Green Triangle
Forest Industries Hub

Trees on Farms initiative

A spatial analysis study of suitable land areas for trees into farming

Prepared by Esk Spatial for the Green Triangle Forestry Industries Hub Project 3 – June 2023

This project is delivered by the Green Triangle Forest Industries Hub (GTFIH) as part of the South Australian Trees on Farms Initiative and is only possible from the support and funding provided by the South Australian Government through the Department of Primary Industries and Regions, and funding contributed by the Australian Government.

Australian Government
Department of Agriculture, Fisheries and Forestry

Government of South Australia
Department of Primary Industries and Regions

A spatial analysis study of suitable land areas for trees into farming

Information current as of 30 June 2023

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About the Trees on Farms initiative

Launched in March 2022, the Trees on Farm initiative is aimed at growing and developing the on-farm forest plantation sector, particularly in the Green Triangle region. Key components of the program, including this report, are being delivered in partnership with the Green Triangle Forest Industries Hub (GTFIH).

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- Forestry SA
- Green Triangle Forest Products
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Acknowledgment is also made to the APSIM Initiative which takes responsibility for quality assurance and a structured innovation program for APSIM’s modelling software, which is provided free for public good research and development use (see www.apsim.info for details).

Acronyms

Acronym		Definition
ACCU		Australian Carbon Credit Unit
AOI		Area Of Interest
APSIM		**A**gricultural **P**roduction **S**ystems s**IM**ulator
ASRIS		Australian Soil Resource Information System
CSIRO		Commonwealth Scientific and Industrial Research Organisation
DAFF		Department of Agriculture, Fisheries and Forestry
DISR		Department of Industry Science Energy and Resources
ERF		Emissions Reduction Fund
FullCAM		Full Carbon Accounting Model
GHG		Green-House Gas
GTFIH		Green Triangle Forestry Industry Hub
MAI		Mean Annual Increment
PGP		Permanent Growth Plot
PIRSA		Department of Primary Industries and Regions, South Australia
SLGA		Soil and Landscape Grid of Australia

Glossary

Term		Definition
Carbon credit		A certified and tradeable unit that represents one tonne of carbon dioxide equivalent that has been removed from the atmosphere. By purchasing or generating, and then retiring a carbon credit, an entity can offset one tonne of carbon dioxide equivalent emissions they generate. Under the ERF, the Australian carbon credit unit is an ACCU.
CFI Rule		Carbon Credits (Carbon Farming Initiative) Rule 2015
Green-House Gas		A green-house gas (GHG) is a gas in the Earth’s atmosphere that can absorb radiation being emitted from the earth’s surface, despite being transparent to radiation from the Sun. These gases trap that radiation in the atmosphere in the form of heat, and so have been referred to as acting like a green-house. The primary greenhouse gases in Earth's atmosphere are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3).
Mean Annual Increment		Average growth per year of a tree or stand of trees has been undertaken up to a specified age, typically expressed in the units of m^3/ha/year. Knowing the age at which MAI is being described is essential as MAI can vary greatly at any given point in the life of a tree or forest. MAI’s presented in this project are expressed at the age of final harvest and include all volume harvested over the rotation (i.e., include thinning and final clearfell volume)
Plantation Forest		A planting of forest tree species for the harvest of saleable forest products
Permanent Growth Plot		A small area of forest (i.e. 0.01 to 0.1ha in size) that is regularly measured/sampled, say annually, over the life of the forest to build up a record of tree metrics (i.e. diameter, height, bark thickness, stocking) versus age to assist with development of growth models that can be in turn used to predict growth in other forests.
Permanent Planting		A planting of tree species in which the trees are not generally intended to be harvested, and certainly not for generation of saleable forest products

Introduction

Project Background

This project is one of a portfolio of research activities, including specific outcome communications, to underpin support of expansion of the planted forest resources of South Australia, with an emphasis on integrating forestry enterprise into the existing productive farming environment.

The activities were developed under a Funding Deed between the Green Triangle Forest Industries Hub (GTFIH - the recipient) and the Department of Primary Industries and Regions, South Australia (PIRSA - the funder). The funding for these projects from PIRSA, while directed at South Australia, will provide benefit to all southeast South Australia and southwest Victoria, stretching from Port Augusta down to Geelong.

The process of suitability analysis of a site for plantation development is very specific to the intent. That is, suitability is relative to the intent and purpose of a plantation defined by site attributes, distance to an intended mill door and the growers time frames to final harvest. Therefore, this is no single rating of suitability. Recognising this reality, this analysis and report provides the inputs to a suitability assessment for each land title in the study area.

Project Objectives

The goal of this project was to determine plantation and carbon productivity information for privately owned agricultural areas within the southeast South Australia and southwest Victoria area to support plantation forest expansion. That is, to provide information to support growing the right trees, in the right place, at the right scale, with no waste, to support a world leading, local processing and manufacturing industry. With the existing forestry industry defining the "*right trees"* based on extensive research and experience in the region, and farmers/landowners deciding which "*right places at the right scale"* are available for *"how long*" based on their knowledge and experience of the local landscape.

The area of interest for the project, some 191,000 square kilometers, is centered around the existing Green Triangle and, Mount Lofty Ranges and Kangaroo Island, National Plantation Inventory regions (refer Figure 1). Note that the project was limited to private land and excluded the pre-existing industrial scale forestry management estates.

The ultimate deliverable for the project was production of an interactive web map from which the results of the modelling undertaken in this report could be easily interrogated by existing and hopeful plantation growers alike to provide relevant estimation of the amount of saleable wood and carbon credits for any given property, and to provide an indication of distance to current markets for that property. In creating the models and layers, no assumptions were made on agricultural land use, land size, haulage distances, accessibility, land values or available land which will all need to be considered as part of any standard due diligence required before embarking on a plantation forestry enterprise or carbon project for any given property.

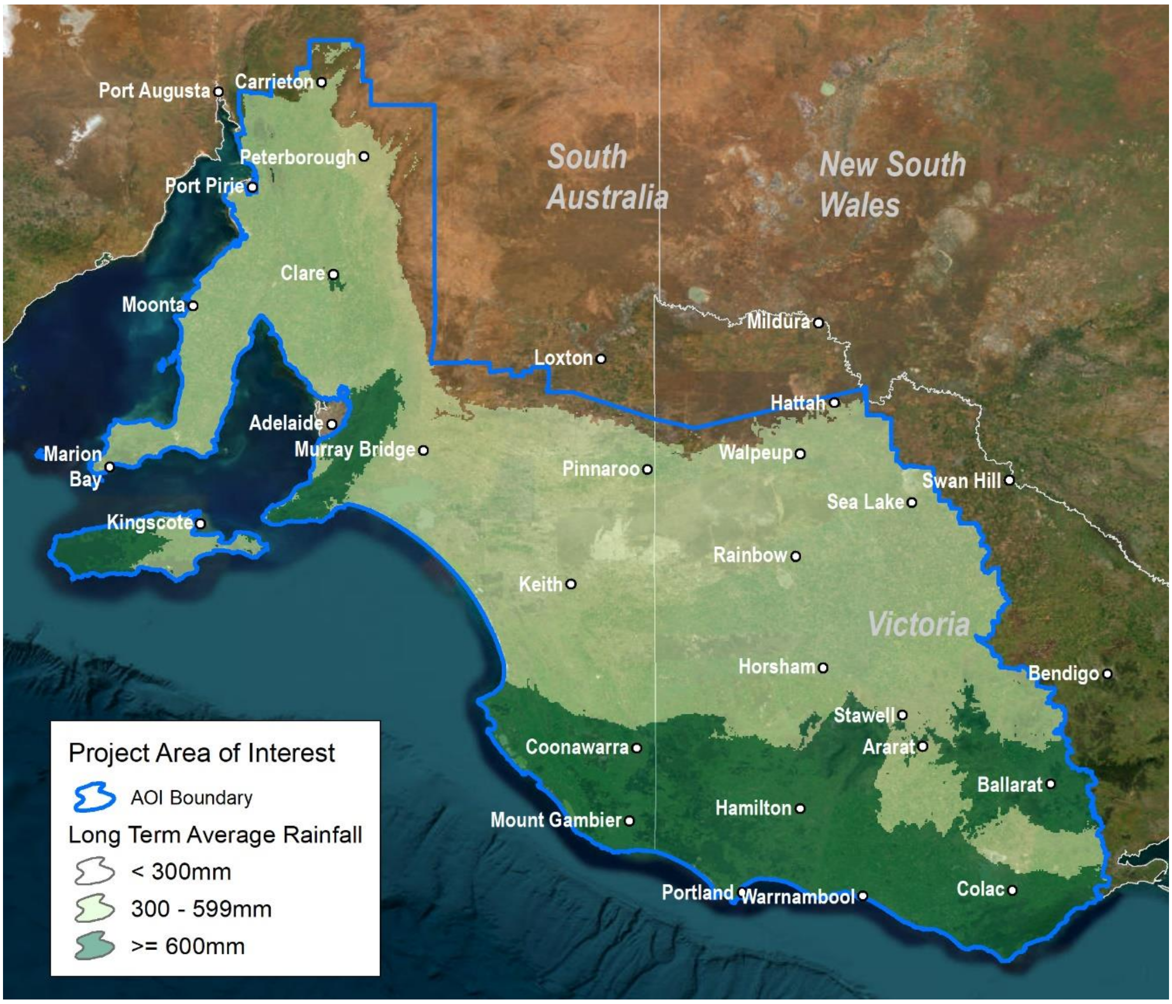

Figure 1: Project area of interest covering southeast South Australia and southwest Victoria down to approximately 300mm long term average rainfall[1]

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[1] Long term rainfall Source: DCCEEW, 2019 Calculated from period 1921 to 2010.

The scale of the modelling was set to 1km resolution, reflecting the working scale of input data such as digital climatic and soil information, so will not provide results suitable for on-farm planning but will certainly provide enough information to assist with decisions around entry into relevant plantation forestry enterprises and carbon market schemes alike. Finer scale modelling is possible on a more localized basis, but that was beyond the scope of this project.

Plantation Species

In early 2019 the Australian Government announced funding for the 'A Billion Tees' Plan, the aim being to establish significant additional plantations across Australia by 2030, with a strong emphasis for plantings on farming land to meet both forecasted timber demand in Australia by 2050 and on-farm benefits including provision of shelter, reducing erosion and reducing dryland salinity (DAFF, 2018). This original plan was aimed at establishing an additional 400,000 hectares to the 2 million hectares of plantations that were in place at the time, and the regional forestry hubs such as the Green Triangle Forestry Industries Hub (GTFIH), were established to support and promote forest industries locally (DAFF, 2018).

Within the three National Plantation Regions[2] (NPI) covered by the project AOI, the dominant commercial plantation species are Tasmanian Blue Gum (*Eucalyptus globulus*) and Radiata Pine or Monterey Pine (*Pinus radiata*) as shown in Figure 2 and Figure 3 respectively, accounting for about 6% of the total land use in the region[3].

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[2] The project AOI covers the Mt Lofty Ranges and Kangaroo Island NPI, Green Triangle NPI and Central Victoria NPI

[3] Source: GTFIH website

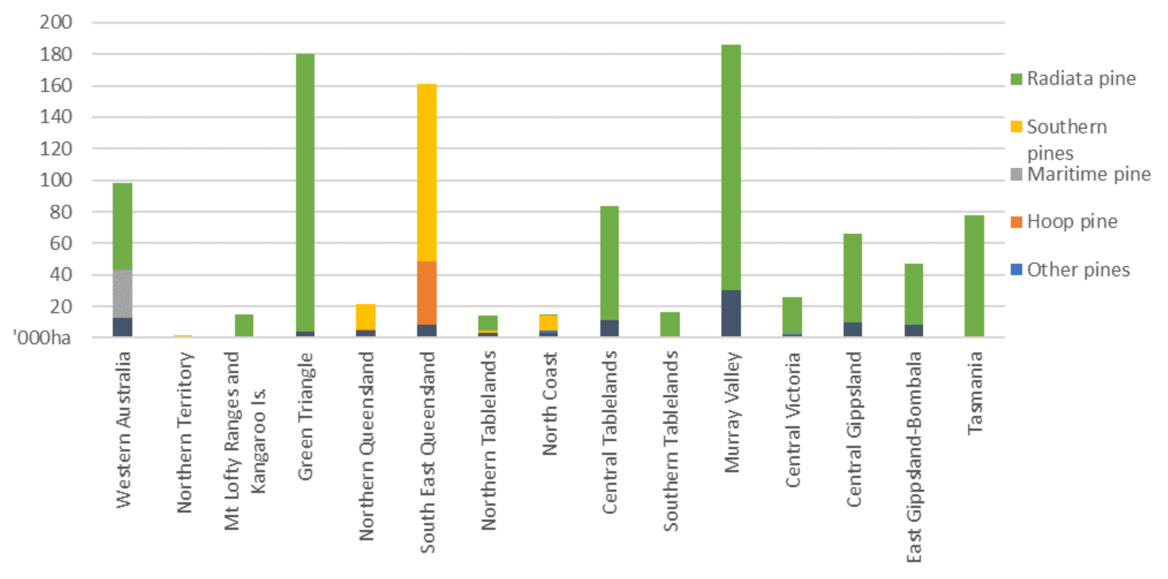

Figure 2: Area of softwood plantations by species and NPI region[4]

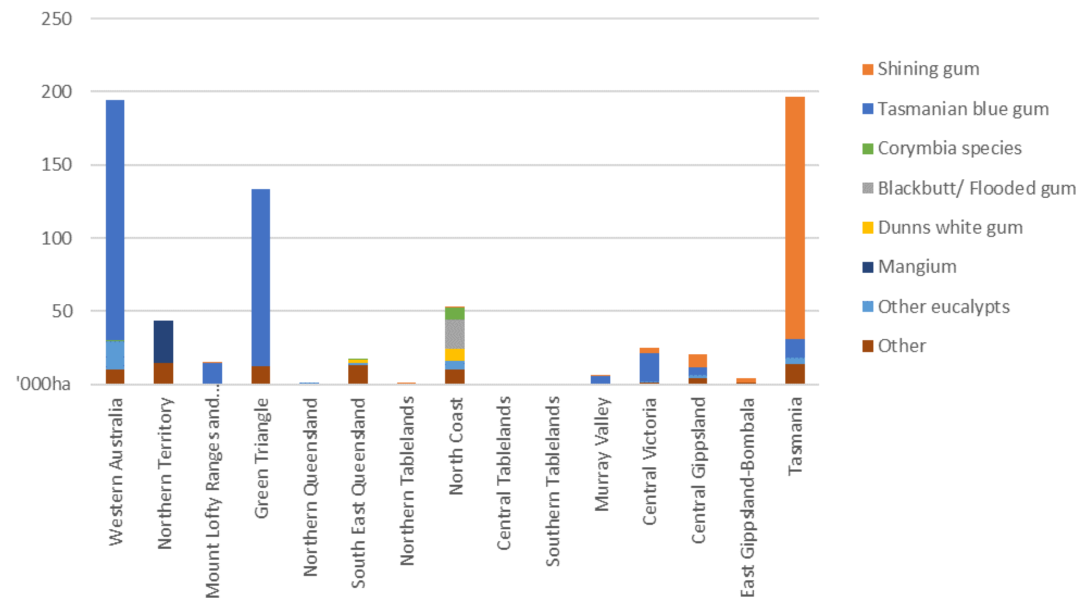

Figure 3: Area of hardwood plantations by species and NPI region[5]

The national area under plantations peaked around 2010, and since 2019 there has been a small decline of hardwood plantation area, whilst softwood areas have remained static. No significant new plantings have been recorded either locally or nationwide (ABARES, 2022).

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[4] Source: National Plantation Statistics 2022 (ABARES, 2022)
[5] Source: National Plantation Statistics 2022 (ABARES, 2022)

Radiata pine is generally grown as long rotation crops (28-40 years) with one, two or three thinning events required to maximise the production of larger diameter sawlog products, Tasmanian Blue Gum plantations are typically managed as short rotation (10-15 years) crops and remain unthinned to generate pulp-based products (PIRSA, 2023).

To date the majority of plantations have been established in the higher rainfall areas of the region (refer Figure 4) and it is generally recommended a minimum of 600 mm rainfall is accepted as a reasonable cut-off to achieve a viable plantation for these species (Severino & Hasanka, 2018), though some forest management companies use 700mm. Given their proven record in the existing forestry industry, these two species were chosen to be modelled in this project.

Figure 4: Current extent of softwood and hardwood plantation within the project area[6]

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[6] Source: Forests of Australia 2018 (ABARES, 2018), noting that the majority of plantations shown on Kangaroo Island were burned in 2020 bushfires, some 18,000ha, and are being converted to agriculture (ABC Rural, 2021).

To be eligible under the Plantation forestry 2022 Method, new plantations must meet these basic requirements, amongst others (refer to the Clean Energy Regulator [CER] website for full details on eligibility requirements):

- the land they are planted on has been clear of plantation or forest cover for the last 7 years;
- the land they are planted on must not have been a drained wetland in the last 7 years;
- The species planted must not be a known weed species and needs to have the potential to gain a height of 2m or more and a crown cover of more than 20 percentage of the land area;
- The project must not have commenced at the time the project is registered; and
- You must notify the Minister for Agriculture (via DAFF) of the proposed plantation project so that they can assess and decide as to whether the project may lead to an undesirable impact on agricultural production.

These eligibility criteria were not modelled within this project, and you will need to undertake your own due diligence to determine if you meet such criteria.

