a diversity of species and variable growth rates across the trial. It could be feasible to commence thinning around age 15 years and to extract stems for on-site peeling using a mobile unit to produce posts for replacements in the Lowlands vineyard provided that the trees have developed adequate hardwood.

4.3.1 Emissions calculations – Holdaway property

In this case study, industry averages from the SWNZ 2022 report have been used to estimate emissions from the vineyard and winery (2020 vintage) as follows:

Vineyard: 155 ha; emissions of 1.28 t CO2e/ha/yr = total emissions of 198.86 tCO2e/yr

Winery: although some wine is sold in bulk, most emissions are associated with the wine that is bottled by Lowlands (1,440 tonnes of grapes was converted into 54,844 litres, or 73,125 bottles of wine, in 2020).

Industry emissions per bottle are estimated at 258g CO2/e per bottle, giving total emissions for **the winery of 18.87 tCO_2e/yr to the winery gate.**

Total emissions for the year based on industry averages for both the vineyard and the winery: (198.86 + 18.87) = 217.73 t CO2e/year.

More detailed calculations
Robert Holdaway is working towards sustainability certification and is calculating both the vineyard and wineries GHG emissions in detail. Robert's calculations include Scope 2 and 3 emissions. For example, vineyard emissions accounted for are predominantly different types of fuel (mainly diesel, also some petrol and LPG); also, electricity, gypsum (embodied emissions and application by contractor, sprays (embodied emissions), and waste disposal.

Winery emissions accounted for include wine production, bottles, caps, labels and cartons, as well as transport of packaging to the winery and emissions associated with transporting bottled wine to domestic and international markets. Also, overseas travel by business representatives associated with wine marketing.

These calculations are currently confidential. However, both vineyard and bottled wine emissions at Lowlands are below industry averages.

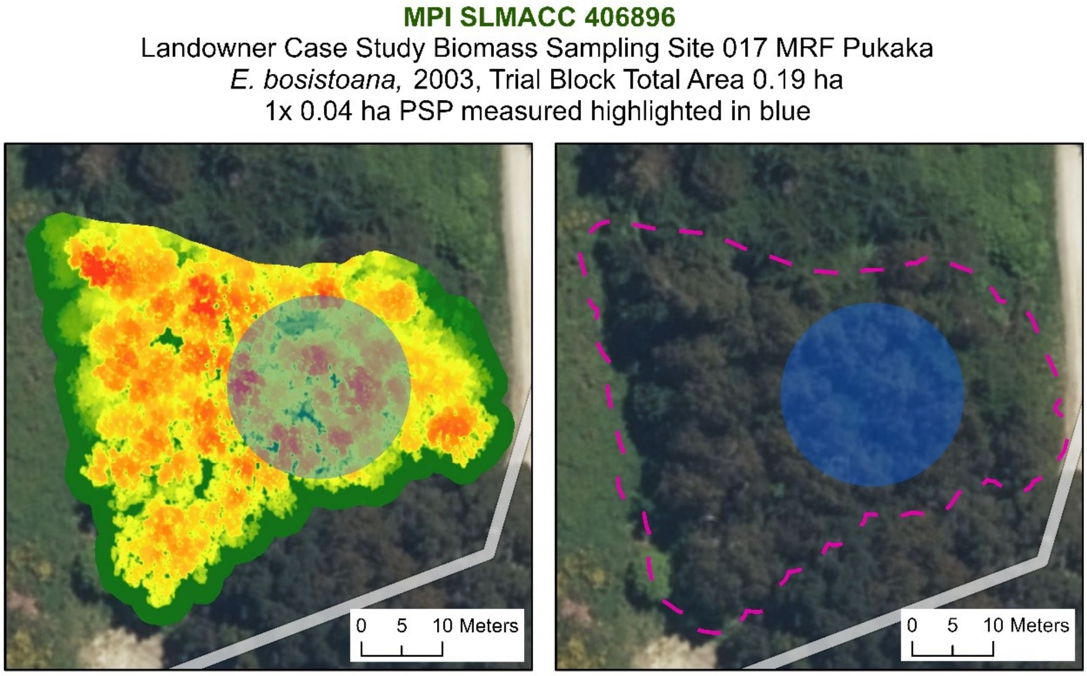
4.4 Marlborough Regional Forests Pukaka Forest

Marlborough Regional Forests (MRF) Pukaka Forest is a pre-1990 forest and is part of a bigger estate owned by Marlborough District Council and Kaikoura District Council. The forest topography is steep hill slopes with low fertility soils derived from schist. The average annual rainfall is 936mm with average July minimum temperature of 3.2 degrees.

Pukaka Forest is around 27 km from the Kaituna hub and a similar distance to the Riverlands hub.

