Evaluation of *Eucalyptus macrorhyncha* and class 1 durable red timber eucalypts for New Zealand environments

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EXECUTIVE SUMMARY

This report follows on from SWP Technical Report T164 and ITP Technical Report T013. These reports provide comprehensive results and analysis from twenty-two of New Zealand Dryland Forest Innovation's (NZDFI) demonstration trials planted between 2011 and 2018.

Rich red appearance-grade timber for decorative joinery, furniture and other high-end products attracts premium value in Australian and Asian markets. New Zealand-grown hardwoods have the potential to replace unsustainable wood from natural stands of tropical species to supply local and international markets.

The NZDFI selected four red-timber eucalypt species, *Eucalyptus macrorhyncha, E. argophloia, E. tricarpa* and *E. longifolia* for their potential to be grown in New Zealand environments and produce a resource of high-value timber.

These species are represented in NZDFI breeding and silviculture trials planted between 2011-2018 across a range of site types in the North Island and north-eastern South Island, from Northland to Canterbury. Permanent sample plots (PSPs) were measured in these trials to evaluate each species' adaptability and productivity in New Zealand.

Eucalyptus macrorhyncha and *E. tricarpa* have shown good growth and site adaptability and are candidates for genetic development. Further investment in testing the wood properties of *E. tricarpa* in the breeding population is recommended.

Conversely, *E. argophloia* and *E. longifolia* were generally less adaptable and productive with poor stem form across the 19 trials. No further investment is required other than remeasurement of the PSPs every 3 – 5 years.

INTRODUCTION

Background

New Zealand's annual imports of high-value sawn lumber and other hardwood products have a 5-year average value of over $1,500/m^3$ in 2019 hardwood sawn timber imports had a total estimated value of over $112.5 million. Investment in planting regional wood supply catchments of eucalypt forests to produce naturally durable/high-stiffness hardwood, and centred on regional processing operations, could largely replace these imported timbers.

Rich red appearance grade timber attracts premium value in Australian and Asian markets, where they are used for decorative joinery, furniture and other high-end products. Global supply of these timbers is unsustainable being mainly from natural stands of tropical species (often illegally logged). Greater protection and law enforcement to restrict logging of these forests will reduce future supply to international markets. For example, West Australia's jarrah *(E. marginata)* timber industry will close in 2024.

NZDFI's long-term strategy is to enable large-scale establishment of diverse durable eucalypt forests that will provide economic returns to growers, produce timber and timber products for domestic and export markets, and improve the New Zealand forestry and wood products sectors' resilience to supply chain challenges, climate change, and other biological and economic risks.

In 2010 NZDFI selected class 3 pink-brown coloured timber species - *E. macrorhyncha* and three class 1 red coloured timber species *E. argophloia, E. tricarpa* and *E. longifolia* - to test their potential to grow a resource of high value timber in New Zealand environments (Table 1).

Table 1: Red timber species selected by NZDFI for trialling.

Group	Botanical name	Common name	AS 5604 In ground durability	AS 5604 Above ground	Heartwood colour
Class 2 & 3 Brown Heartwood	*E. macrorhyncha*	Red stringy bark	3	1	Pink/brown
Class 1 & 2 Red Heartwood	*E. argophloia*	Qld western white gum	1	1	Dark red/brown
	E. longifolia	Woollybutt	1	1	Red
	E. tricarpa	Red ironbark	1	1	Dark red

Eucalyptus macrorhyncha was first identified twenty years ago as a potential New Zealand plantation species and was subsequently established in a succession of regional trials. These trials demonstrated the site versatility and high natural insect tolerance of this species. It is reported to produce a pink-brown coloured class 2-3 hardwood useful for above ground applications. It flowers in autumn, producing nectar and pollen for bees and native birds. Selection and improvement of *E. macrorhyncha* has potential to diversify and extend planting of durable hardwood forests to colder dry New Zealand environments.

Eucalyptus argophloia, E. longifolia and *E. tricarpa* are renowned in Australia for producing rich red-coloured class 1 durable timber. The potential commercial opportunity to grow *E. argophloia, E. tricarpa* and *E. longifolia* was identified by NZDFI in 2009. This was despite there being little experience with growing these species in New Zealand. In 2011, NZ Dryland Forests Initiative (now New Zealand Dryland Forests Innovation) deployed trials to evaluate all of these species' adaptability to dryland New Zealand environments.