An environmental planting option was also modelled in this project to provide a carbon project solution in areas down to 300 mm rainfall, where commercial plantations are unlikely to be financially viable. To be eligible under the Reforestation by Environmental or Mallee Plantings 2014 Method, an environmental planting must meet these basic requirements, amongst others (refer to the CER website for full details on eligibility requirements):

- Land must have been clear of forest cover for the previous 5 years;
- The species planted need to have the potential to gain a height of 2 m or more and a crown cover of more than 20% of the land area; and
- Must consist of a mixture of tree and shrub species that:
    - are native to the local area of the planting;
    - are sourced from seeds from within the natural distribution of the species and that are appropriate to the biophysical characteristics of the area of the planting;

  - may be a mix of trees, shrubs, and understorey species where the mix reflects the structure and composition of the local native vegetation community; and
  - are established through planting.

Again, these eligibility criteria were not modelled within this project.

In general, the less removal of trees that takes place during the life of the project by way of thinning, or harvesting and replanting, the higher the yield in terms of long-term average carbon abatement over a 100-year period, so permanent plantings can have advantages over traditional harvest plantations in terms of total carbon sequestration benefits. Alternatively, traditional plantations provide saleable wood products.

It should be noted that some areas in the Green Triangle have specific water licensing requirements for plantation forestry activities. The Lower Limestone Coast Prescribed Wells Area (LLCPWA) is a declared forestry area where all commercial forests must have a forest water licence including a water allocation that offsets the plantation's impact on the groundwater resource, unless the forest is classified as farm forestry (PIRSA, 2023).

In the Eastern and Western Mount Lofty Ranges Prescribed Water Resources Areas, forestry is a water affecting activity that requires a commercial forest water permit.

FullCAM

The Full Carbon Accounting Model (FullCAM) was originally developed in 2001 and is a calculation tool used in Australia’s National Greenhouse Gas Accounts for the land use, land use change and forestry sectors, the outputs from which are the basis of annual National Inventory Reports. FullCAM can model carbon dioxide removal from the atmosphere by forests, croplands, grasslands and other vegetation, and can model the emissions from such vegetation by way of clearing, harvesting, decay or fire. Australia's land sector is approximately 769 million hectares so a model-based approach to estimate emissions and abatement was chosen as a far more practical approach to national accounting than field sampling (DCCEEW, 2020).

FullCAM is also used to generate abatement estimates for vegetation methodology determinations (methods) under the Emissions Reduction Fund (ERF), of which the following have specific relevance to carbon projects related to new plantings of forest in the Green Triangle:

- Plantation Forestry 2022 Method[7]
- Farm Forestry 2014 Method[8]
- Reforestation by Environmental or Mallee Plantings 2014 Method[9]

In Australia, these projects generate carbon credits in the form of Australian Carbon Credit Units (ACCUs).

The main inputs into FullCAM are a geographic location (in the form of a Latitude and Longitude), and a forest management regime, which cover timing and characteristics of activities such as planting, weed control, fertiliser application, thinning, fire and harvesting. The FullCAM software uses the location information to automatically extract relevant climatic, edaphic and environmental values from a cloud-based database as additional inputs, and these drive the internal growth and decay models. From this FullCAM estimates the carbon stock change over time in the forest including:

- above and belowground biomass
- standing and decomposing debris
- storage in harvested forest wood products
- emissions from fire and fuel use

FullCAM was used in this project to model the likely total ACCU to be generated over the life of the project for any given square kilometer within the project AOI under the following scenarios:

- ACCU/ha was modelled for the Plantation Forestry 2022 Method (specifically Schedule 1) under two Tasmanian Blue Gum and two Radiata Pine management regimes for areas of long-term average rainfall greater than or equal to 600mm; and

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[7] Carbon Credits (Carbon Farming Initiative-Plantation Forestry) Methodology Determination 2022

[8] Carbon Credits (Carbon Farming Initiative) (Measurement Based Methods for New Farm Forestry Plantations) Methodology Determination 2014

[9] Carbon Credits (Carbon Farming Initiative) (Reforestation by Environmental or Mallee Plantings—FullCAM) Methodology Determination 2014

- ACCU/ha was modelled for the Environmental and Mallee Plantings 2014 Method for a mixed native species permanent environment planting regime for areas of long-term average rainfall greater than or equal to 300mm.

APSIM

Originally developed in 1991, the **A**gricultural **P**roduction **S**ystems s**IM**ulator (APSIM[10]) is a computer software model that simulates biophysical processes in agricultural systems structured around plant, soil, climate and management modules. One key use of the system is to provide understanding of how climate change might impact agricultural systems, and to support the development of solutions where adverse effects are identified. Since 2007 APSIM has been actively managed and supported by the APSIM Initiative, and from 2020 models for *Eucalyptus grandis*, *E. globulus* and *E. nitens* were introduced, as were models for *Pinus radiata* and *P. elliotii*. As for agricultural crops, for forest plantations APSIM simulates plant biomass production by mimicking the bio-physical process that drive growth, i.e., process-based modelling. Standard forest inventory data like tree heights, stem diameters at breast height, and volume per hectare are then calculated empirically, i.e., using regressions relationships between biomass and these variables.

Unlike FullCAM, APSIM is very open and flexible in how it can be run, providing access to manipulate a vast array of input variables used for simulating all components of plant production system, from seed to harvest, including soil-based processes in user-defined range of scenarios. APSIM as standard does not come with any pre-existing data, so for any simulation run it needs to be populated with all relevant climatic, soil, plant and management values that drive ecosystem processes. However, there are publicly available soil and climate databases with a range of such pre-defined model inputs that can be accessed. These are generally downloaded and can be manipulated to suit the specific regime or scenario you are modelling. There are also publicly available templates for standard tree growth models and management regimes that can be accessed which can be manipulated to your simulation needs.

APSIM was used in this project to model the likely volumes of forest wood to be generated at thinning and harvest events for two Tasmanian Blue Gum and two Radiata Pine

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[10] (Holzworth, Dean, N. I. Huth, J. Fainges, H. Brown, E. Zurcher, R. Cichota, S. Verrall, N. I. Herrmann, B. Zheng, and V. Snow. , 2018)

management regimes for areas of long-term average rainfall greater than or equal to 600 mm.

Although APSIM can model carbon sequestration and nitrous oxide emissions like FullCAM, because the legislated methodologies to generate carbon credits under the ERF require the use of FullCAM, there was no benefit in modelling such from APSIM for this project.

Web Map

As mentioned above, the main deliverable of this project is an interactive web map. Specific outputs from the project which will be made available on the web map include spatial layers describing at 1km resolution are:

- **Wood productivity**: A layer generated from APSIM model outputs which displays for any given point the total standing volume (m^3/ha) available for extraction for each thinning or clearfell harvest event during a single rotation of standard Tasmanian Blue Gum and Radiata Pine plantation management regimes suitable to the region.
- **Carbon productivity for harvest plantations**: A spatial layer generated from FullCAM model outputs which describes for any given point, the total estimated ACCUs that would be available to the landowner under industry standard Tasmanian Blue Gum and Radiata Pine plantation management regimes. The ACCU calculations were based on a 25-year permanence period for a project entered under Schedule 1 of the Carbon Credits (Carbon Farming Initiative – Plantation Forestry) Methodology Determination 2022 of the Emissions Reduction Fund (ERF). The model was limited to areas of 600 mm long term average rainfall or greater, below which it is generally accepted that commercial plantation forestry is not viable.
- **Carbon productivity for environmental plantings**: A spatial layer generated from FullCAM model outputs describing for any given point, the total estimated ACCUs under a permanent environmental planting regime, which can be a mixture of tree and shrub species that are native to the area. The ACCU calculations were based on a 25-year permanence period of a project entered under the Carbon Credits (Carbon Farming Initiative) (Reforestation by Environmental or Mallee Plantings—FullCAM) Methodology Determination 2014 of the ERF. The model was limited to areas down to 300 mm long-term average rainfall. This modelling was included to provide a carbon project option for areas where the commercial plantations described above may not be financially viable.

- **Cartage distance to market destination matrix**: A spatial layer generated from GIS Network Analysis modelling describing for any given point, a matrix of cartage distances to the key ports or processing hubs currently available across southeast South Australia and southwest Victoria.

A secondary objective of the web map was that it would provide access to other reference layers which would provide information to support due diligence and decision making around barriers to entry for both plantation forestry in general in the region, and into the Plantation Forestry Method 2022 under the ERF. Such layers include boundaries defining:

- **Specified Regions for the ERF Water Rule**: a spatial layer showing the specific regions exempt from the Water Rule (as per CFI Rule Part 3 Section 20AB); and

- **Water Management Area**: a spatial layer showing the Lower Limestone Coast Prescribed Wells Area (LLCPWA) within South Australia, which is a declared forestry area in which all commercial forests must have a forest water licence.

Methodology

Forest Management Regimes

A key input into both the APSIM and FullCAM models was the regimes under which the plantations were to be managed. Project 1 (Jenkin, et al., 2023) of the current PIRSA and GTFIH projects provided the following Tasmanian Blue Gum and Radiata Pine management regimes for use in this project, including a short and long rotation option for both species:

Radiata Pine - Standard regime

- Establishment: planted at 1,600 stems/ha.
- T1: at age 11 to 13 (12) years removing every 5th row and thinning from below[11] the remaining four bays to leave 650 stems/ha.
- T2: at age 16 to 18 (17) years thinning from below removing to leave 430 stems/ha.
- T3: at age 21 to 23 (22) years thinning from below removing to leave 320 stems/ha.
- CF: at age 28 to 34 (31) years.

Radiata Pine - Shorter rotation regime

- Establishment: planted at 1,600 stems/ha.
- T1: at age 11 to 13 (12) years removing every 5th row and thinning from below the remaining four bays to leave 650 stems/ha.
- T2: at age 16 to 18 (17) years thinning from below removing to leave 430 stems/ha.
- CF: at age 25 years.

Tasmanian Blue Gum - Standard regime

- Establishment: planted at 900 to 1,000 (1,000) stems/ha.

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[11] 'Thinning from below' refers to the removal of smaller/suppressed trees, which leaves larger/dominant trees to maximise the size of individual trees in the crop at final harvest.

- CF: at age 12 to 15 (13) years.

Tasmanian Blue Gum - Longer rotation regime:

- Establishment: planted at 1,100 stems/ha.
- T1: at age 9 years removing every 5th row (220 stems/ha) and thinning the four bays remaining from below to leave 600 stems/ha.
- CF: at age 15 to 20 (18) years.

From these guidelines, four specific regimes were developed for input into APSIM and FullCAM, fixing the displayed range of establishment stockings, thinning ages and clearfell ages to a single option each (refer text in blue above) as summarised in Table 1 below, noting that the additional ‘Environmental Planting’ option listed was only run in FullCAM as an alternative path to carbon credit generation in areas unlikely to be financially viable for commercial plantations.

Table 1: Tasmanian Blue Gum and Radiata Pine management regimes modelled in APSIM and FullCAM

Species	Rotation Length	Initial SPH	T1 Age (Residual SPH)	T2 Age (Residual SPH)	T3 Age (Residual SPH)	Clearfell Age
P. radiata	Long	1,600	12 (650)	17 (430)	22 (320)	31
P. radiata	Short	1,600	13 (650)	18 (430)	NA	25
E. globulus	Long	1,100	9 (600)	NA	NA	18
E. globulus	Short	1,000	NA	NA	NA	13
Environmental Planting[12]	Permanent	200-1,500	NA	NA	NA	NA

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[12] This regime was not modelled in APSIM as it does not represent a commercial harvest plantation.

Plantation Suitability Grid

The AOI was covered with a grid of 1 km^2 squares which were then converted to a grid of points with each point made from the centroid of each grid feature. The grid was then categorized into >600 mm rainfall and 300-600 mm rainfall areas. There were approximately 197,000 points required to cover the 300-600 mm rainfall areas shown as brown area in Figure 5, and 48,000 points to cover the >600 mm rainfall areas, shown as green area in Figure 5. All National Parks and industrial-scale forest plantation areas were excluded from the analysis.

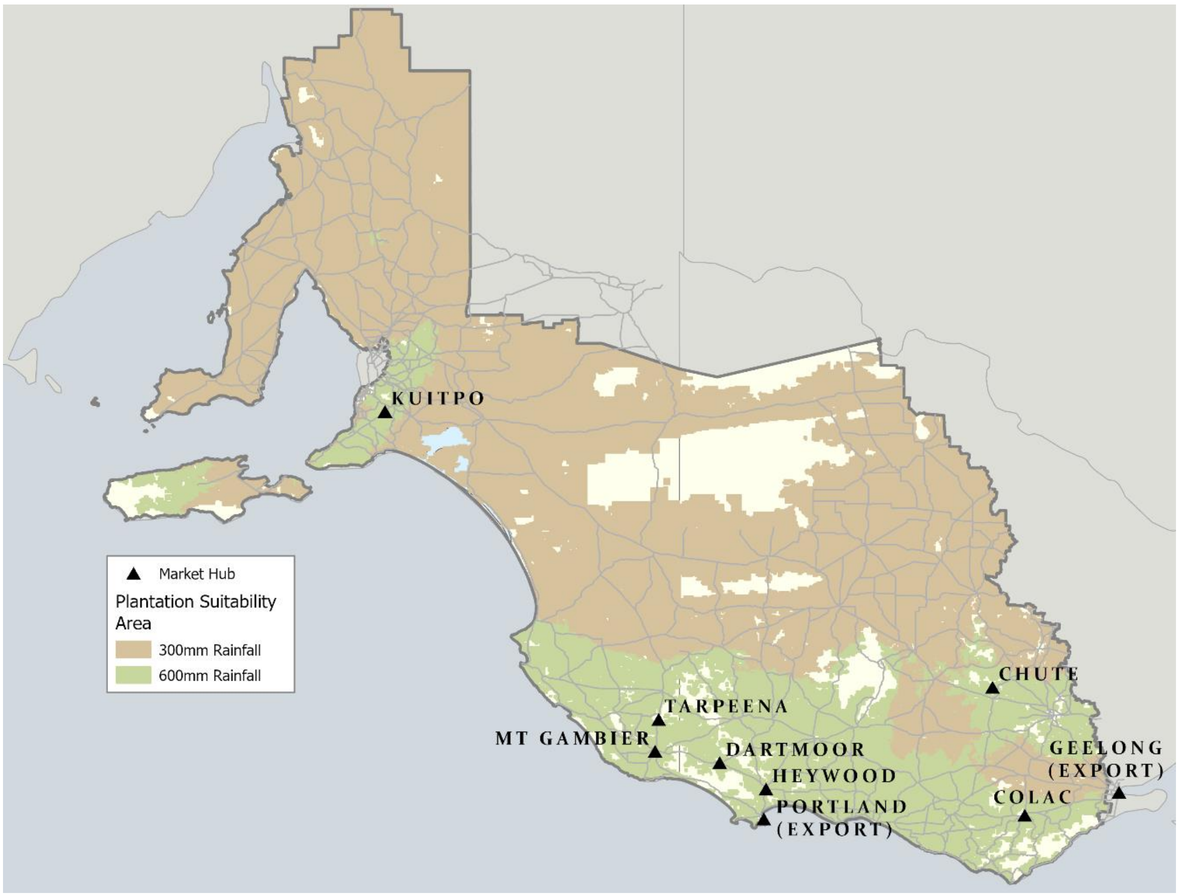

Figure 5: Plantation Suitability Grid

Land use data for SA (General Land Use, 2021[13]) and VIC (Victoria Land Cover, 2017[14]) was used to exclude areas from the modelling that were not agricultural. The following land use types were included in the modelling:

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[13] Source: https://data.sa.gov.au/data/dataset/land-use-generalised
[14] Source: https://discover.data.vic.gov.au/dataset/victorian-land-use-information-system-2016-2017

- SA - Agriculture, Horticulture, Livestock, Rural
- VIC - Agriculture Cropping, Livestock Grazing, Mixed Farming and Grazing, Livestock - special purpose, Horticulture Fruit and Vegetable Crops, Horticulture-Special Purpose

Any grid point within the 600 mm rainfall area and within 500 m of an included land use was included in the modelling for the 600 mm rainfall area. Similarly, any grid point within 300 mm rainfall area and within 500 m of an included land use was included in the modelling for the 300 mm rainfall area.

Wood Productivity Modelling

APSIM was modelled against the plantation suitability grid described in the previous section for the four commercial plantation regimes described in the 'Forest Management Regimes' section of this document. APSIM templates for the plantation regimes were developed with assistance from Dr Philip Smethurst, Soil and Water Scientist, and Plant Nutritionist, from CSIRO. The APSIM modelling was only undertaken on the 600 mm rainfall grid points, some 48,000 in total.

Weather and soil data was required to be downloaded for each grid point for APSIM to run the tree growth and related ecosystem process models. Soil, weather and water table data were all recorded at the centroid of each 1 km^2 grid location.

The weather data was downloaded from the SILO API[15] ('LongPaddock') as hosted by the Queensland Government. Given the weather data was historic in nature, the regimes were modelled in APSIM retrospectively to achieve a harvest as of June 2022 thus ensuring digital weather files would exist, the resultant rotation start, and end dates shown in Table 2.