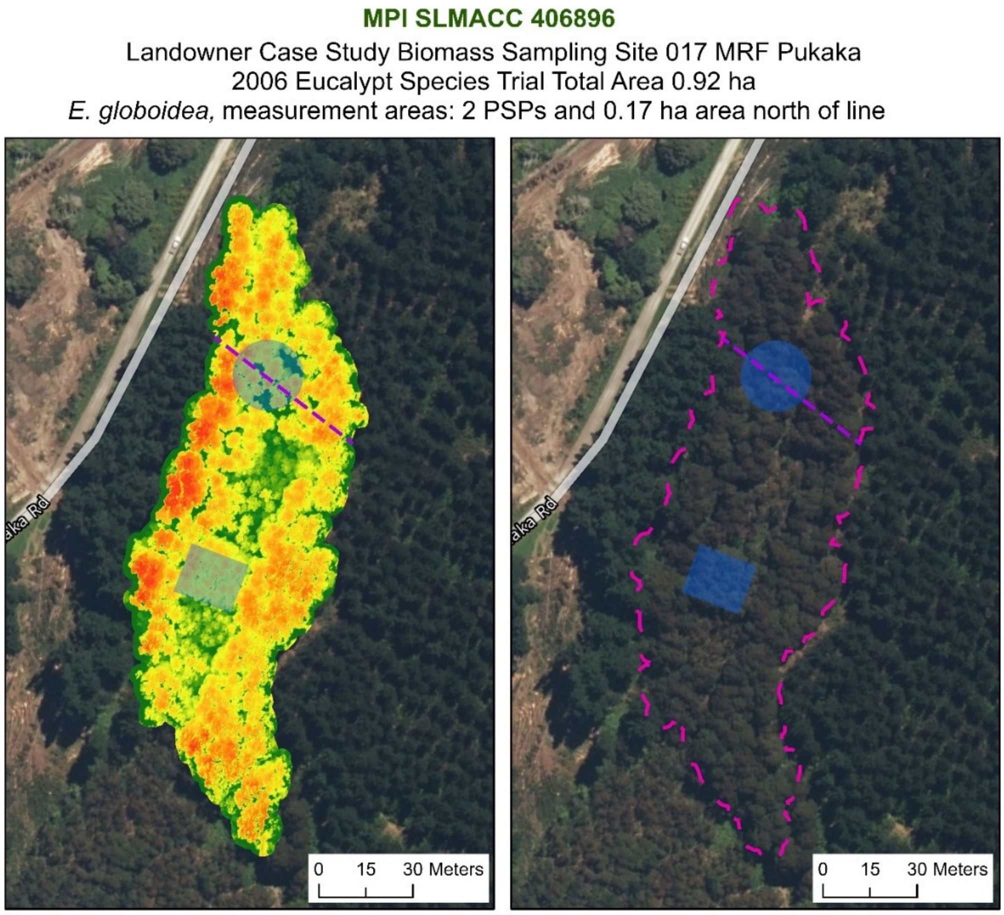
In this forest, there are two durable eucalypt forestry blocks with PSPs that were measured re-measured in summer 2022/23.

One of these is a small roadside 0.19 ha stand of *E. bosistoana* planted in 2003 (Map 4).



Map 4: The MRF Pukaka E. bosistoana trial area-. Left: LiDAR image Right: Drone based aerial image

The second is a steep pine cutover site planted with pine in early 1970's and harvested in 2005. When replanted in 2006 a 0.92 ha mixed species trial block was established with a surround of predominantly *E. globoidea* (Map 5)



Map 5: The MRF Pukaka durable eucalypt trial area-. Left: LiDAR image Right: Drone based aerial image

4.4.1 Plot level model simulation outputs – Pukaka Forest

Eucalyptus bosistoana
This informal trial block of *E. bosistoana* was planted in 2003 on an open grassed flat river terrace at around 3m x 2m spacing which is 1667 spha. There was good survival following planting and tress were form pruned at age 2. Low pruning was undertaken at age 4 followed by high pruning at age 7 and the trial then thinned to its current stocking of around 775 spha. A PSP that was first established in part of trial at age 12, was remeasured in summer 2022/23 for the case study.

As the trial block was already age 19 at the time of measurement the plot level model simulations predict at that a total stem volume of 165 m³/ha. This is an MAI of 8.7 m³/ha which is more than double that predicted in the Lawson trial block.

Table 10: Model simulations at age 19 for 0.04ha E. bosistoana PSP at Marlborough Regional Forests Pukaka property.

Age	Mean top height /m	Basal area m²/ha	Stem diameter at breast height cm	Stems/ha	Stem vol m³/ha	Heartwood vol m³/ha	CO2-e t/ha	Stem biomass t/ha	Branch biomass t/ha
19	20.75	32.6	23	775	165	37	346	81	96

Based on these outputs, there may be suitable sites within the MRF estate that could be suitable for new *E. bosistoana* plantations and managing these under a 25-year post regime.

Eucalyptus globoidea
This informal trial *E. globoidea* was planted in 2006 on a pine cutover north facing hill slope at around 3m x 2m spacing which is 1667 spha. There was good survival and the block was form pruned at age 2. Low pruning was undertaken at age 4 followed by high pruning at age 7. The block was then thinned to its current stocking of around 500-550 spha. A PSP was first established in part of trial at age 9 and was remeasured in summer 2022/23 for the case study. In addition, a 0.17 ha block was also measured to provide a much greater data set for plot level modelling.