The NZDFI demonstration trial network

NZDFI's breeding, research and development programme centres around a comprehensive network of demonstration trials established between 2011 and 2018 across much of the North Island and north-eastern South Island (Fig 1). These trials have been established thanks to the cooperation of landowners who host the trials, and often contribute significantly to their establishment and maintenance.

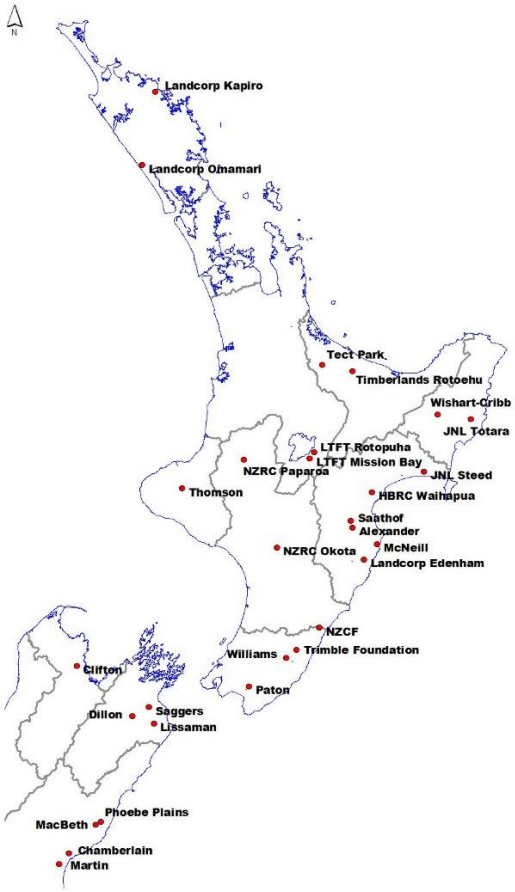

Fig 1: NZDFI demonstration trials planted 2011-2018.

Full details describing the species choice and other factors about these trials, including results from recent analyses, are provided in SWP Technical Report-T164: *Variation in adaptability and productivity between durable eucalypt species in different New Zealand environments*. An ITP Technical Report-T0013:*A comparison of the performance of six eucalypt species planted in 2018 NZDFI demonstration trials* is also available.

Eucalyptus macrorhyncha, E. argophloia, E. tricarpa and *E. longifolia* are represented in NZDFI trials planted 2011-2018 with over 50 PSPs located across 21 sites. In addition, NZDFI has small breeding programmes of *E. argophloia* planted in 2011 and *E. tricarpa* planted in 2011 and 2017. This trial network provided a valuable resource and 18 trials located across eight regions were measured to evaluate tree growth and site adaptability and select candidate trees for heartwood sampling.

In 2005 a mass selection planting with a mix of five provenance seedlots from Australia (Clare, Gunning, Stromlo, Avoca and Uriarra Road) of *E. macrorhyncha* was planted at Waikakaho, Marlborough. *Eucalyptus macrorhyncha* was also planted in a number of trials in Marlborough Regional Forests in 2005 and by Marlborough landowner, Roy Grose, between 2006 and 2009. These forest stands and trials of *E. macrorhyncha* provide a NZ genetic pool for selecting locally adapted elite trees for a future tree breeding programme.

Planning the current project

This project was planned under two stages:

Stage 1 – Trial assessment and candidate tree selection (February to June 2023) to:

a) report on the plantation potential of *E. macrorhyncha* for New Zealand environments

b) select elite individuals of *E. macrorhyncha* for seed collection to extend NZDFI's durable eucalypt breeding programme and diversify New Zealand's future hardwood forests

c) evaluate and report on the suitability of *E. argophloia, E. tricarpa* and *E. longifolia* for commercial plantation deployment in New Zealand dryland environments.

Stage 2 – Heartwood assessments and report on project outcomes (July 2023 to June 2024).