Table 2: Rotation Start and End Dates modelled in ASPIM for each regime

Species	Rotation Length	Clearfell Age	Rotation Start Date	Rotation End Date
P. radiata	Standard	31	16th June 1991	16th June 2022
P. radiata	Shorter	25	16th June 1997	16th June 2022
E. globulus	Standard	13	16th June 2009	16th June 2022
E. globulus	Longer	18	16th June 2004	16th June 2022

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[15] Source: https://www.longpaddock.qld.gov.au/silo/

The soil data was downloaded from the Soil and Landscape Grid of Australia (SLGA) via the Australian Soil Resource Information System (ASRIS) API[16], hosted by CSIRO.

A range of assumptions were required to represent the environmental conditions under which the tree growth was simulated for each grid location that were not represented in the downloaded data, with reference to conditions likely to be encountered in the project AOI. These assumptions are recorded in the section below.

Prior to modelling all points on the plantation suitability grid, to ensure the APSIM model generated outputs fit for the local growing conditions of the area of interest, APSIM outputs were compared with a population of observed plot data from comparable regimes provided by collaborators, for which stocking was a key matching criterion. The Pinus and Eucalyptus models in APSIM were not recalibrated in the model for this project, i.e., the standard models downloaded with the APSIM software were used. Likewise, there was also no soil, climate, or management calibration for individual sites. Instead, a calibration and adjustment process was undertaken on APSIM outputs if required.

The calibration process involved comparison of in-field measurements from permanent growth plots (PGP) against predicted values generated by the baseline APSIM model Pinus and Eucalyptus models. These PGPs are established and managed by plantation management companies across the Green Triangle, and they provided the measurements for this project for a range of sites and ages. Of the supplied PGP data, a random selection of half of the sites supplied was made for use in the calibration process, from which, where possible, the APSIM model could then be adjusted to better predict growth for a given site.

The other half of the PGPs not used in the calibration process were used in a validation process to ensure any APSIM model adjustments made were fit for purpose.

Baseline APSIM models

As a starting point for the calibration of the APSIM Radiata Pine and Tasmanian Blue Gum models, the following assumptions were made to generate baseline tree growth for each location on the plantation suitability grid. These baseline outputs were then compared against observed data to determine if any adjustments were required\ as described in the next section.

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[16] Source: https://www.asris.csiro.au/ASRISApi

Climatic Assumptions

The following climatic assumptions were made:

- 350 ppm CO_2 was assumed.

Soil Nutrient Assumptions

The following soil nutrient assumptions were made:

- Soil nitrogen (N):
  - Sites were assumed to have adequate N and non-N (P, K, etc.) fertility.
  - Fertilizer 50 kg N/ha was applied at planting, then 100kg N/ha four times per year on 15th January, 15th April, 15th July and 15th October to ensure the trees did not grow under any N-related stress.
  - No decomposable organic matter or mineralizable N below 80 cm depth
  - No initial mineral N
- No initial surface organic matter residues
- Water table N – when a water table was present, to emulate approximately constant NO_3 concentrations into the water table (assumed from outside the area), 5 kg N/ha of NO_3N fertiliser was injected into water table 4 times a year (15-jan, 15-apr, 15-jul, 15-oct) at a depth within 200 mm above the bottom of the water table depth.
- Soil Depth – As the downloaded soil data only contained data to a depth of about 100 cm, all soil data depth was extended by appending the last 20 cm horizon information down to a depth of 200 cm where there was no depth to water table data. Where there was a water table data present the soil data was extended in the same manner as above to a depth of 40 cm deeper than the water table depth in maximum steps of 100 cm

Soil Water Assumptions

- Soil plant available water assumed to be 100% at start of simulation.

- Accurate water table depth data was only available for the Lower Limestone coast region[17]. We assumed the values obtained were constant for the whole simulation. No other sites had water table depth included in the modelling. For naturally swampy (waterlogged areas), we assumed they could be drained to provide adequate aeration for tree growth.

Tree Modelling Assumptions

The following tree modelling assumptions were made:

- Across all species and regimes:
  - Zero loss from weeds, pests or diseases
  - Zero Mortality
  - Planting date 16th June
  - Whole-tree harvesting (no harvest residues retained)
- Both Radiata Pine regimes:
  - Planting spacing: 3 m between rows, 2.1 m between trees
  - APSIM Cultivar: BFG[18]
- Standard Tasmanian Blue Gum regime:
  - Planting Spacing: 3.333333 between rows, 3 m between trees
  - APSIM Cultivar: FSABlueGum[19]
- Longer Tasmanian Blue Gum regime:
  - Planting Spacing: 3. between rows, 3m between trees

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[17] Depth to Groundwater surface was created with assistance of UniSA using water bore data downloaded from SA governments Water Connect data portal [Groundwater Data Default (waterconnect.sa.gov.au)]

[18] This cultivar was based on calibration of a wide range of plantation attributes properties at the 'Biology of Forest Growth' CSIRO experimental site near Canberra (Waterworth et al, 2006)

[19] This cultivar was based on calibrations of stem measurements from four Forestry SA growth plots in the Mount Gambier and Adelaide hills area.

    - Cultivar: FSABlueGum

Environmental Assumptions

The following environmental assumptions were made:

- All sites were modelled as an area of one hectare with northern aspect, at an elevation of 50 m and a slope angle of 0 degrees, which forces the model to assume no lateral flow into and out of soil profiles.
- Surface runoff was assumed according to parameters downloaded from the SLGA.

Water Usage Modelling

During the tree modelling, APSIM also recorded the amount of water used by the tree roots (the 'FineRoot.WaterUptake' variable) as they grew, and the results for average annual and maximum annual water use were reported by this project. These results were not at all validated within this project and are provided for general interest only but should not be relied upon. Validation of such values can be undertaken via comparison with satellite derived evapotranspiration models, for example refer (Smethurst, et al., 2022), but this would be significant work to undertake and was beyond the scope of this project.

Carbon Modelling

The following two sub-sections describe how FullCAM was used to model carbon productivity for the four plantation forestry scenarios and a single environmental planting scenario. To ensure the calculations used in this project would be relevant for carbon projects going forward, the 2023 beta version[20] of the FullCAM software was used over the current 2016 public version currently in force under the ERF. No initial establishment fertiliser or weed control events were modelled in this project, based on CER feedback during the FullCAM 2023 Public Release Webinar (13th October 2022) indicating that the re-calibrated growth models in this version already accounted for these standard industry practices.

FullCAM was modelled against the plantation suitability grid described in the previous 'Plantation Suitability Grid' section. Any grid point that did not fall within an ABS census

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[20] The public 2023 version of FullCAM was to be released by the CER in Q1 of 2023 and was planned for use in this project but as of submission of this report it still has not been released.

Statistical Area was removed from the FullCAM modelling as the FullCAM inputs must be within one. This removed some grid points that sat right on the coast as they fell just outside the statistical boundary.

Plantation Forestry Carbon Modelling

Under the Plantation Forestry 2022 Method, the total available credits that can be generated over the life of a newly established plantation (i.e., Schedule 1 of the Method) is capped based on the long-term (100-year) average carbon abatement. To model this, the four harvest plantation regimes (refer ‘Forest Management Regimes’ section) were run through FullCAM for 100-year multi-rotation scenarios, a continuous repeated cycle of planting, tending, thinning where relevant, and then harvest. Each scenario was run against each of the 48,000 sample locations which were identified as receiving 600 mm or greater long term average rainfall in the project AOI. The following outputs were generated from FullCAM, expressed in tonnes per hectare:

- carbon (C) stored in trees, debris and harvested forest products, or emitted by harvest, fire or decay events.
- methane (CH_4) emitted by fire events and fuel use.
- nitrous oxide ($N0_2$) emitted by fire events and fuel use.

The above outputs from these scenarios were converted to tonnes of carbon dioxide equivalents ($tC0_{2\text{-}e}$) based on the equations set out in the Method, and the net abatement for each month calculated based on gross abatement minus emissions. Under the Method, the credits issued are not based directly on the calculated net abatement, a risk of reversal discount and permanence period discount need to be applied first to account for potential that the project may fail, say from bushfire, and the abatement ‘reversed’.

The discounts applied in this model are described in Table 3. The total of all monthly discounted abatement figures was then averaged over the 100-year period, and this becomes the total amount of ACCU/ha that can be generated over the life of the project.

Table 3: Risk of Reversal and Permanence Discounts applied to long term average net abatement to calculate total carbon credits to be issued

Species	Clearfell Age	Risk of Reversal Discount (%)	25-Year Permanence Period Discount (%)	Total Discount applied to 100-year long term average abatement (%)
Radiata Pine	31	5	20	25
Radiata Pine	25[21]	5	20	25
Tasmanian Blue Gum	18[22]	5	25	30
Tasmanian Blue Gum	13	5	25	30

A 25-year permanence period was chosen for this model to ensure the results were conservative, under a 100-year permanence period the permanence discounts for this method would be zero. Under either permanence period, ACCUs are only generated during the first 25 years of the project life (i.e., the crediting period) after which crediting ceases. During the crediting period, ACCUs are issued in proportion to the abatement achieved in each reporting period (anywhere from 6 months to 5 years).

Environmental Planting Carbon Modelling

Under the Reforestation by Environmental or Mallee Plantings 2014 Method, the total amount of carbon credits that can be generated is not capped by the long-term average, but still attracts a 5% risk of reversal and 20% permanence discount under a 25-year permanence period. A 25-year permanence period was chosen for this model to ensure the results were conservative, under a 100-year permanence period the permanence discounts for this method would be zero. For either permanence period, ACCUs are only generated during the first 25 years of the project life (i.e., the crediting period) after which crediting ceases. During the crediting period, ACCUs are issued in proportion to the abatement achieved in each reporting period (anywhere from 6 months to 5 years).

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[21] Although the 25-year rotation Radiata Pine regime is described as ‘shorter’ rotation in this document, under the Plantation Forestry 2022 Method, this would still be determined to be a long rotation and so receives a 20% permanence discount under a 25-year permanence period.
[22] Although the 18-year rotation Tasmanian Blue Gum regime is described as ‘longer’ rotation in this document, under the Plantation Forestry 2022 Method, this would still be determined to be a short rotation and so receives a 25% permanence discount under a 25-year permanence period.

The environmental planting scenario was run against each of the 245,000 sample locations which were identified as receiving 300mmm or greater long term average rainfall in the project AOI. The following outputs were generated from FullCAM, expressed in tonnes per hectare:

- carbon (C) stored in trees, debris and harvested forest products, or emitted by ‘decay’ events from those pools.

These outputs were converted into the total ACCU/ha likely to be generated over the crediting period of the project.

Results

Wood Productivity Model

Radiata Pine Model Calibration

Figure 6 shows the distribution of the PGPs used in the calibration process of the Radiata Pine APSIM model.

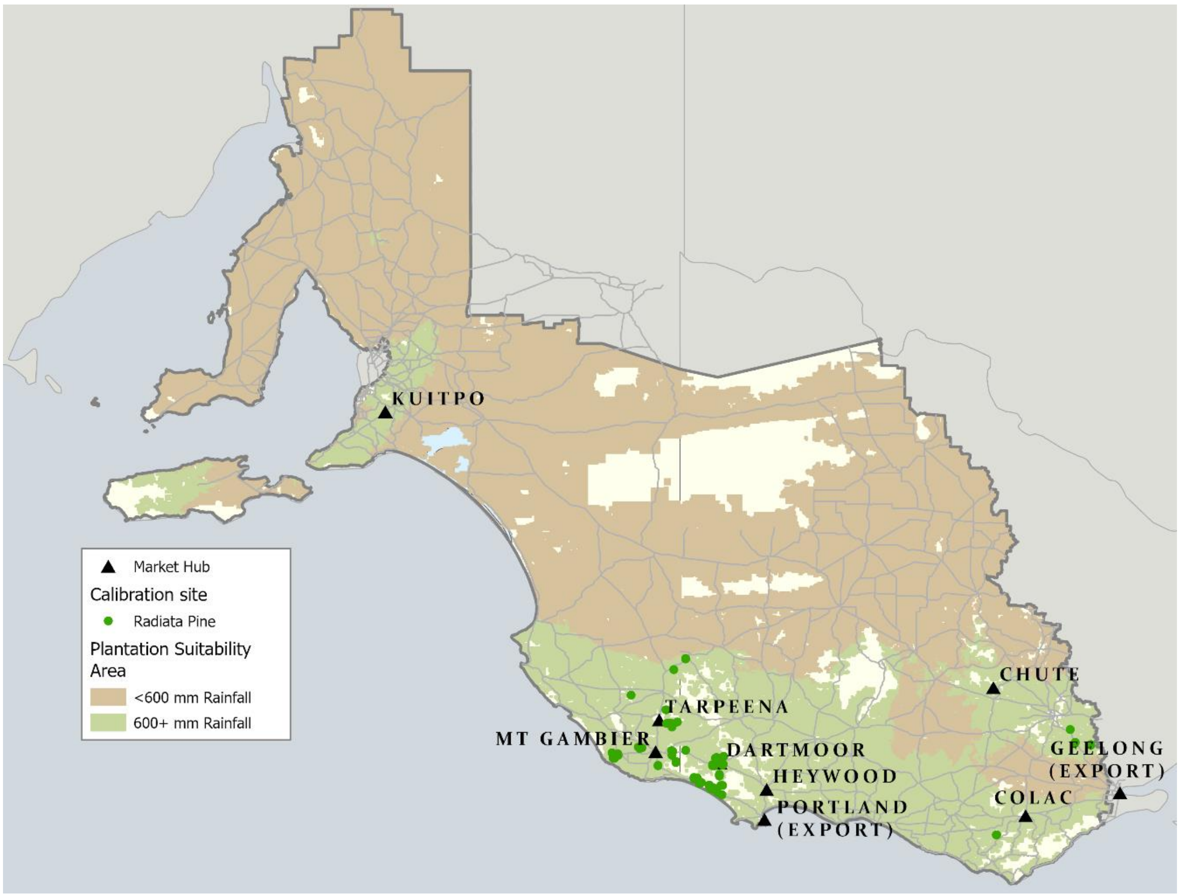

Figure 6: Location of permanent growth plots used to calibrate outputs of the Radiata Pine APSIM model

Modelled Outputs

Using the baseline parameters defined previously, the standard Radiata Pine regime was modelled using APSIM at each location corresponding to a PGP, and the predicted values generated from the APSIM model were compared against the observed values from the PGP measurements.

Key modelled outputs compared included:

- Tree Basal Area (TreeBA): basal area at breast height of an average tree expressed in square metres (m^2). This is the cross-sectional area of an average tree for the site at 1.3 m height.
- Stand Basal Area (StandBA): total basal area at breast height for the whole plantation stand expressed in square metres per hectare (m^2/ha). This is the average total cross-sectional area of all trees on the site at 1.3 m height over a one hectare area.
- Tree Height (TreeHt): height of an average tree expressed in metres (m).
- Tree Volume Under Bark[23] (TreeVolUB): average stem volume under bark of a tree expressed in cubic metres (m^3). This is the total volume of an average tree for the site with the bark removed.
- Stand Volume Under Bark (StandVolUB): total stem volume under bark for the whole plantation stand expressed in cubic metres per hectare (m^3/ha). This is the average total volume of all trees on the site over a one hectare area.

Stocking Comparison

Under a thinning regime, Stand BA & StandVolUB are influenced by the number of trees that are growing on a site for a given area, so predicted values will appear to vary significantly if the tree stocking for any given year of measurement does not align with the modelled tree stocking. Although stocking also obviously drives TreeBA and TreeVolUB growth within a forest, comparing these parameters at the tree-level removes some of the variability associated with stocking where the timing of thinning is slightly misaligned.

To this end, only PGP data which had annual measurements in which the predicted and observed stocking were within reasonable alignment were compared, based on the following arbitrary rules:

- for unthinned PGPs, any measurements which had a stocking that deviated more than +/- 250 sph from the modelled stocking of 1600 sph were excluded; and

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[23] A conic volume equation (i.e., 1/3 x TreeBA x TreeHt x 0.9) was used to estimate tree volume in both the observed and predicted values. The 0.9 figure is applied within APSIM to account for the removal of bark volume to achieve an estimate of under bark volume.

- for first thinned PGPs, any which had a stocking that deviated more than +/- 150 sph from the modelled stocking of 650 sph were excluded.
- for second thinned PGPs, any which had a stocking that deviated more than +/- 100 sph from the modelled stocking of 430 sph were excluded.
- for third thinned PGPs, any which had a stocking that deviated more than +/- 75 sph from the modelled stocking of 320 sph were excluded.

In some cases, although the stocking aligned for a given annual measurement, the thinning history did not align, for example the observed values were the result of a very late first thinning, and such PGPs were also excluded, as this difference was likely to cause significant difference in individual tree size.

After excluding PGPs based on the above rules, this resulted in 73 calibration sites which in total had 142 distinct annual measurements (i.e., observations) made against them (refer Figure 6 for geographic distribution). Measurements for age less than 5 years were excluded from the analysis to avoid possible issues with the site not yet being fully occupied, leaving 132 observations in total.

To assist with the comparison process, the data was classified on thinned status to ensure alignment of stocking rates and general growth conditions between the observed and predicted data, and some classes were further divided into age classes to better represent key outputs required from the project:

- UT (5-9yo): values which represent unthinned sites for ages 5 to 9 years;
- UT (10-11yo): values which represent unthinned sites of ages 10 and 11years, this class being representative of the standing volume present during a 1st thinning;
- T1: values which represent 1st thinned sites, this class being representative of the standing volume present during a 2nd thinning;
- T2: values which represent 2nd thinned sites, this class being representative of the standing volume present during a 3rd thinning;
- T3 (22-26yo): values which represent more recently 3rd thinned sites for ages 22 to 26 years, this class being representative of the standing volume present at final clearfell harvest under the shorter Radiata Pine Regime; and

- T3 (27-30yo): values which represent 3rd thinned sites for ages 27 to 30 years, this class being representative of the standing volume present at final clearfell harvest of the standard Radiata Pine regime.