Plot level model simulations predict that a total stem volume of 467 m³/ha is possible from this trial block by age 25 with a low level of natural mortality. The MAI predicted is 18.7 m³/ha which is three times greater than the predicted MAI of only 6.5 m³/ha for the Avery trial.

Table 11: Model simulations at age 16 for E. globoidea 0.17ha trial block at Marlborough Regional Forests' Pukaka property.

Age	Mean top height /m	Basal area m²/ha	Stem diameter at breast height cm	Stems/ha	Stem vol m³/ha	Heartwood vol m³/ha	CO2-e t/ha	Stem biomass t/ha	Branch biomass t/ha
16	26.3	51.4	34.4	553	292	193	461	125	38
17	27	54.4	35.5	550	316	213	496	135	40
18	27.6	57.2	36.5	547	338	232	529	144	43
19	28.2	59.9	37.4	544	360	251	560	153	45
20	28.7	62.3	38.3	541	380	268	589	162	47
21	29.1	64.7	39.1	538	399	284	617	170	50
22	29.5	66.9	39.9	535	418	300	642	178	51
23	29.9	68.9	40.6	532	435	315	667	185	53
24	30.2	70.9	41.3	529	451	329	689	192	55
25	30.5	72.7	42	526	467	343	710	199	56

Based on these outputs, the MRF estate has suitable sites for new *E. globoidea* plantations and managing these under a 28–32-year sawlog regime to produce a total of 500-600 m^3/ha at harvest.

The high productivity on the Pukaka Valley site is largely due to the annual rainfall of around 1200mm being almost double that of the Avery (and Lawson) sites.

For MRF, the decision to replant radiata pine cut-over with durable eucalypts is likely to be based on (i) confidence in future markets where returns will be competitive with pine, (ii) a desire to diversify away from a forest enterprise dominated by a single species.

4.4.2 Emissions calculations – Pukaka Forest

Because the forest is pre-1990, and initially was planted on land probably cleared of woody vegetation, we have assumed that there is no 'new' carbon being sequestered. However, harvesting and replanting operations are happening as the plantation crops mature, and one element of interest is the emissions associated with forest operations, roading and harvest operations (i.e. machinery).

For these calculations, a 91 ha radiata pine compartment planted in 2006 alongside the 0.92ha durable eucalypt trial block was used to undertake an evaluation. Harvesting has been estimated at an annual rate of 3.48ha per year, based on a 28-year rotation. In reality, the actual amount of harvesting will be 'lumpy', with no harvesting is some years and much larger areas harvested in others.

Harvest operations emissions can be estimated using data published by the University of Canterbury School of Forestry[14] A total recoverable volume (TRV) of 600t/ha has been used to calculate the estimated emissions by forest harvesting machines, and it is estimated that 80% of the area is harvested using a tower yarder (cable hauler) and 20% using ground-based methods.

Roading and forest management emissions (i.e. emissions associated with activities such as pruning, thinning and forest management during the rotation) have been estimated by correlating harvesting emissions with the emissions information published by large Marlborough/Nelson forest owner OneFortyOne in their Environment and Social Monitoring Report 2020, which gives details of the proportions of total emissions produced by different forest production activities.

Based on the estimated annualised harvest of 3.48 ha/yr, the annual emissions within the forest gate calculated are as follows:

Table 12: Estimated annual operating emissions, Pukaka Forest

Annual operating emissions	t CO2e
Harvesting operations	29.04
Forest operations	1.94
Roading operations	6.78
Total estimated annual emissions within the forest gate	**37.75**

(N.B. The average annual emissions associated with log transport including shipping have been excluded from these calculations, but based on OneFortyOne estimates, these are likely to be around double the total emissions within the forest gate.)

A calculation using the ETS look-up tables of net annualised sequestration of the forest (including losses from harvest and residual decay and the above operating emissions) gives a positive figure of over 1,965 tCO_2 e for the total 97.5ha area. Because this is not 'new' carbon, and the forest is ineligible for the ETS, these gains have no monetary value. They would largely have to be repaid at harvest. However, they do provide an indication of the value of standing forests in short-term carbon sequestration.

[14] https://fgr.nz/documents/download/10587?161537090

5 Conclusion

These case studies are intended to inform the landowners involved and others that may want to invest in planting durable eucalypts for potential timber, carbon or environmental benefits (or a combination of these). The case study outcomes demonstrate there are both environmental variation and ETS provisions that need consideration.

Of particular significance is the contrasting north and south Marlborough environments with modelling outputs for both *E. bosistoana* and *E. globoidea* revealing that north Marlborough has over 100% greater productivity for both species.

As landowners will have different site and environmental conditions: species must be matched to site. Also harvesting must be feasible and the site well located to supply one of the future regional hubs for processing into posts, timber, veneer and woody biomass. The scale of forest area needs to match what any given landowner can plant and manage.

Ultimately future returns to growers will depend on several key factors including planting costs and interest rates; growing regime, site productivity and harvest age; transport distances to processing hubs, and product value being driven by market demand and supply. For sites that register in the Emissions Trading Scheme, the NZU (carbon) value could significantly improve grower economics.