METHODS

Stage 1 involved site visits to 19 trials located across eight regions to assess tree growth, form and select candidate trees for heartwood sampling. In addition, candidate seed trees of *E. macrorhyncha* were identified (Fig 2). Two NZDFI demonstration trial sites planted in 2014 were planned for assessment but could not be visited due to the impact of Cyclone Gabrielle in February 2023. These are located at the Hawkes Bay Regional Council Waihapua forest and Lake Taupo Forest Trust. Details of the trial location, silviculture and environmental factors for each site is provided in Appendix 3.

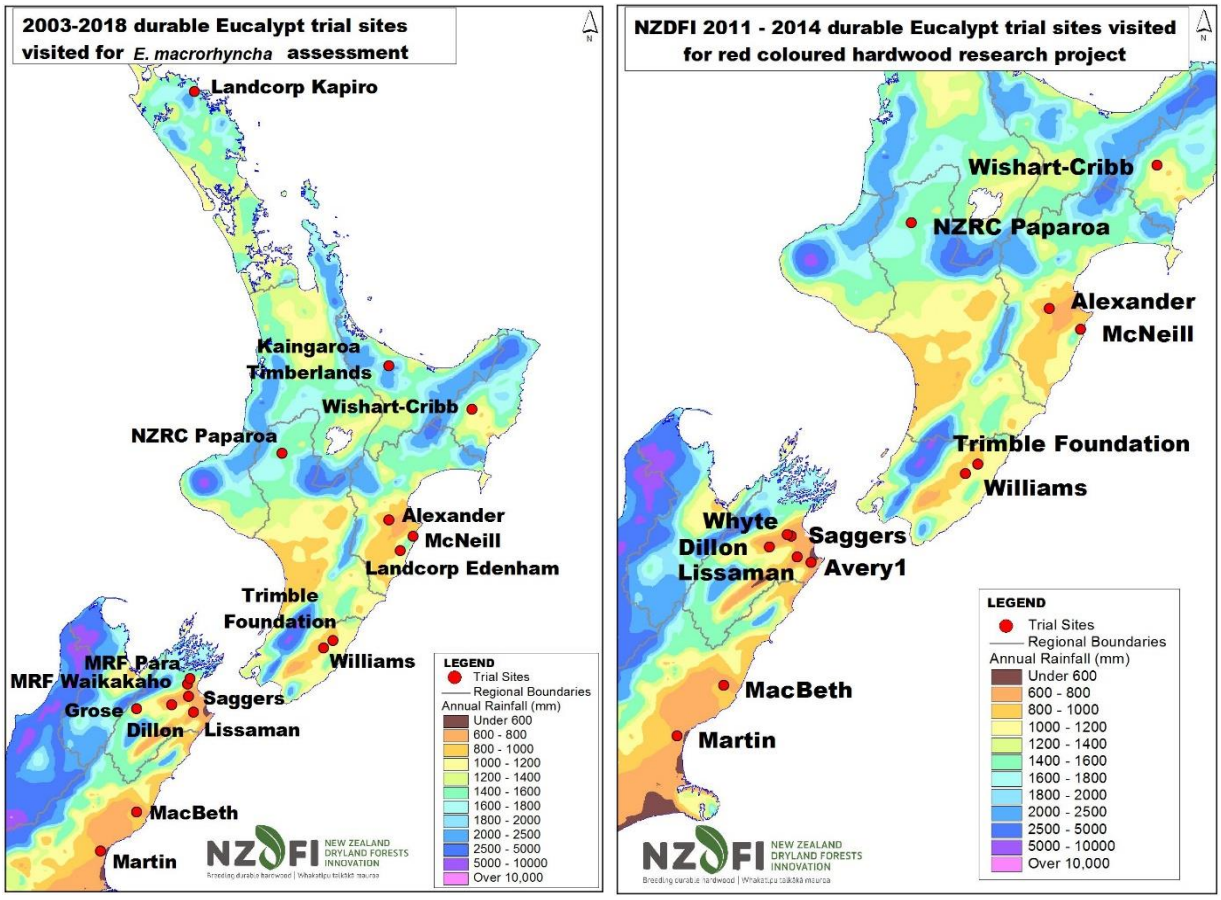

Fig 2. Location of trial sites assessed.