Figure 7 below provides the resultant distribution of difference in stocking between the predicted and observed data used in the calibration process, based on thinned status.

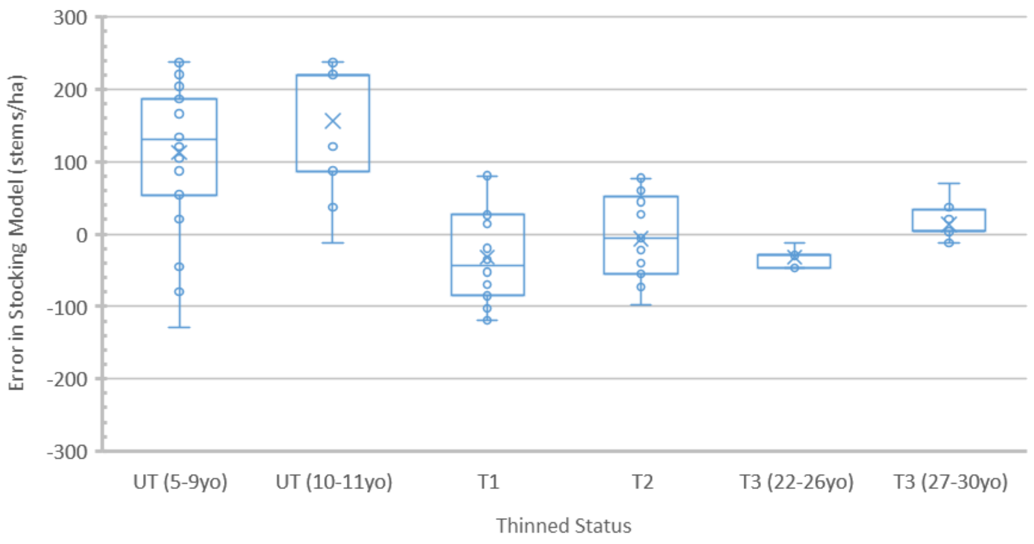

Figure 7: Distribution of modelled stocking error (Predicted – Observed) by thinned status for the Radiata Pine calibration sites

Basal Area Comparison

Comparing the APSIM average tree basal area outputs against observed PGP measurements for the calibration sites, the predicted values displayed a good linear relationship with observed values (refer Figure 8).

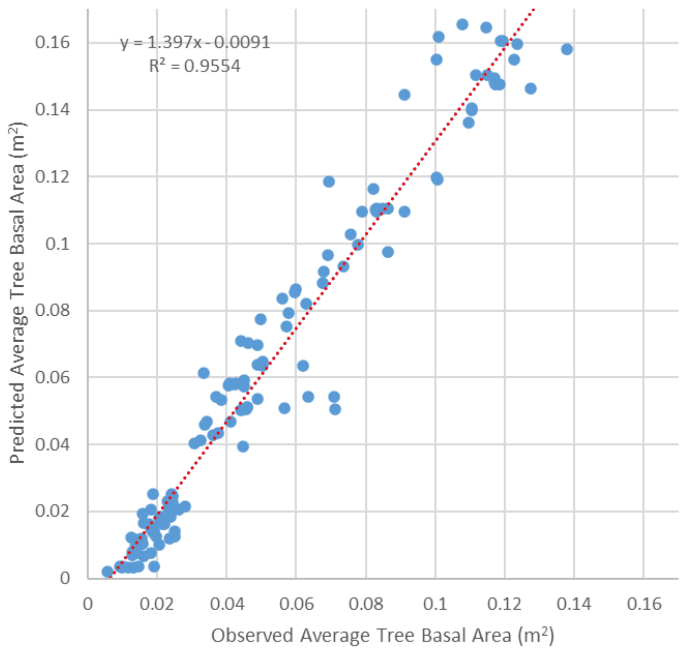

Figure 8: Comparison of predicted to observed average tree basal area (TreeBA) for the Radiata Pine calibration sites

However, the predictions for average tree basal area displayed positive bias as age increased (i.e., over-predicting) as shown in Figure 9, and there was a much wider range of difference between predicted and observed values in the 1st thinned and 3rd thinned (>=27yo) classes.

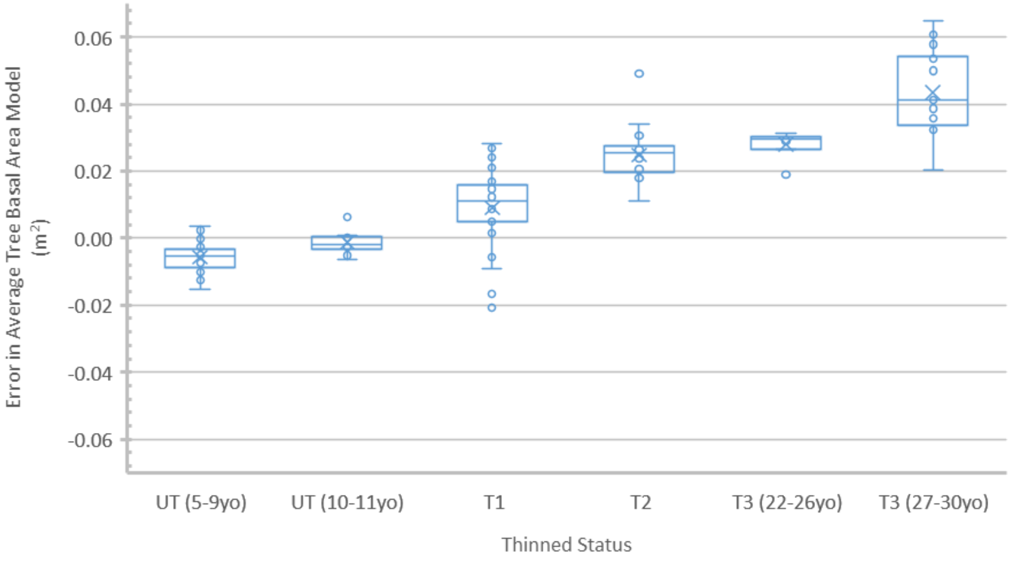

Figure 9: Distribution of modelled average tree basal area error (Predicted – Observed) by thinned status for the Radiata Pine calibration sites

At the stand level, there was less of a linear relationship between predicted and observed basal area (refer Figure 10) than there was for average tree level basal area, likely a result of some misalignment between stocking rates for observed and predicted thinning regimes.

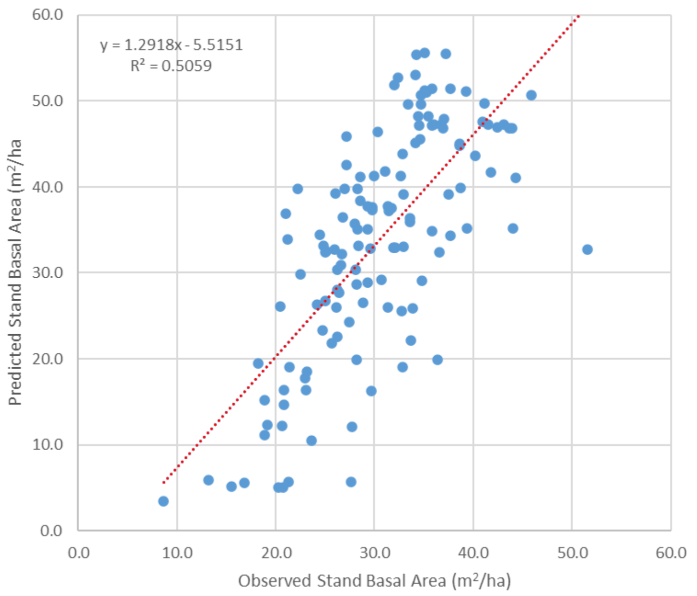

Figure 10: Comparison of predicted to observed stand basal area per hectare (StandBA) for the Radiata Pine calibration sites

Plotting the distribution of error in predictions of stand basal area against age class showed considerable variation between predicted and observed values at nearly all age classes (refer Figure 11).

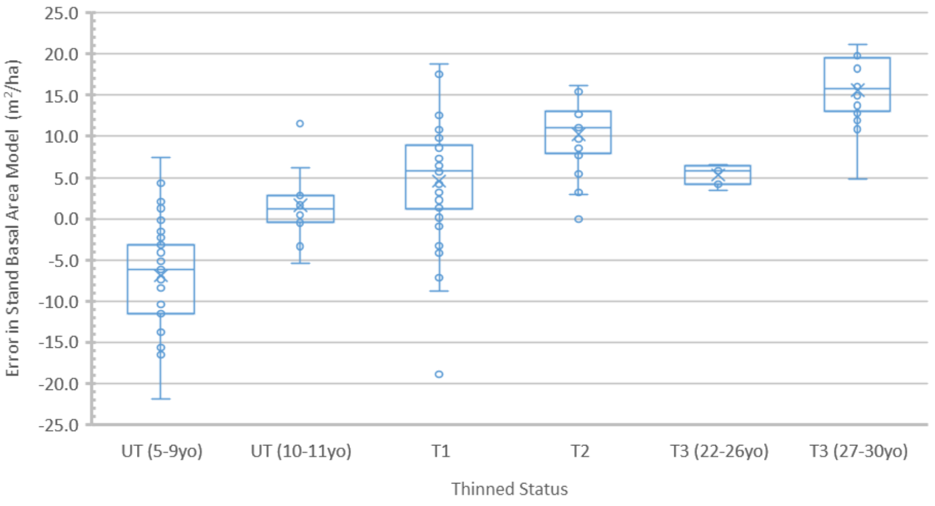

Figure 11: Distribution of modelled stand basal area error (Predicted – Observed) by thinned status for the Radiata Pine calibration sites

Similar to the tree level results, predictions for stand basal area display increasing positive bias (i.e., over-predicting) as age increased.

Height Comparison

Predicted average tree height displayed a good linear relationship to observed height (refer Figure 12).

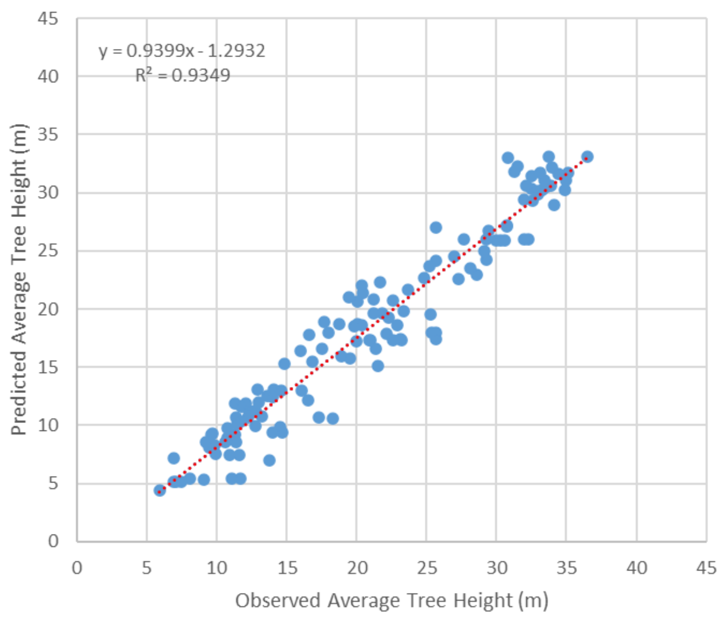

Figure 12: Comparison of predicted to observed average tree height (TreeHt) for the Radiata Pine calibration sites

Plotting the distribution of error in predictions of average tree height against thinned status displayed a consistent negative bias (i.e., under-predicting) across all classes (refer Figure 13).

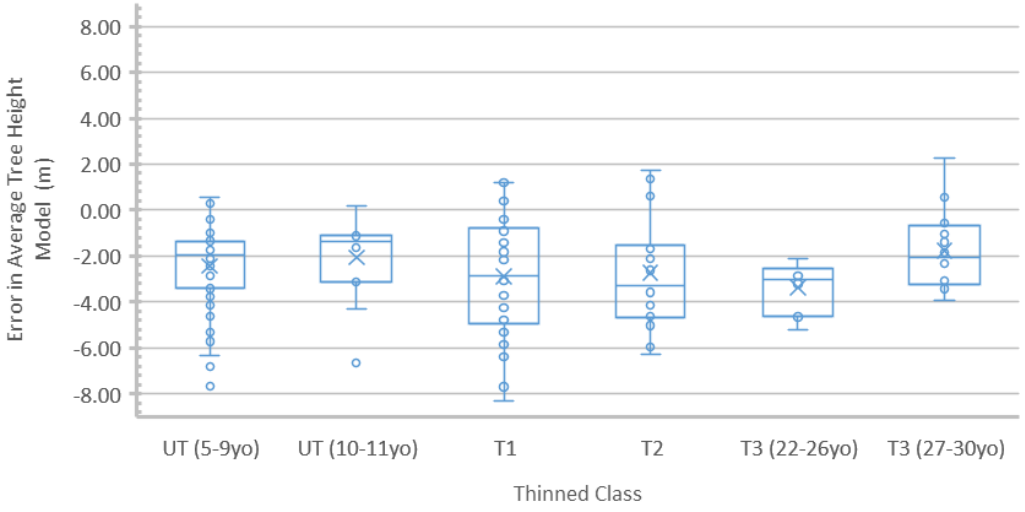

Figure 13: Distribution of modelled average tree height error (Predicted – Observed) by thinned status for the Radiata Pine calibration sites

Volume Comparison

The key outputs for this modelling work are the volumes available at each thinning event and at final harvest, as this informs the value that can be derived from the plantation. At the tree level, there was a good linear relationship between predicted and observed volumes (refer Figure 14).

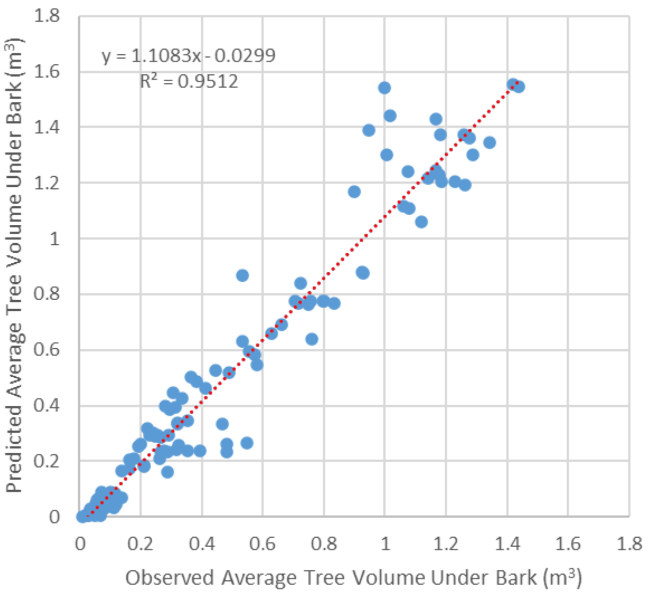

Figure 14: Comparison of predicted to observed average tree volume under bark per hectare (TreeVolUB) for the Radiata Pine calibration sites

This result suggests that the over-prediction of basal area mentioned earlier were somewhat balanced by the under-prediction of height when it came to calculation of tree volume.

Plotting the distribution of error in predictions of average tree volume under bark displayed a positive bias (i.e., over-prediction) for all the thinned classes, which increased with age (refer Figure 15), reflecting the bias in the tree basal area estimates.

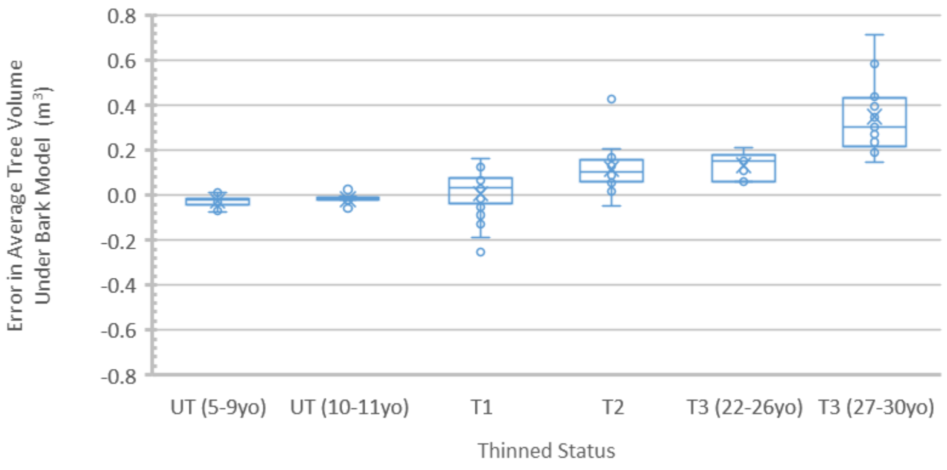

Figure 15: Distribution of modelled average tree volume under bark error (Predicted – Observed) per hectare by thinned status for the Radiata Pine calibration sites

The average stand volume predictions were well-correlated with observed values (R^2 = 0.82), but with a spread of data that reflected the errors contributing to both observed and predicted values (refer Figure 16).

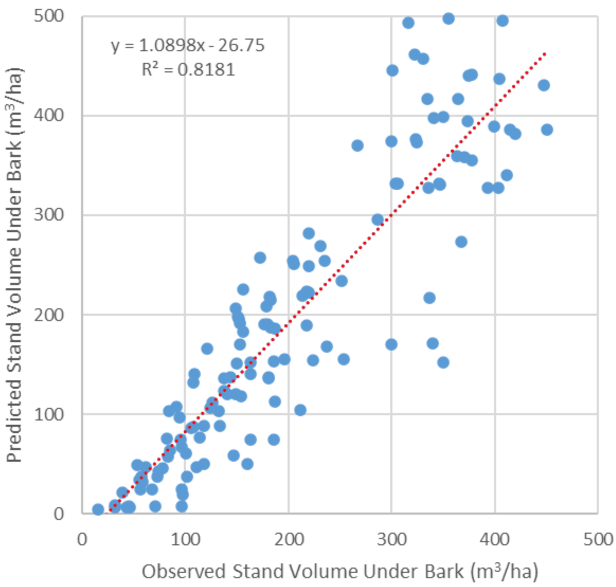

Figure 16: Comparison of predicted to observed stand volume under bark per hectare (StandVolUB) for the Radiata Pine calibration sites

Plotting the distribution of error in predictions of stand volume under bark displayed a similar positive bias at T3 to the average tree volume under bark prediction errors for the thinned classes (refer Figure 17) but also showed a wide level of distribution in error, likely due to the differences in basal area as displayed in the previous section.

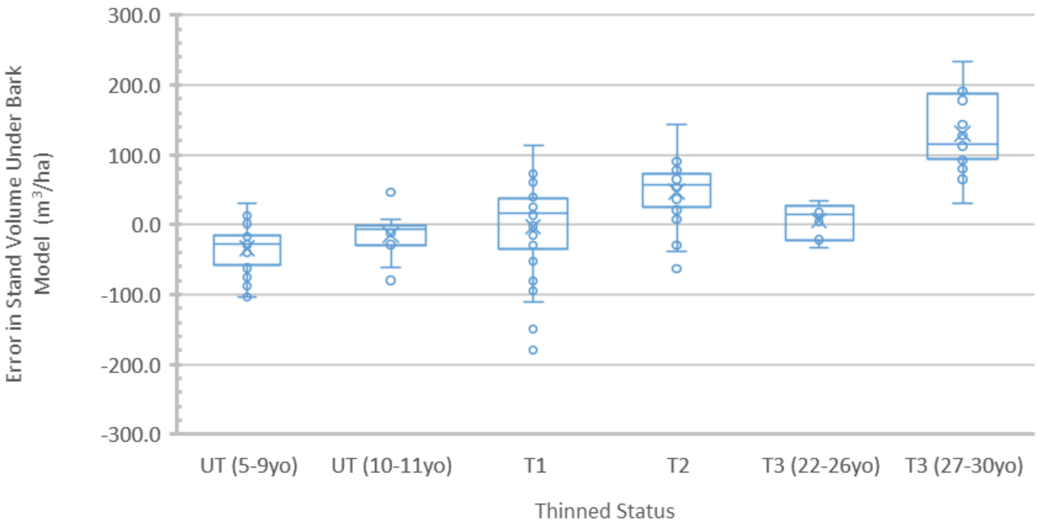

Figure 17: Distribution of modelled stand volume under bark error (Predicted – Observed) per hectare by thinned status for the Radiata Pine calibration sites

Adjustment Factors

Volume predictions at thinning and final harvest ages were the key outputs of this project to assist users of the web map with determining suitability of Radiata Pine plantations for a site. From the above volume comparisons, it appeared that the volume estimates within the thinned classes were over-predicted and so it was recommended that adjustment factors should be applied prior to release on the public website to reduce the possibility of such bias in the final outputs.

To reduce some of the interference from stocking differences between the predicted and observed management regimes, average tree volume, rather than stand volume, was used to determine what level of adjustments should be applied to reduce bias in the final model.

Table 4 compares the average tree volume under bark values for predicted and observed values by thinned class, from which an adjustment factor was calculated.

Table 4: Calculation of adjustment factors to be applied to the APSIM Radiata Pine model

Thinned Class	Average Tree Volume Under Bark (m3)		Adjustment Factor
	Predicted	Observed	
Unthinned (5-9yo)	0.03	0.06	1.82
Unthinned (10-11yo)	0.08	0.10	1.23
1st Thinned	0.30	0.29	0.98
2nd Thinned	0.74	0.62	0.84
3rd Thinned (22-26yo)	1.29	1.15	0.90
3rd Thinned (>=27yo)	1.52	1.17	0.77

Table 5 describes how the above adjustment factors were applied to the standard and shorter rotation Radiata Pine regime values to be published to the web map to ensure that the thinning and final harvest volumes presented were not biased for the local conditions.

Table 5: Adjustment factors applied to final APSIM Radiata Pine model for each thinning and the final clearfell event

Species	Rotation Length	Initial SPH	1st Thin Event (Age)	2nd Thin Event (Age)	3rd Thin Event (Age)	Clearfell Event (Age)
P. radiata	Long	1,600	1.23 (12)	0.98 (17)	0.84 (22)	0.77 (31)
P. radiata	Short	1,600	1.23 (13)	0.98 (18)	NA	0.77 (25)

Validation

The validation PGP locations were modelled against the adjusted APSIM model developed during the calibration process and the resulting predicted stand volume values were compared to the observed values. As per the calibration process, PGP plots in the validation pool were excluded where their predicted stocking differed from the observed values as per the exclusion rules outlined in the ‘Stocking Comparison’ section above. This resulted in a validation pool of 57 PGPs representing 132 observations, their geographic distribution as shown in Figure 18 below.

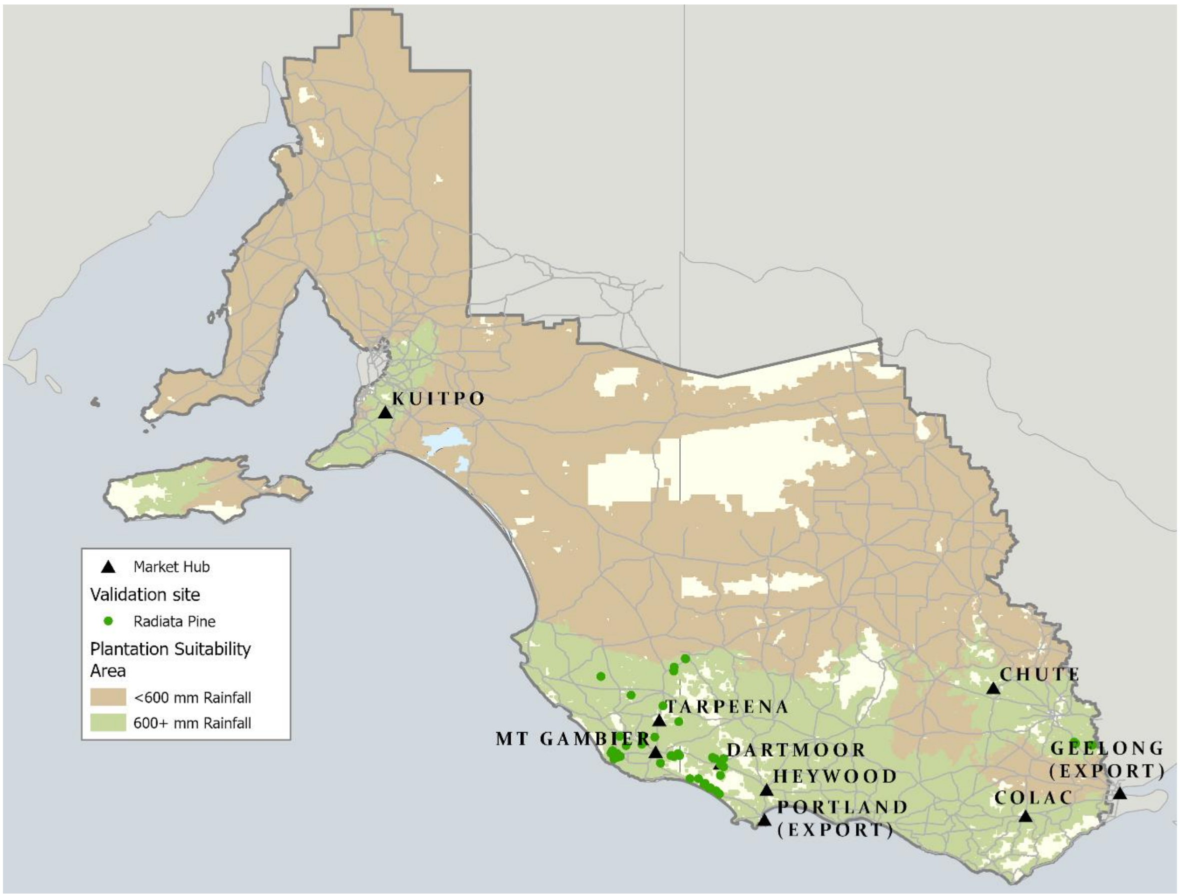

Figure 18: Location of permanent growth plots used to validate outputs of the Radiata Pine APSIM model

Figure 19 shows the relationship between predicted and observed stand volume under bark values for the validation sites and Figure 20 shows the relationship between the adjusted and observed values.

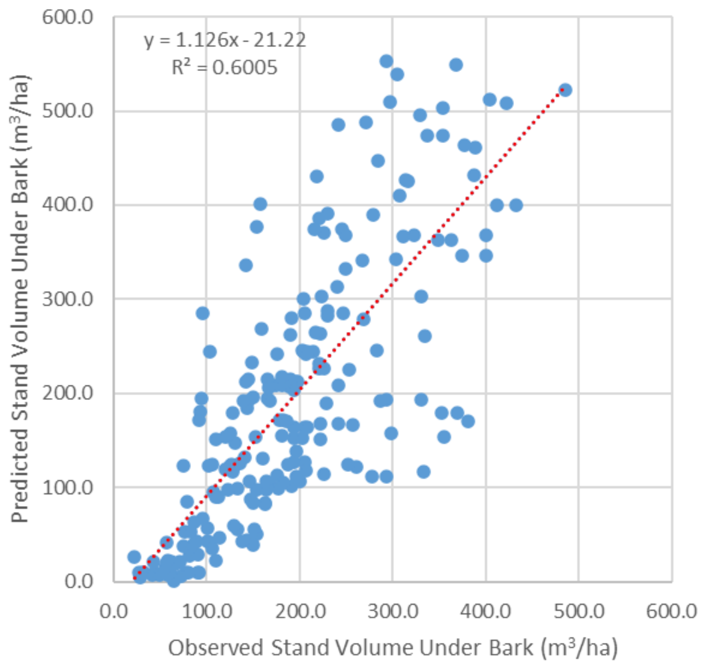

Figure 19: Comparison of predicted to observed stand volume under bark per hectare (StandVolUB) for the Radiata Pine validation sites

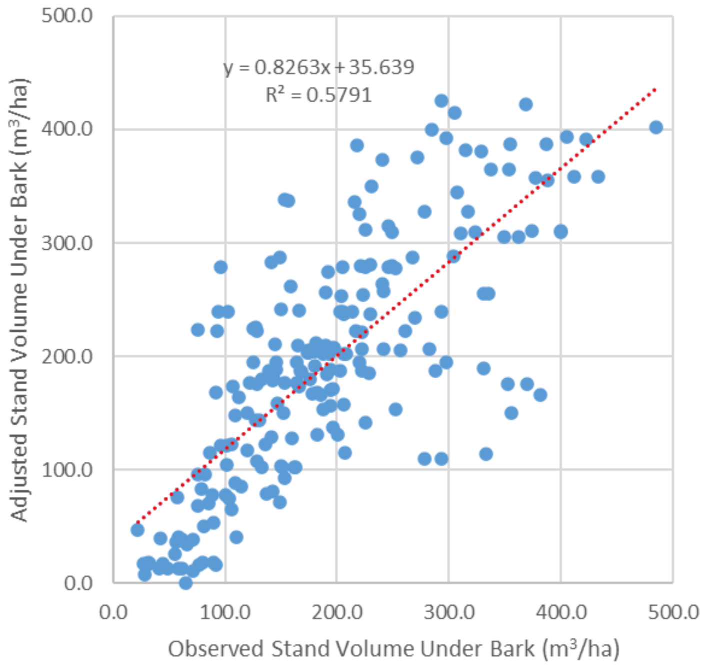

Figure 20: Comparison of adjusted to observed stand volume under bark per hectare (StandVolUB) for the Radiata Pine validation sites

Figure 21 shows the distribution of error between unadjusted predicted stand volume and the observed stand volume under bark values for the validation sites.

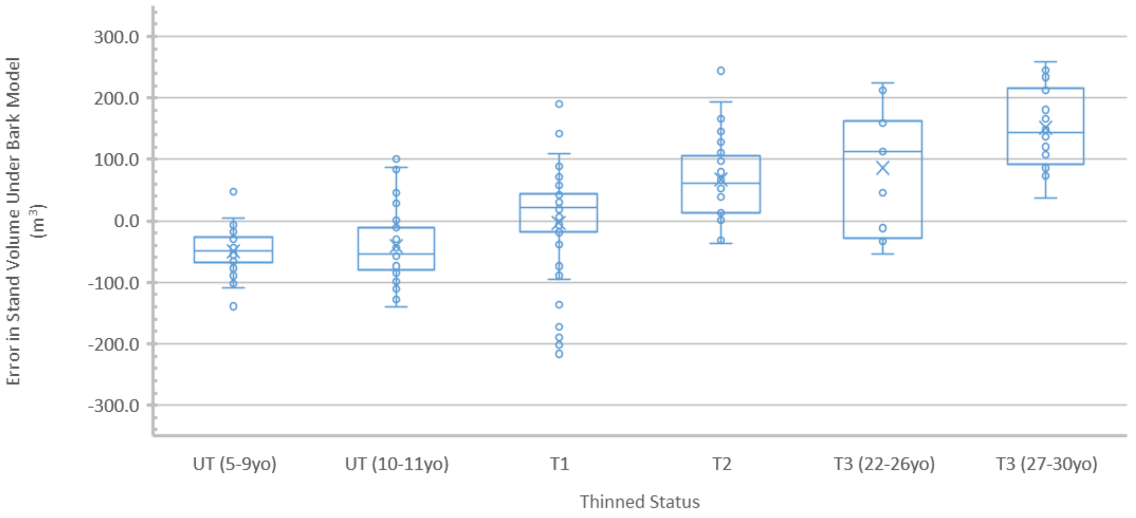

Figure 21: Distribution of modelled stand volume under bark error (Predicted – Observed) per hectare by thinned status for the Radiata Pine validation sites

Figure 22 shows the distribution between the adjusted predicted stand volume and the observed stand volume under bark values for the validation sites.

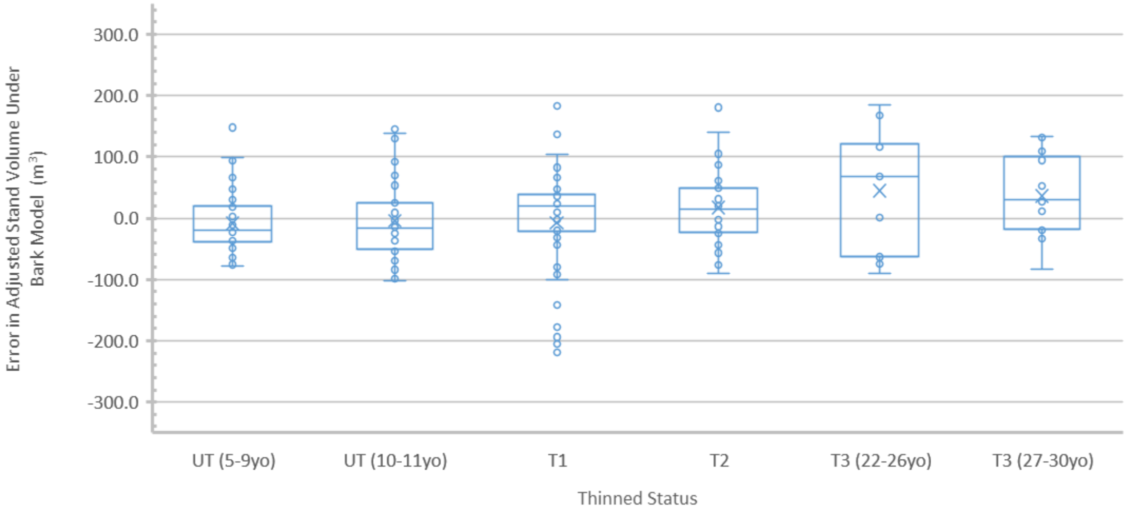

Figure 22: Distribution of modelled stand volume under bark error (Adjusted – Observed) per hectare by thinned statis for the Radiata Pine validation sites

Summarising the effects of the adjustments on the validation sites, Table 6 displays the average unadjusted and adjusted model average tree volume under bark values and compares this with the observed values.

Table 6: Effect on average tree volume under bark of the adjustment factors applied to the APSIM Radiata Pine model for the validation sites

	Average Tree Volume Under Bark (m^3)			Percentage of Observed	
Thinned Class	Unadjusted	Adjusted	Observed	Unadjusted	Adjusted
Unthinned (5-10yo)	51	92	100	51%	92%
Unthinned (10-11yo)	156	192	196	79%	98%
1st Thinned	190	186	194	98%	96%
2nd Thinned	318	267	250	127%	107%
3rd Thinned (22-26yo)[24]	397	356	311	128%	115%
3rd Thinned (>=27yo)	498	383	347	144%	111%

Table 7 provides the same comparison but for the average stand volume values.