Origin of the seedlots planted in the trials

E. argopholia	First generation seed imported from DAF Orchard, Australia, deployed in 2011 and 2014.
E. longifolia	Seedlot 09/738, a Proseed collection from Kerikeri, deployed in 2011 and in 2014.
E. macrorhyncha	A mix of three unimproved Australian provenance seedlots, deployed in 2011, 2013 and 2014.
	12 individual families selected from a mixed provenance planting at MRF Waikakaho, Marlborough, deployed in 2018.
	A mix of four unimproved Australian provenance seedlots, deployed at Grose property, 2006-2009.
E. tricarpa	A mix of two unimproved Australian seedlots, deployed in 2011 with only one of these planted in 2013 and 2014.
	Mixed Australian seedlot of 4 families planted in NZDFI 2016 breeding population trials, deployed in 2018.

The demonstration trials were initially planted as replicated species blocks of 49 or 100 trees. The diameter breast height (DBH) and total height of all surviving trees was measured and a score, 0 and 1, recorded for each tree to identify an unacceptable or acceptable crop tree. This is a simple and efficient method to characterise the tree form and growth. The full list of trials assessed and results is summarised in Appendix 1.

A target sample of 25 trees per site of each species was to be marked for coring. However, at some sites there were insufficient suitable trees and fewer trees were selected. A list of the species and number of trees marked at each site is shown in Appendix 2.

The mean top height mean annual increment (MTHMAI) of the top 25% of each species was calculated. The percentage of acceptable stems of each species was averaged and reported for each trial.

In addition to the trial assessments, a University of Canterbury review and report on known *E. macrorhyncha* biological risks in New Zealand and Australia was completed by Dr Steve Pawson, 2023.

Both the trial assessment results and the biological risks report were presented to a NZDFI Project Science Team workshop in August 2023. There were key outcomes to report on about each species' potential commercial plantation deployment in New Zealand dryland environments and further investment by NZDFI.

In addition, core samples to evaluate and the quantity and quality of the heartwood produced by *E. macrorhyncha* were taken from a selection of 36 trees of different genetic origin located in the 2005 Marlborough Regional Forests Waikakaho seedling seed stand. These cores have been assessed and the variation in *E. macrorhyncha* wood properties reported by Vikash Ghildiyal, a PhD student at the University of Canterbury.

RESULTS

Eucalyptus macrorhyncha – Red stringybark

A total of 40 PSPs were assessed across 16 sites. This included 2011, 2013, 2014 and 2018 demonstration trials as well as one early trial planted in Marlborough in 2005 at MRF Waikakaho and a new PSP established in the Grose informal trial blocks.
Overall, this species has demonstrated good form, survival, adaptability and productivity across many trial sites. It has proven to have low levels of Paropsine browse on most sites except McNeill and Timberlands Rotoehu. There is a significant increase in productivity of *E. macrorhyncha* planted in the 2018 trials with a seedlot from the Waikakaho seedling seed stand.

Eucalpytus tricarpa – Red iron bark

A total of 33 PSPs were assessed across fourteen of the 2011, 2013 and 2014 demonstration trials.
In addition, the 2011 progeny trial at Dillons was fully assessed and the PSP measured in the progeny trial at Avery.
This species has a similar MTHMAI as *E. macrorhyncha*, with the exception of the two Wairarapa sites. Results show the best growth in the 2014 trial at the NZ Redwood Company site - 1.3m MTHMAI - however no trees measured have acceptable stems. The MTHMAI at the Macbeth site is 1.2m and at Wishart-Cribb and Alexander it is 1.1m. Tree acceptability is equally good at these sites, 80.5 – 85.7%.
The PSPs measured in the breeding population at Avery had a MTHMAI 0.7m. This is a hard site with low rainfall.

Eucalyptus longifolia – Woolly butt

A total of 17 PSPs were assessed in 2011 and 2014 demonstration trials. The seedlot was from a small NZ grown stand of unknown genetic origin.

The average MTHMAI is 0.9m, with a range of 0.6m at low rainfall Marlborough sites to 1.4m at the high rainfall site located in the Horizons region.

A high number of unacceptable trees were observed, due to double leaders in the stem.