Table 7: Effect on average stand volume under bark of the adjustment factors applied to the APSIM Radiata Pine model for the validation sites

	Average Stand Volume Under Bark (m^3/ha)			Percentage of Observed (%)	
Thinned Class	Unadjusted	Adjusted	Observed	Unadjusted	Adjusted
Unthinned (5-10yo)	0.02	0.04	0.05	47%	86%
Unthinned (10-11yo)	0.10	0.12	0.12	79%	97%
1st Thinned	0.29	0.29	0.30	98%	96%
2nd Thinned	0.74	0.63	0.55	134%	113%
3rd Thinned (22-26yo)	1.24	1.11	0.96	129%	116%
3rd Thinned (>=27yo)	1.55	1.19	1.13	137%	106%

Example Outputs

The full set of APSIM generated layers is available on the Web Map from the GTFIH website, but the figures below provide examples of mean annual increment at harvest for Radiata Pine under the standard (refer Figure 23) and shorter rotation (refer Figure 24) plantation management regimes. These values reflect the adjusted model outputs.

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[24] The adjustments for the ‘3rd thinned (22-26yo)’ thinned class have no corresponding output in the web map and so have no effect on the deliverables for this project.

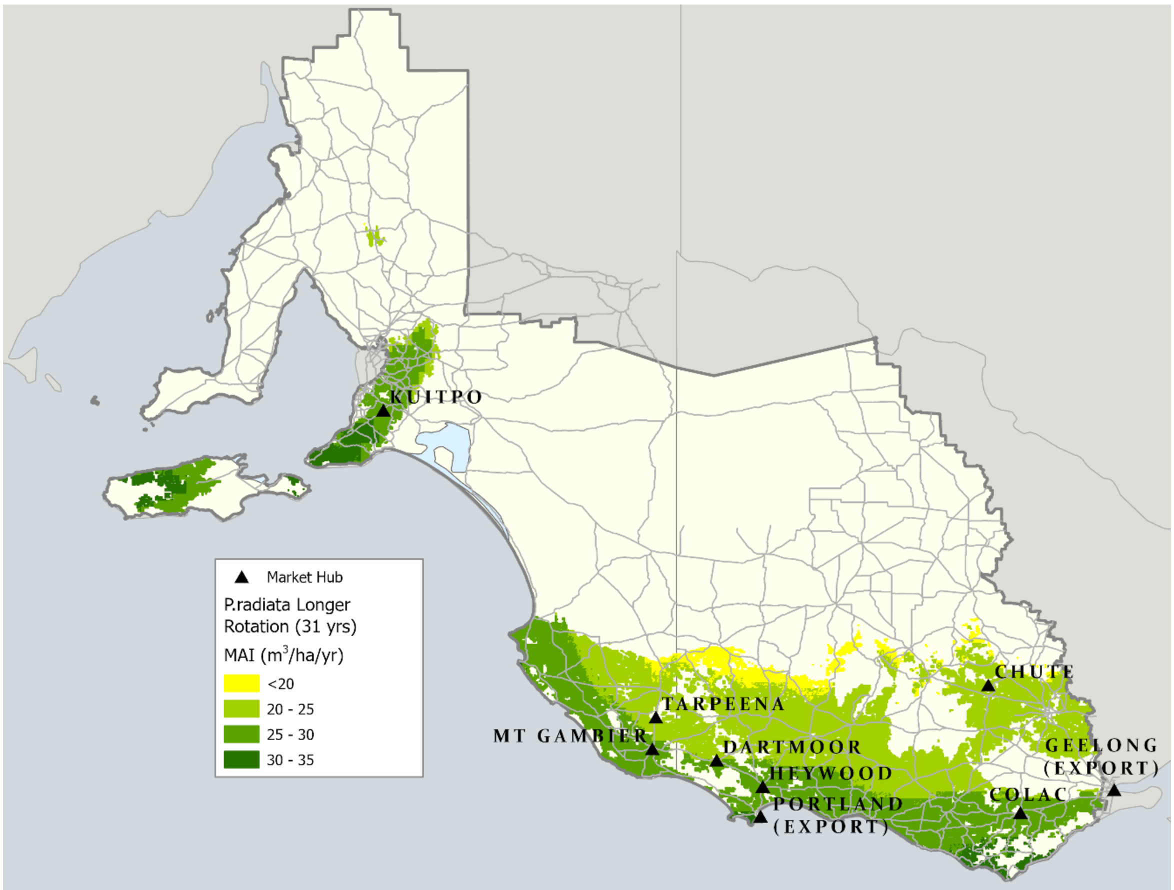

Figure 23: Mean Annual Increment (m3/ha/year) at Harvest Age (31) for the standard Radiata Pine regime as generated by APSIM

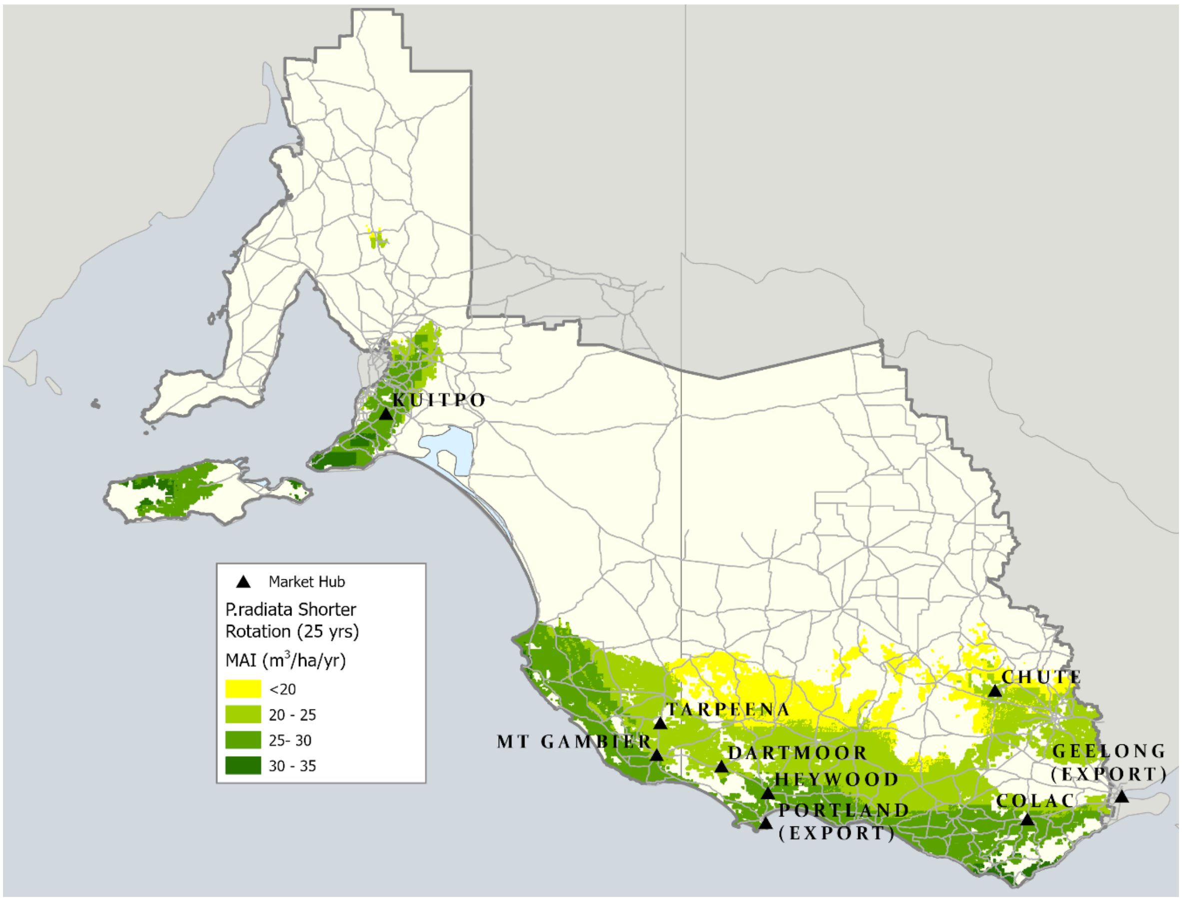

Figure 24: Mean Annual Increment (m3/ha/year) at Harvest Age (25) for the shorter regime Radiata Pine regime as generated by APSIM

Tasmanian Blue Gum Model Calibration

Figure 25 shows the distribution of the PGPs used in the calibration process of the Tasmanian Blue Gum APSIM model.

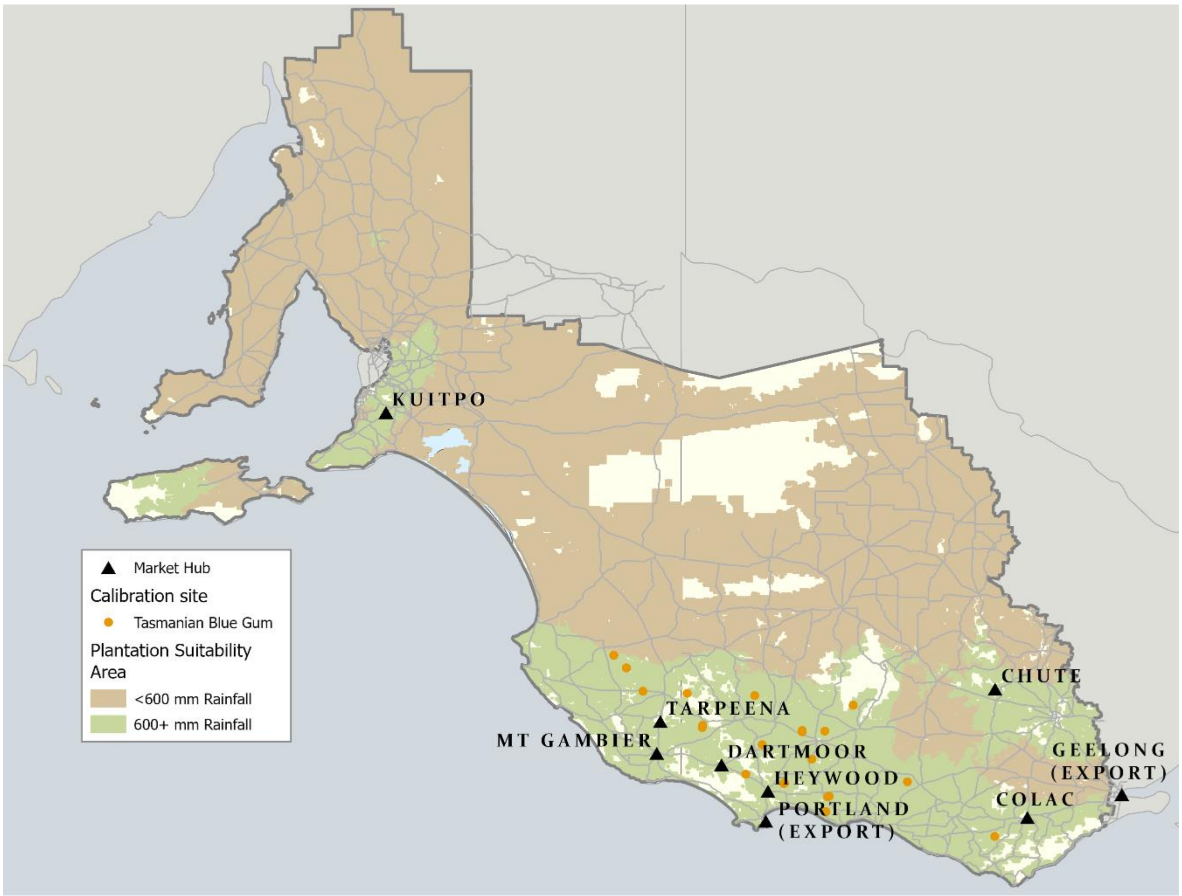

Figure 25: Location of permanent growth plots used to calibrate outputs of the Tasmanian Blue Gum APSIM model

Based on the calibration process the following assumptions were made to the APSIM models that differed from the assumptions used in the baseline APSIM models.

Modelled Outputs

Using the baseline parameters defined in the previous section, the standard Tasmanian Blue Gum regime was modelled using APSIM at each location corresponding to a PGP, and the predicted values generated from APSIM model were compared against the observed values from the PGP measurements.

The same modelled outputs (TreeBA, StandBA, TreeHt, TreeVolUB and StandVolUB) as run for Radiata Pine were compared for the Tasmanian Blue Gum model.

It was noted that the average initial stocking for the calibration PGP was 1,100 stems/ha, so for calibration purposes, the initial stocking for the modelled regime was increased from 1,000 stems/ha to 1,1000 stems/ha to match. Within APSIM this was represented as an initial planting spacing of 3.333333 m between rows and 3 m between trees.

Stocking Comparison

Comparing stocking over the rotation of observed data it was apparent that some form of mortality was required within the Tasmanian Blue Gum model to reflect reality. Analysis of the supplied observation data suggested that mortality averaged at a loss of around 33% of initial stocking over the rotation, an average of 8% per annum of initial stocking. To mimic mortality within APSIM, we had to apply an annual non-commercial thinning, which was set at 3.3% per annum. Given that the way APSIM applied this figure was compounded over time, it achieved the required overall mortality of 33% over the whole rotation.

To ensure reasonable alignment between the silvicultural regime applied on ground to the PGPs and the APSIM predictions, only PGP data which had annual measurements in which the predicted and observed stocking were within reasonable alignment were compared, based on the following rules:

- any PGPs which appeared to suffer more extreme mortality (i.e., >= 50% loss over the life of the plantation) or which were thinned were excluded.
- any measurements which had a planted stocking that deviated more than +/- 200 sph from the initial modelled stocking were excluded.

After excluding PGPs based on the above rules, this resulted in 21 calibration sites which in total had 143 distinct annual measurements (i.e., observations) made against them. Measurements for ages less than 5 years were excluded from the analysis to avoid possible issues with the site not yet being fully occupied, leaving 133 observations in total. Only two of the remaining sites had a measurement at age 13 years so comparison at this age was less reliable than the other ages.

Figure 26 below provides the resultant range of difference in stocking between the predicted and observed data used in the calibration process. There was a general under-prediction of stocking across all ages using the 3.3% per annum mortality rate.

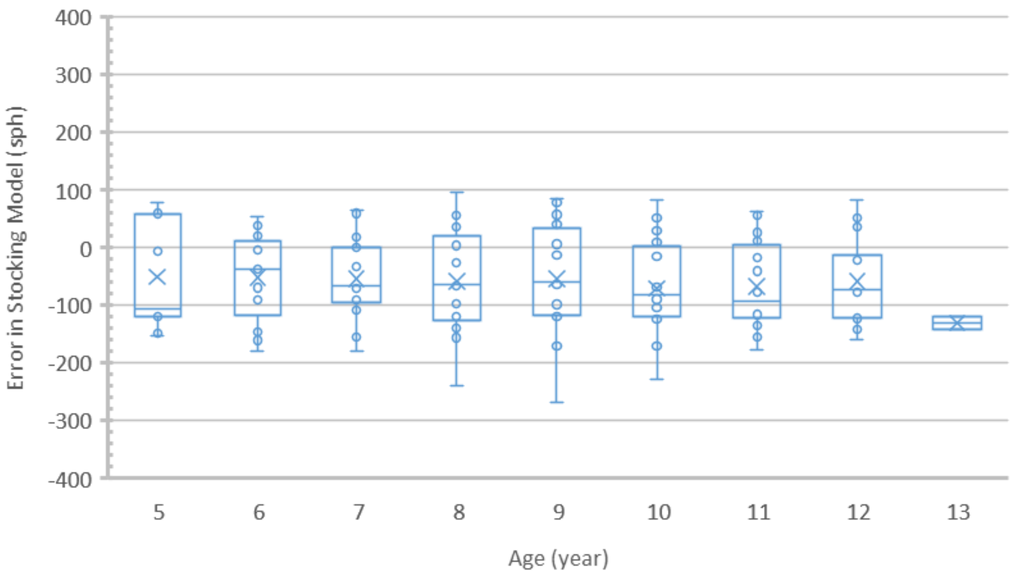

Figure 26: Variability in modelled stocking error (Predicted – Observed) by age for the Tasmanian Blue Gum calibration sites

Basal Area Comparison

Comparing the APSIM average tree basal area outputs against observed PGP measurements for the calibration sites, the predicted values displayed a reasonable linear relationship with observed values (refer Figure 27).

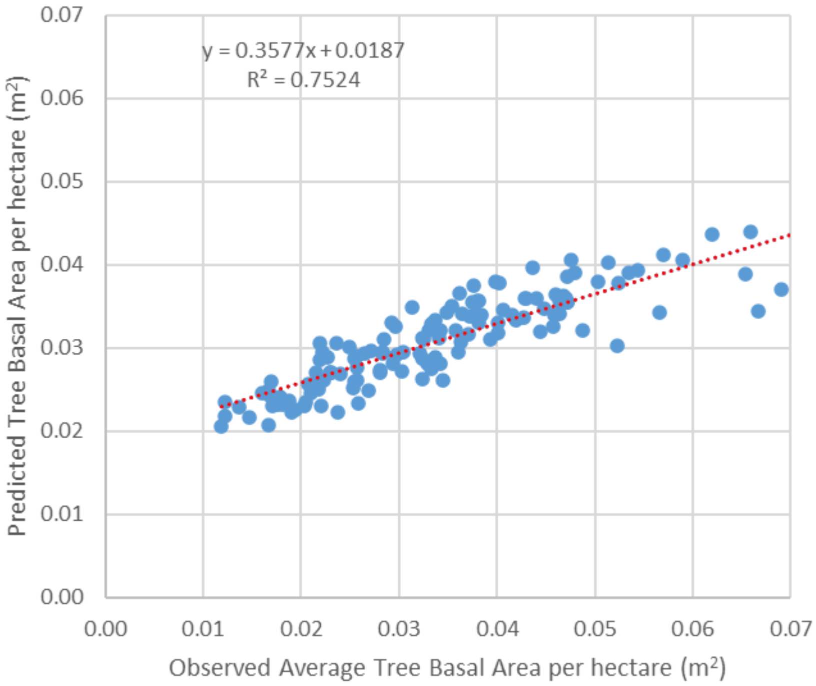

Figure 27: Comparison of predicted to observed average tree basal area per hectare (TreeBA) for the Tasmanian Blue Gum calibration sites

However, there was a trend of positive to negative bias with age, the estimates at ages under 7 over-predicting and those over age 9 under-predicting as shown in Figure 28.