Eucalyptus argophloia – Western white gum

A total of 10 PSPs were assessed in six of the 2011 demonstration trials and a PSP in the 2011 progeny trial at Cuddon-Whyte property. The seedlot deployed in the PSPs originated from a seedling seed orchard established in the 1990s by the Department of Primary Industries, Queensland (DPI) tree conservation programme. The breeding population trial is a mix of untested families supplied by DPI. The best growth of *E. argophloia* was at Wishart-Cribb, Alexander and Saggers with some trees producing flowers. The average MTHMAI across all measurement sites is 0.8m and this is the poorest result of the four species.

Results for all species at the Alexander and Saggers sites show a higher percentage of acceptable stems because these plots have been thinned and the poorer stems removed.

The average difference in MTHMAI between the species planted between 2005-2014 is minimal. The Alexander, NZ Redwood Company and Wishart- Cribb sites have the best growth across all species and these sites have a higher rainfall compared to the other sites. These trials are all planted with unimproved seedlots.

DISCUSSION

The *E. macrorhyncha* block planted at Marlborough Regional Forests' Waikakaho forest has been used as a seedling seed stand since 2015 with NZDFI's 2018 demonstration trials planted using seed collected from the best trees. Recent measurement of these 2018 trials has shown the potential for a 50% gain in productivity versus the provenance seedlots planted in the 2011 and 2014 trials.

However, the species heartwood properties are reported to be only average when compared to other durable eucalypts. Little is known about the early onset of heartwood and also about wood collapse which can be a problem with some stringybarks.

Thirty-six cores were taken from a selection of *E. macrorhyncha* trees in the Waikakaho seed stand with known provenance. These were sent to the University of Canterbury to measure basic density, heartwood content, tangential and volumetric collapse on drying, and extractive content. There was no significant difference between provenances for heartwood and basic density and some significant difference between provenances for extractive content and collapse.

Seed has been collected from 23 plus trees selected for superior growth and form from across five of the trial sites assessed. These represent only five different provenances of the species' very large natural distribution that extends inland in New South Wales to inland Victoria with a small disjunct population in South Australia (Fig.3).

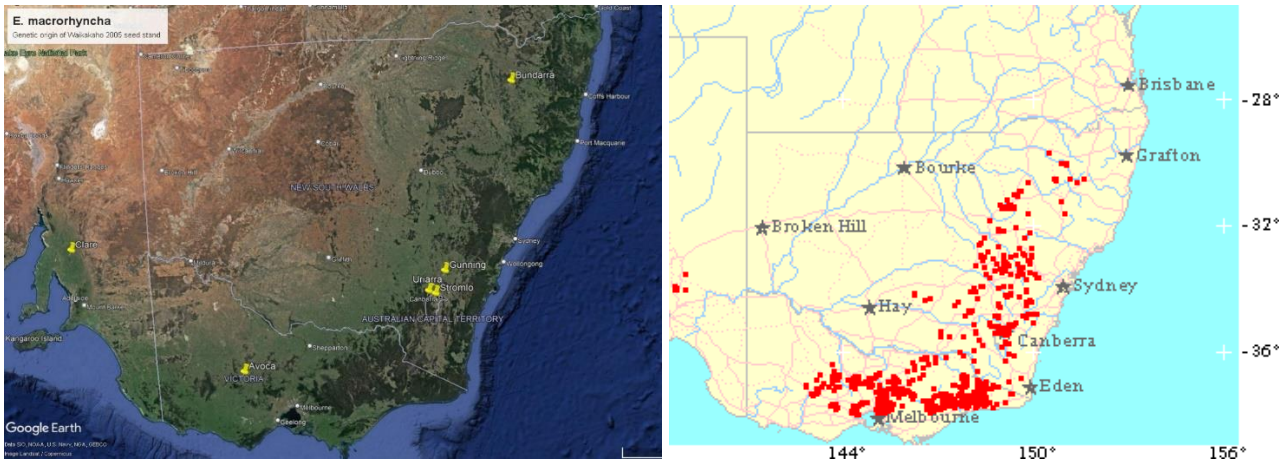

Fig.3. Location of E. macrorhyncha provenance seedlots assessed in trials (left) and the natural distribution of the species in Australia (right).

The trees at Waikakaho are becoming tall and difficult to collect seed from. A seedling seed stand could be established using some of the seed from the 23 plus tree seedlots collected. This could be an immediate low-cost step to provide a future seed source with moderate genetic improvement in growth and form only. The seedlots can also be stored for deployment in a breeding programme that would require sourcing at least 100 additional seedlots from across the natural distribution of the species to establish large scale replicated progeny trials.

The major biological risk for wide commercial deployment is the potential for a pathogen including *Phytophera* or brown leaf spot having a significant impact particularly if there are large scale plantings.

There have already been significant pathogen outbreaks killing eucalypts in New Zealand. Research to gain a greater understanding of the risks posed by these pathogens could be

undertaken, in collaboration with other eucalypt growers. Trends point to a likely increasing risk in regions that become wetter and warmer.

Also, the recent loss of a replicate trial block in the Landcorp Kapiro site due to the two wet summers highlights the need for site-species matching to ensure long term success.

Eucalyptus tricarpa has demonstrated good overall form, adaptability and productivity by its survival and performance across many NZDFI trial sites. This is despite very high Paropsine defoliation being recorded in the NZDFI's Hawkes Bay and Marlborough trials.

There is a significant *E. tricarpa* natural population located principally from inland mid-west Victoria and throughout eastern Victoria. This is largely discontinuous with *E. sideroxylon's* (also called 'red ironbark') natural distribution, which occurs north of *E. tricarpa,* mainly in drier regions of inland New South Wales.

'Red ironbark' timber is renowned in Australia and internationally and it is a popular farm forestry species in Victoria. There is a small Australian breeding programme and NZDFI has some common families planted in the 2011 progeny trials.

The major risk for large-scale commercial deployment could be greater defoliation by Paropsine or other insect pests. This may not be an issue if grown in smaller woodlots by farm foresters growing high-value timber. The potential to plant mixed species woodlots to reduce this risk needs further research.

Little is known about the early onset of heartwood in *E. tricarpa*. If wood properties are to be improved through breeding, some trees need to produce heartwood by age 12 years.
While NZDFI's breeding population at Dillons and Averys only includes a total of 17 families these are 12 years old and large enough for core sampling and analysis. This would provide an initial evaluation of the species' wood properties and guide further research investment.

Eucalyptus longifolia has demonstrated good survival, adaptability and productivity across many trial sites. However, it has heavy persistent branches and produces double and multi leader trees. On some low rainfall sites it tended to produce a mallee type form.

The seedlot planted in the demonstration trials was from a small NZ grown stand of unknown genetic origin. No further selection is planned in the demonstration trials due to the narrow genetic base deployed, however plots will be remeasured at the better growth sites.
The species has a relatively limited natural distribution in coastal NSW and there is no commercial interest in the species in Australia.

Eucalyptus argophloia has a very small natural distribution in Australia with a mixed seedlot deployed in the demonstration trials and pedigreed trees planted in the breeding trial. There has been a total of 10 PSPs assessed in six of the 2011 demonstration trials and a PSP in the 2011 progeny trial at the Cuddon-Whyte property.

No further work on *E. argopholia* is planned due to its poor form and productivity and low survival at some sites.

CONCLUSIONS

Based on the assessment of the trial sites in this study, *E. macrorhyncha* and *E. tricarpa* have shown potential for commercial plantation deployment in New Zealand dryland environments.

Further development of these species is required to refine siting and silviculture requirements, expand the breeding populations to improve the genetic resource, establish seed stands for future seed supply, and increase the sampling and evaluation of key wood property traits.

ACKNOWLEDGEMENTS

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- NZDFI partners; Proseed NZ, University of Canterbury and Marlborough Research Centre Trust
- Forestry and Wood processing Industry Transformation Plan fund
- Forest Growers Levy Trust
- NZ Farm Forestry Association
- PF Olsen, Greater Wellington Regional Council, Pamu/Landcorp and Timberlands personnel that assisted with PSP measurements.