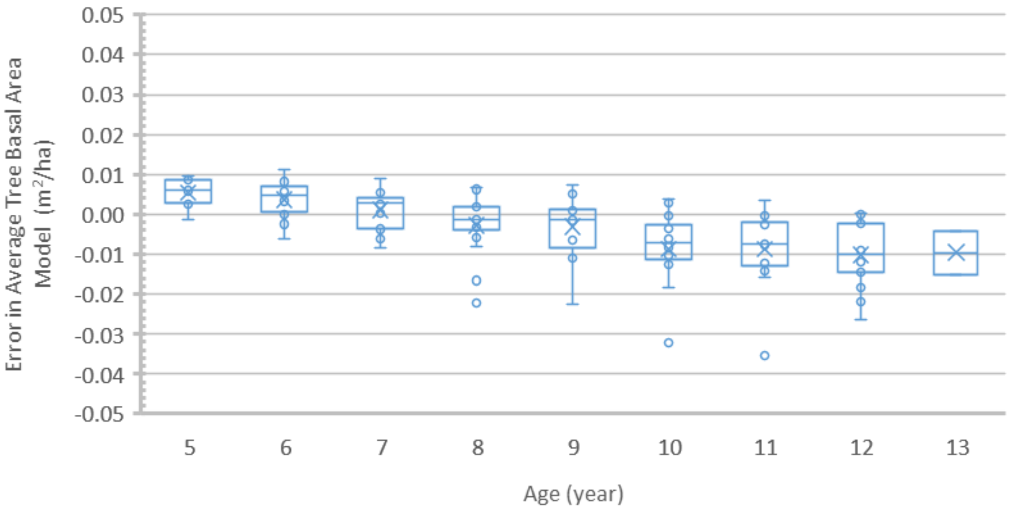

Figure 28: Distribution of modelled average tree basal area error (Predicted – Observed) by age class for the Tasmanian Blue Gum calibration sites

At the stand level, there also a reasonable linear correlation between predicted and observed basal area (refer Figure 29).

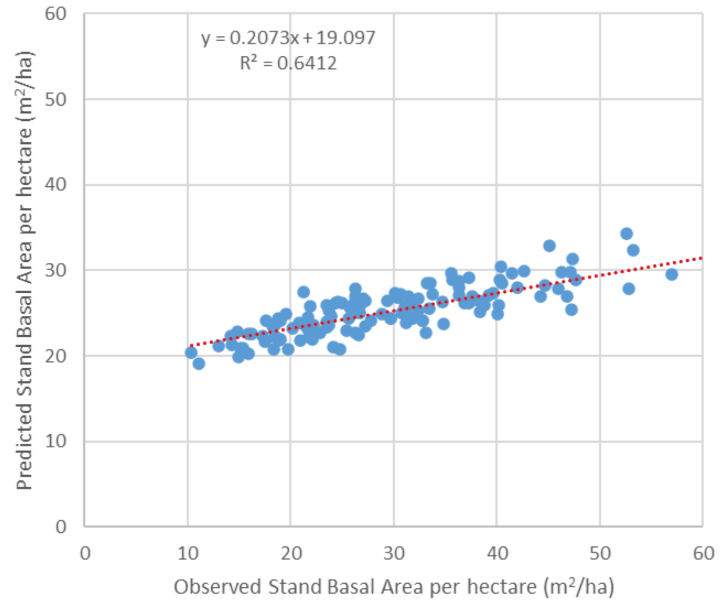

Figure 29: Comparison of predicted to observed stand basal area per hectare (StandBA) for the Tasmanian Blue Gum calibration sites

Plotting the distribution of error in predictions of stand basal area against age class showed a similar trend as the tree level predictions, an increasing negative bias with age (refer Figure 30).

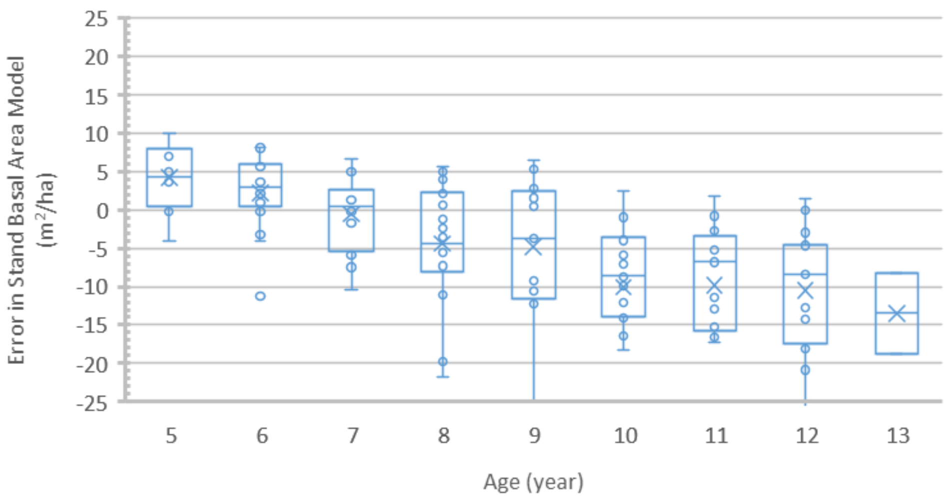

Figure 30: Distribution of modelled stand basal area error (Predicted – Observed) by age class for the Tasmanian Blue Gum calibration sites

Height Comparison

Predicted average tree height displayed a good relationship to observed height (refer Figure 31) but displayed a large positive bias (i.e. over-prediction) across all ages (refer Figure 32).

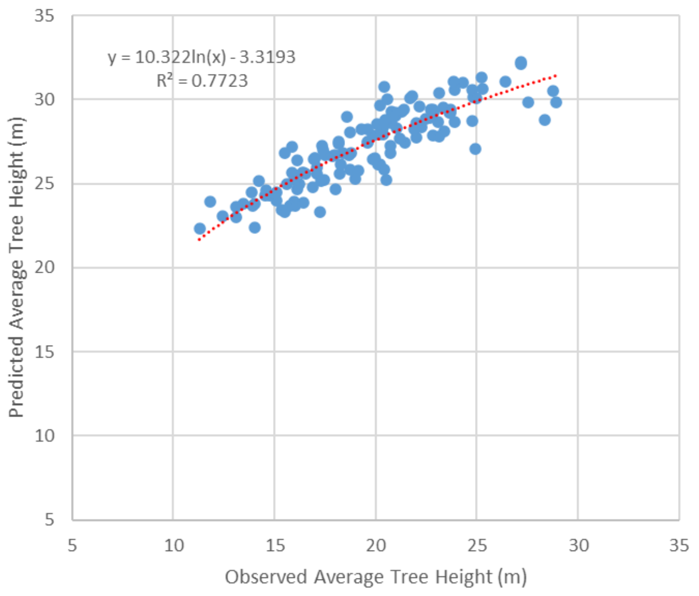

Figure 31: Comparison of predicted to observed average tree height (TreeHt) for the Tasmanian Blue Gum calibration sites

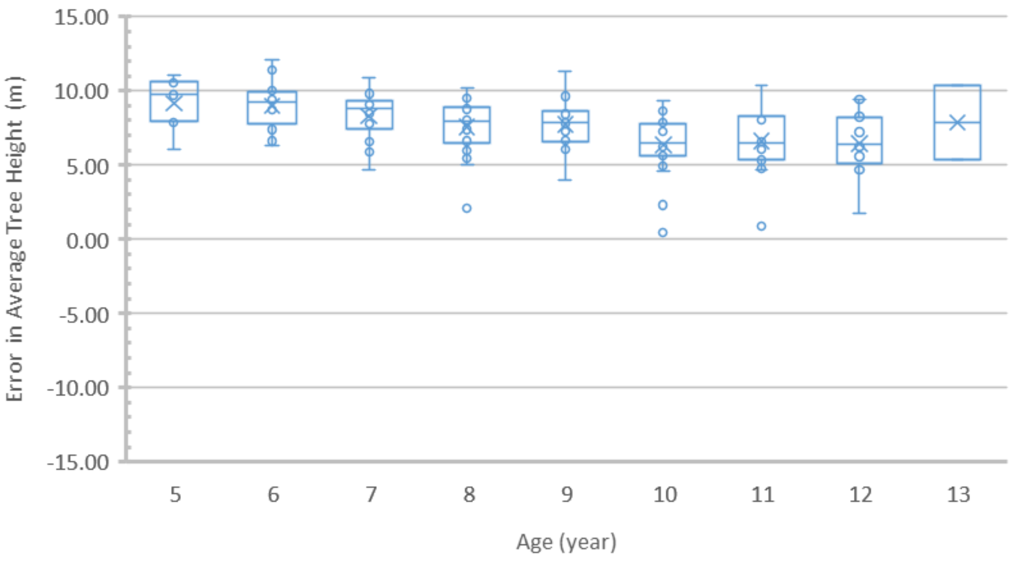

Figure 32: Distribution of modelled average tree height error (Predicted – Observed) by age class for the Tasmanian Blue Gum calibration sites

Volume Comparison

The key output for this modelling work is the volume available at final harvest which informs the value that can be derived from the plantation. At the tree level, a logarithmic relationship provided the best fit between predicted and observed volumes (refer Figure 33), likely reflecting the relationship between predicted and observed height values shown previously.

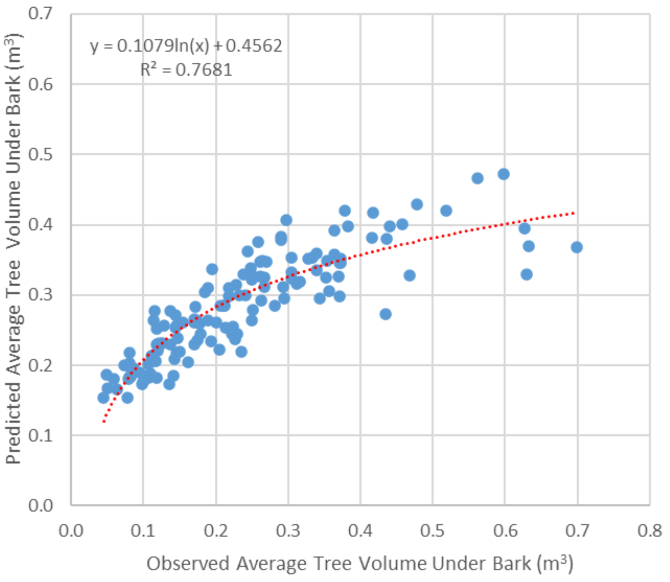

Figure 33: Comparison of predicted to observed average tree volume under bark per hectare (TreeVolUB) for the Tasmanian Blue Gum calibration sites

Plotting the distribution of error by age showed a positive bias at younger ages which decreased to become unbiased, but more widely distributed, by age 12 (refer Figure 34).

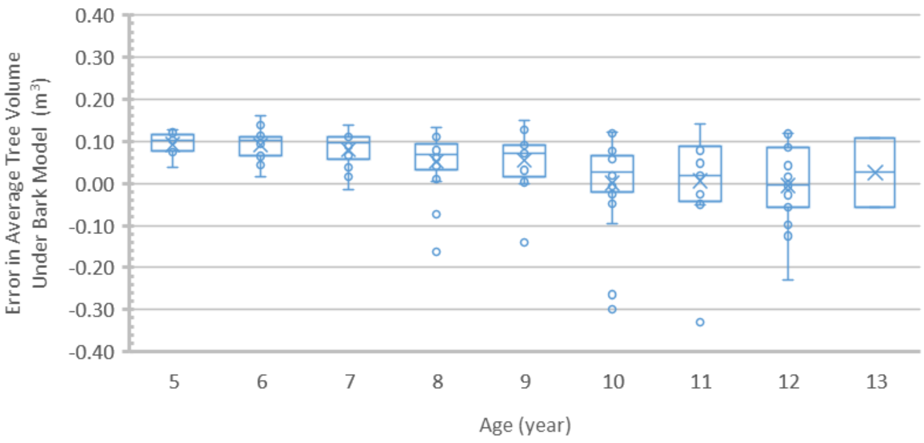

Figure 34: Distribution of modelled average tree volume under bark error (Predicted – Observed) per hectare by age class for the Tasmanian Blue Gum calibration sites

Similarly, the average stand volume predictions had a reasonable logarithmic relationship with observed values (refer Figure 35) and although they presented positive bias at younger ages, appeared relatively unbiased, becoming slightly negatively biased, at older ages, though there was a wider distribution of error at these older ages (refer Figure 36).

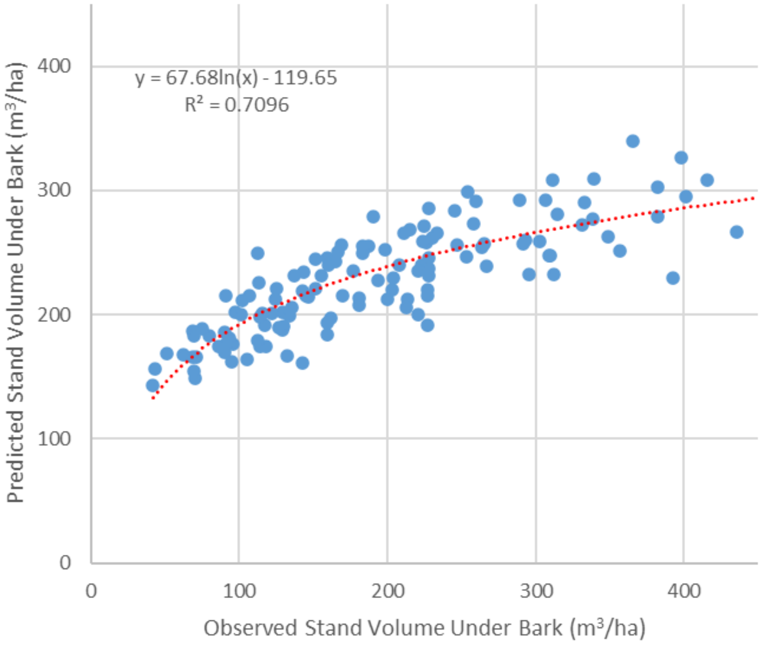

Figure 35: Comparison of predicted to observed stand volume under bark per hectare (StandVolUB) for the Tasmanian Blue Gum calibration sites

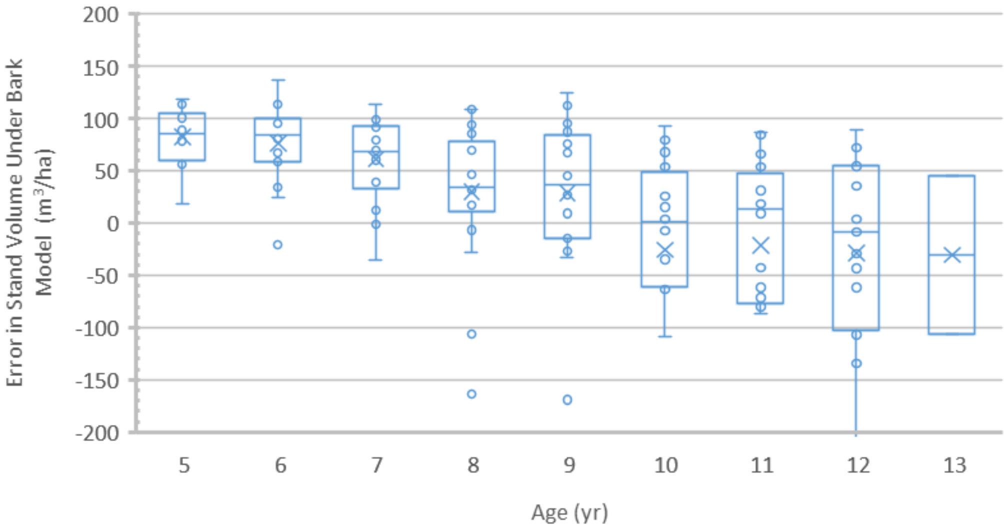

Figure 36: Distribution of modelled stand volume under bark error (Predicted – Observed) per hectare by age class for the Tasmanian Blue Gum calibration sites

Adjustment Factors

Volume predictions at final harvest ages were the key output of this project required in determining suitability of Tasmanian Blue Gum plantations for a site. From the previous comparisons of the APSIM outputs, it appeared that the stand and tree volume estimates for ages of 10 years and beyond were relatively unbiased. To confirm the magnitude of any bias, and to avoid some of the interference from stocking differences between the predicted and observed management regimes, predicted and observed average tree volume values, rather than stand volume, were compared in Table 8.