APPENDICES

Appendix 1. Summary of measurements

Region	Landowner	Plant Yr	Trial Type	E. argophloia		E. longifolia		E. tricarpa		E. macrorhyncha		E. macrorhyncha SSS	
				MTHMAI (m)	% Acceptable Trees	MTHMAI (m)	% Acceptable Trees	MTHMAI (m)	% Acceptable Trees	MTHMAI (m)	% Acceptable Trees	MTHMAI (m)	% Acceptable Trees
Nthld	Landcorp Kapiro	2018	DEMO									2.3	52.5
BOP	Timberlands	2018	DEMO									2.0	26.5
Gisb	Wishart-Cribb	2011	DEMO	1.0	58.8	1.0	37.5	1.1	82.4	1.1	60.7		
HB	McNeill	2011	DEMO	0.7	16.7	0.9	73.3	0.8	62.5	0.9	88.0		
HB	Alexander	2011	DEMO	1.0	56.3	1.1	83.3	1.1	80.5	1.2	78.6		
HB	Landcorp Edenham	2018	DEMO									2.1	51.2
Hor	NZRC	2014	DEMO			1.4	6.2	1.3	0.0	1.7	11.5		
Hor	NZRC	2018	DEMO									2.4	67.7
Wair	Trimble	2011	DEMO					0.7		1.3			
Wair	Williams	2013	DEMO					0.7	78.4	1.0	75.0		
Marl	Avery	2011	BP					0.7	32.6				
Marl	Cuddon-Whyte	2011	BP	0.8	68.4								
Marl	Dillon	2011	DEMO			0.6	18.8	0.7	25.0	0.8	63.3		
Marl	Dillon	2018	DEMO									1.2	68.6
Marl	Lissaman	2013	DEMO					0.8	20.0	0.9	42.1		
Marl	Saggers	2011	DEMO	0.9	30.8	0.6	31.0	0.9	38.3	0.9	57.3		
Marl	Waikakaho	2005	SS							1.1	75.0		
Cant	Macbeth	2014	DEMO	0.8	75.0	1.0	9.1	1.2	85.7	1.0	80.0		
Cant	Martin	2011	DEMO	0.7	4.4	0.9	16.7	1.0	31.0				

Appendix 2. Number of trees marked for coring at each trial site.

Region	Landowner	Plant Yr	Type	Plot Size	No. of trees marked to core			
					E. macrorhyncha	E. argophloia	E. longifolia	E. tricarpa
Nthld	Landcorp Kapiro	2018	DEMO	100 tree	16			
BOP	Timberlands	2018	DEMO	100 tree	12			
Gisb	Wishart-Cribb	2011	DEMO	49 tree	29	22	26	25
HB	McNeill	2011	DEMO	49 tree	38	4	30	25
HB	Alexander	2011	DEMO	49 tree	25	19	11	39
HB	Landcorp Edenham	2018	DEMO	100 tree	24			
Hor	NZRC	2014	DEMO	100 tree	15		15	10
Hor	NZRC	2018	DEMO	100 tree	28			
Wair	Trimble	2011	DEMO	49 tree	25			25
Wair	Williams	2013	DEMO	100 tree	27			31
Marl	Avery	2011	BP	20 tree				25
Marl	Cuddon-Whyte	2011	BP	20 tree		25		
Marl	Dillon	2011	DEMO	49 tree	27		17	24
Marl	Dillon	2018	DEMO	100 tree	3			
Marl	Lissaman	2013	DEMO	100 tree	25			26
Marl	Saggers	2011	DEMO	49 tree	22	16	26	26
Marl	Waikakaho	2005	SS		36			
Cant	Macbeth	2014	DEMO	100 tree	20	5	20	20
Cant	Martin	2011	DEMO	49 tree		13	25	29

Appendix 3. Trial site information

Trial description									Silvicultural			Environmental					
Site name	Region	Easting	Northing	Year planted	Site description	Site prep	Trial spacing (m)	Surrounding vegetation	Thinned	Pruned	Event	Frost-free days	Rainfall (mm)	Feb max temp	July min temp	Altitude (m)	Base Geology
Landcorp Kapiro	Northland	1682193	6111552	2018	Grass cover & old pine cutover; easy slope	Pre plant aerial spray	2.3 x 2.3	Eucalypt forest	No	Yes		365	1601	23	7	161	basalt
Timberlands Rotoehu	Bay of Plenty	1911237	5788789	2018	Pine cutover; moderate slope	Pre plant aerial spray	variable	Eucalypt forest	No	No		351	2035	22	1	331	rhyolite
Wishart-Cribb	Gisborne	2009766	5738024	2011	Grass cover; moderate to steep slope	Pre plant spot spray	2.8 x 2.8	Eucalypt forest	No	No		269	1136	23	3	204	sandstone
McNeill	Hawkes Bay	1939989	5588123	2011	Grass cover; flat	Pre plant spot spray	2.8 x 2.8	Grassland	No	No		271	1061	22	2	265	limestone
Alexander	Hawkes Bay	1911531	5607385	2011	Grass cover; easy to moderate slope	Pre plant spot spray	2.8 x 2.8	Grassland	Yes	Yes	Frost post planting	239	808	23	3	129	limestone
Landcorp Edenham	Hawkes Bay	1924532	5570402	2018	Pine cutover; moderate slope	Pre plant aerial spray	2.3 x 2.3	Eucalypt forest	No	Yes	Frost post planting	251	1156	22	2	184	gravel
NZRC Paparoa	Horizons	1785613	5685723	2014	Grass cover; flat to easy slope	Pre plant spot spray	2.8 x 2.8	Redwood forest	No	No		256	1563	24	2	153	sandstone
NZRC Paparoa	Horizons	1785613	5685723	2018	Grass cover; flat to moderate slope	Pre plant spot spray	2.8 x 2.8	Eucalypt forest	No	Yes		256	1563	24	2	153	sandstone
Trimble Foundation	Greater Wellington	1846079	5465273	2011	Grass cover; flat	Pre plant spot spray	2.8 x 2.8	Grassland	No	No	Waterlogged post planting	258	1006	22	3	214	gravel
Williams	Greater Wellington	1834752	5456394	2013	Grass cover; moderate slope	Post plant spot spray	2.8 x 2.8	Eucalypt forest	No	Yes		233	972	22	2	195	mudstone
Avery	Marlborough	1693286	5378853	2011	Grass cover; moderate slope	Pre plant spot spray	2.4 x 1.8	Grassland	No	No		211	606	21	3	60	mudstone
Cuddon-Whyte	Marlborough	1672494	5400878	2011	Grass cover; moderate slope	Pre plant spot spray	2.4 x 1.8	Grassland	Yes	No	Waterlogging at base of slope	188	670	23	1	50	conglomerate
Dillon	Marlborough	1656217	5389133	2011	Grass cover; flat to moderate slope	Pre plant spot spray	2.8 x 2.8	Grassland	No	No	Frost post planting	183	692	23	0	249	gravel
Dillon	Marlborough	1656217	5389133	2018	Grass cover; moderate slope	Pre plant spot spray	2.8 x 2.8	Grassland	No	No	Frost post planting	183	692	23	0	249	gravel
Lissaman	Marlborough	1681458	5380301	2013	Grass cover; easy to moderate slope	Pre plant spot spray	2.8 x 2.8	Grassland	No	Yes		214	727	22	1	233	conglomerate
Saggers	Marlborough	1675952	5399353	2011	Grass cover; easy to moderate slope	Pre plant spot spray	2.8 x 2.8	Grassland	Yes	No		192	678	23	1	103	conglomerate
MRF Waikakaho	Marlborough	1674737	5414008	2005	Grass cover; flat	Pre plant spot spray	3.0 x 3.0	Eucalypt forest	Yes	Yes		265	1083	22	2	35	gravel
Grose	Marlborough	1614901	5384969	2006, 2008 & 2009	Grass cover; moderate slope	Pre plant spot spray	approx 3.0 x 3.0	Eucalypt forest	No	No		186	1214	22	0	440	gravel
MacBeth	Canterbury	1614499	5263352	2014	Grass cover; moderate slope	Pre plant spot spray	2.3 x 2.3	Eucalypt forest	Yes	Yes	Drought post planting	231	809	22	0	151	siltstone
Martin	Canterbury	1571896	5217535	2011	Grass cover; flat	Pre plant spot spray	2.8 x 2.8	Grassland	No	Yes	Waterlogged post planting	268	699	22	2	92	gravel