Table 8: Percentage comparison of predicted to observed average tree volume under bark per hectare (StemVolUB) for the Tasmanian Blue Gum calibration sites

Age (year)	Average Tree Volume Under Bark (m3)		Percentage Observed/ Predicted
	Predicted	Observed	
5	0.17	0.08	47%
6	0.20	0.11	55%
7	0.24	0.16	66%
8	0.26	0.21	80%
9	0.30	0.24	81%
10	0.33	0.33	100%
11	0.35	0.34	98%
12	0.38	0.38	101%
13	0.40	0.38	94%

The percentage difference in tree volumes at ages 10 to 13 showed little bias and as such, no correction factors were applied to the Tasmanian Blue Gum APSIM outputs to be published on the web map.

Validation

The validation PGP locations were run against the final APSIM model developed during the calibration process and the observed and predicted stand volume values were compared. As per the calibration process, PGP plots in the validation pool were excluded where their predicted stocking differed from the observed values as per the exclusion rules outlined in the ‘Stocking Comparison’ section above. This resulted in a validation pool of 36 PGPs representing 322 observations their geographic distribution as shown in Figure 37 below.

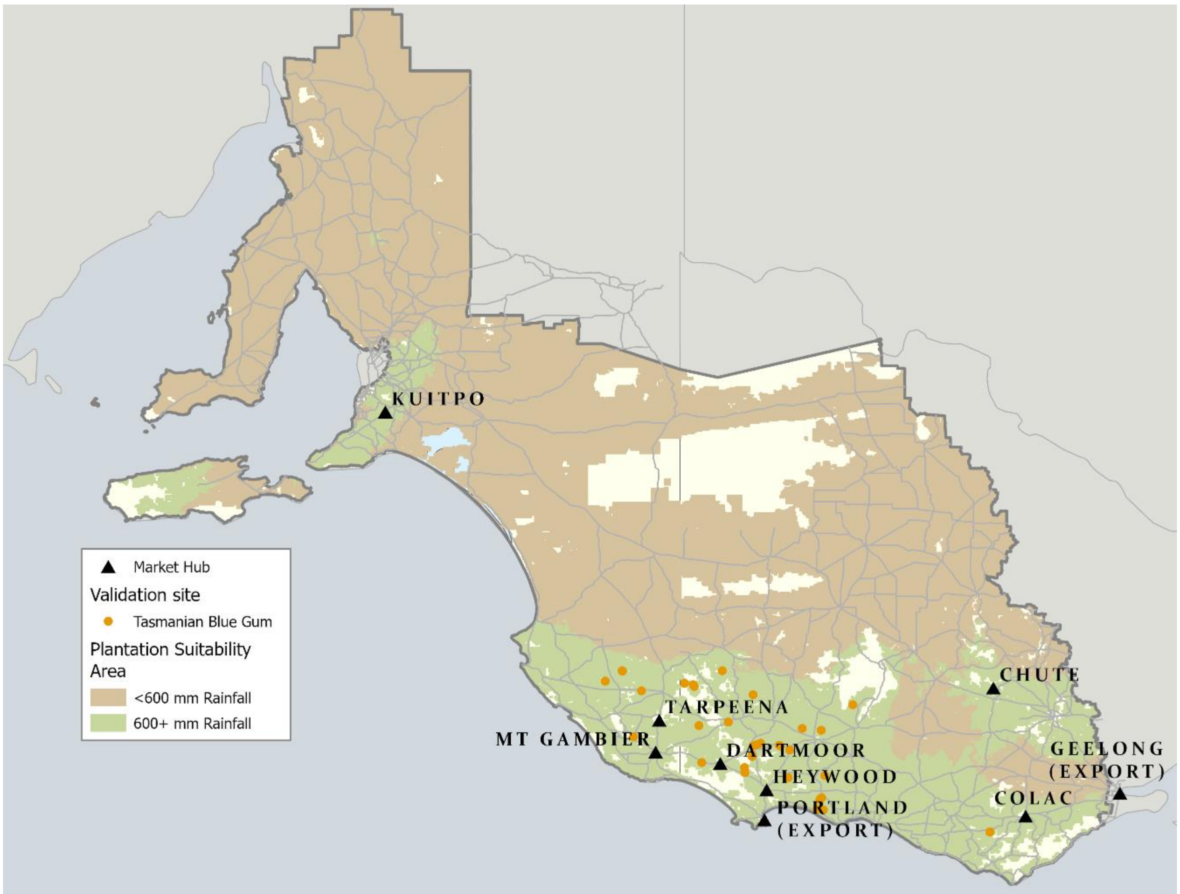

Figure 37: Location of permanent growth plots used to validate outputs of the Tasmanian Blue Gum APSIM model

Similar to the calibration dataset, the validation site predictions of stand volume had a good logarithmic relationship with observed values (refer Figure 38), showing the same flattening of the curve at older ages.

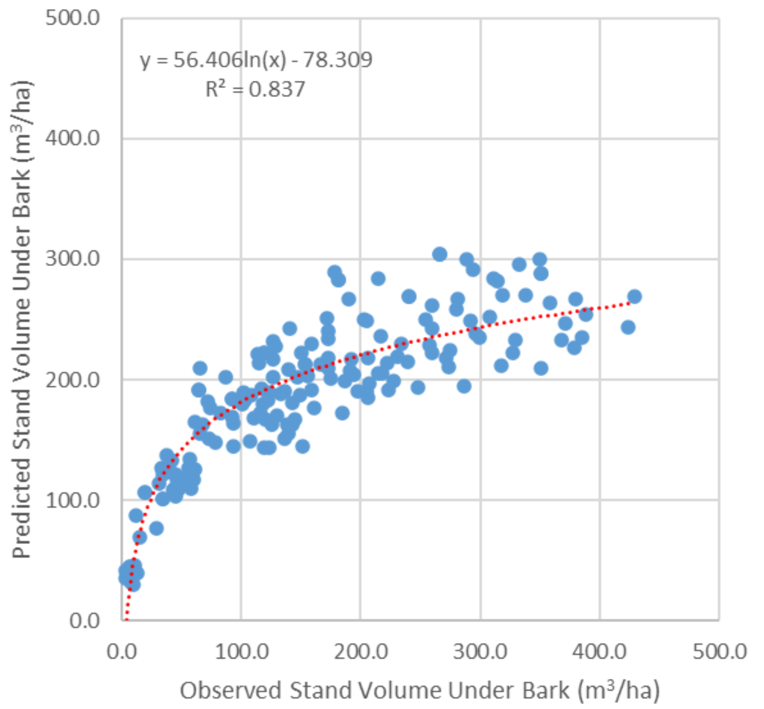

Figure 38: Comparison of predicted to observed stand volume under bark per hectare (StandVolUB) for the Tasmanian Blue Gum validation sites

Plotting the distribution of error in predictions of stand volume under bark, the validation data displayed positive bias at younger ages and negative bias at older ages from age 10 years onwards, and a wide distribution of errors from age 5 years onwards (refer Figure 39).

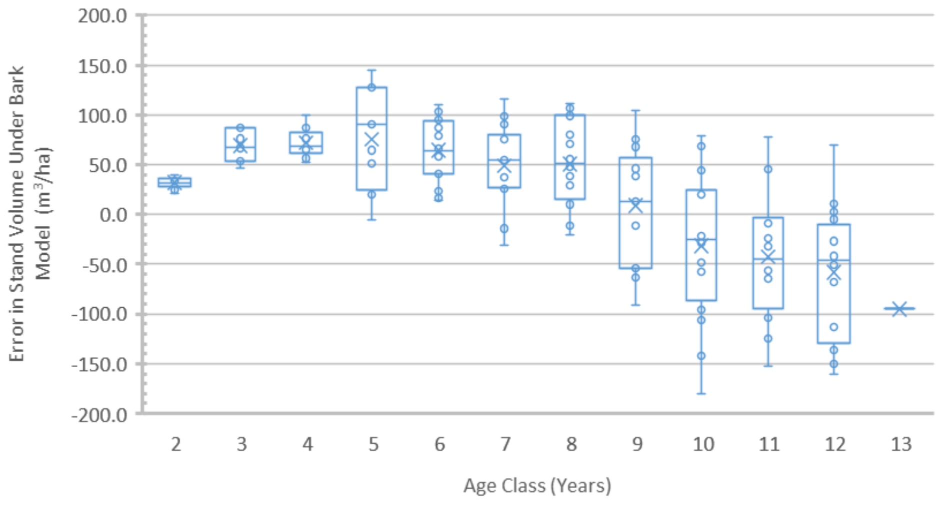

Figure 39: Distribution of modelled stand volume under bark error (Predicted – Observed) per hectare by age class for the Tasmanian Blue Gum validation sites

Table 9 summarises the mean differences between predicted and observed average tree volume under bark values for the validation sites, suggesting that the final outputs published on the web map will underpredict actual growth on average to be expected on-site. Note that calibration and validation data between 13 (short regime) and 18 years (long regime) were not available.

Table 9: Comparison of predicted to observed average tree volume under bark for the Tasmanian Blue Gum validation sites

Age (year)	Average Tree Volume Under Bark (m3)		Percentage Predicted/Observed
	Predicted	Observed	
5	0.17	0.09	195%
6	0.20	0.12	164%
7	0.23	0.16	141%
8	0.26	0.20	127%
9	0.29	0.27	106%
10	0.30	0.33	91%
11	0.33	0.39	86%
12	0.36	0.46	79%
13	0.36	0.40	89%

Table 10 summarises the mean differences between predicted and observed stand volume under bark values for the validation sites.

Table 10: Comparison of predicted to observed stand volume under bark for the Tasmanian Blue Gum validation sites

Age (year)	Average Tree Volume Under Bark (m3)		Percentage Predicted/Observed
	Predicted	Observed	
5	163	86	190%
6	176	111	158%
7	197	149	132%
8	217	174	125%
9	237	242	98%
10	237	259	92%
11	253	295	86%
12	265	350	76%
13	264	358	74%

Example Outputs

The full set of APSIM generated layers is available on the Web Map from the GTFIH website, but the figures below provide examples of mean annual increment at harvest for Tasmanian Blue Gum under the standard (refer Figure 40) and longer (refer Figure 41) plantation management regimes.

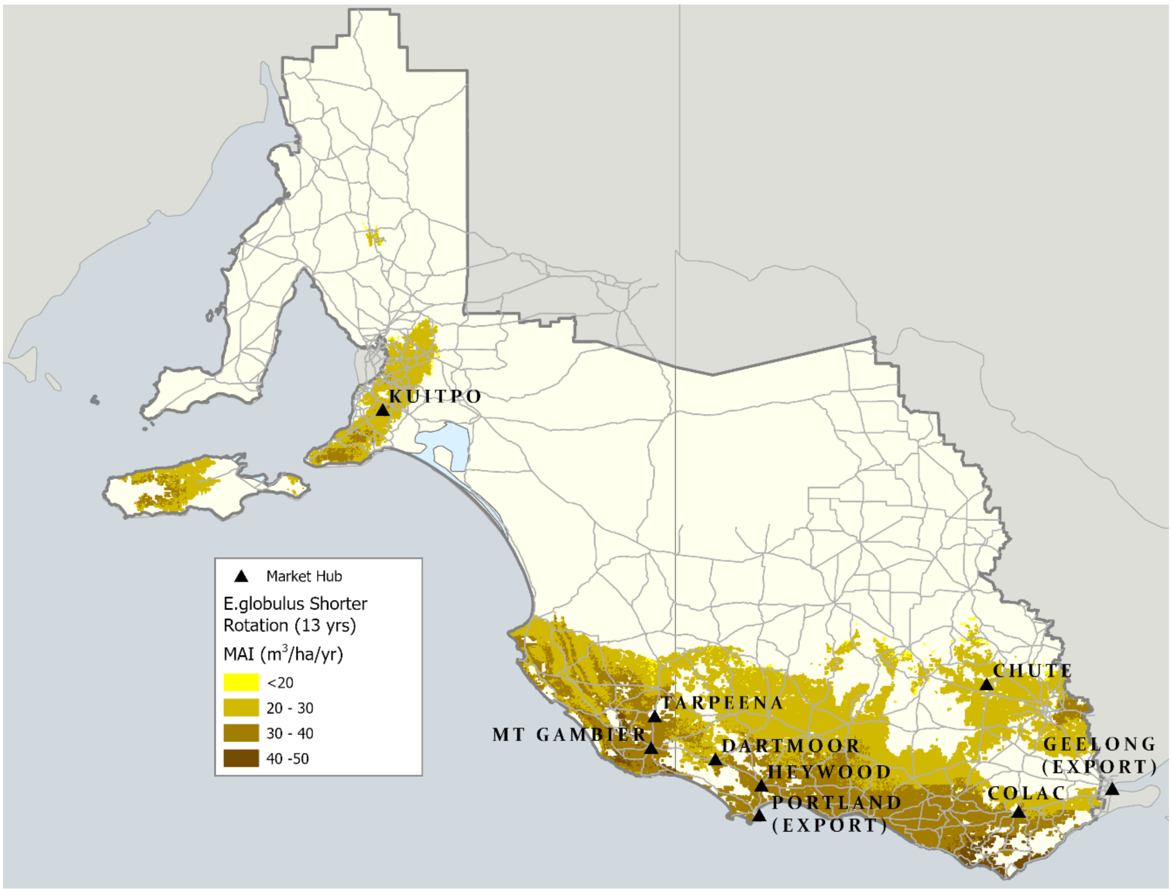

Figure 40: Mean Annual Increment (m3/ha/year) at Harvest Age (13) for the standard Tasmanian Blue Gum regime as generated by APSIM

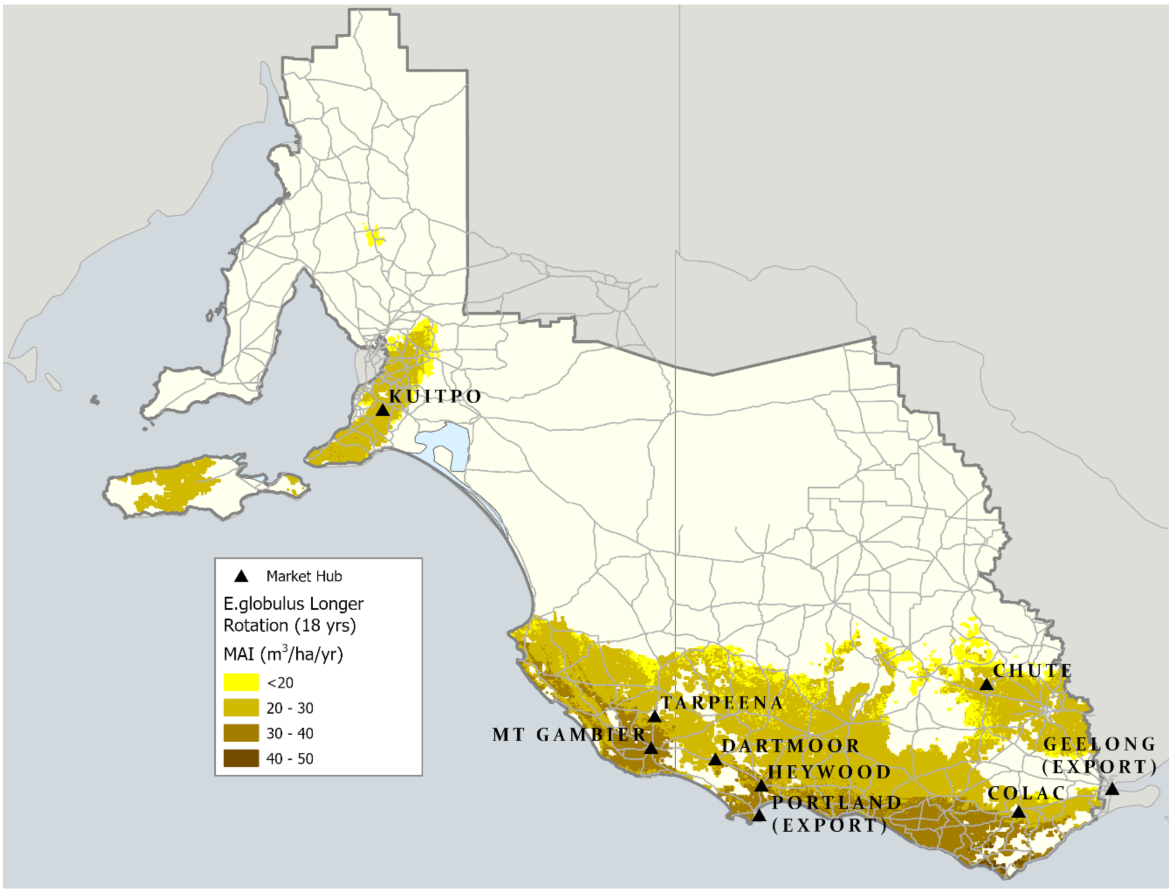

Figure 41: Mean Annual Increment (m3/ha/year) at Harvest Age (18) for the longer rotation Tasmanian Blue Gum regime as generated by APSIM

Water Usage Model

Figure 42 and Figure 43 show the average water usage reported by APSIM for the Radiata Pine and Tasmanian Blue Gum standard regimes respectively.

A recent review of available research into *Pinus spp*. and *Eucalyptus spp.* water use, based on annual evapotranspiration rates, suggested that there was no significant difference in annual water use between the genera for any given climate (White, et al., 2022). The differences in average annual water use shown in the results generated in this project are likely the result of the different rotation length and types of thinning regimes over which the total water use were averaged.

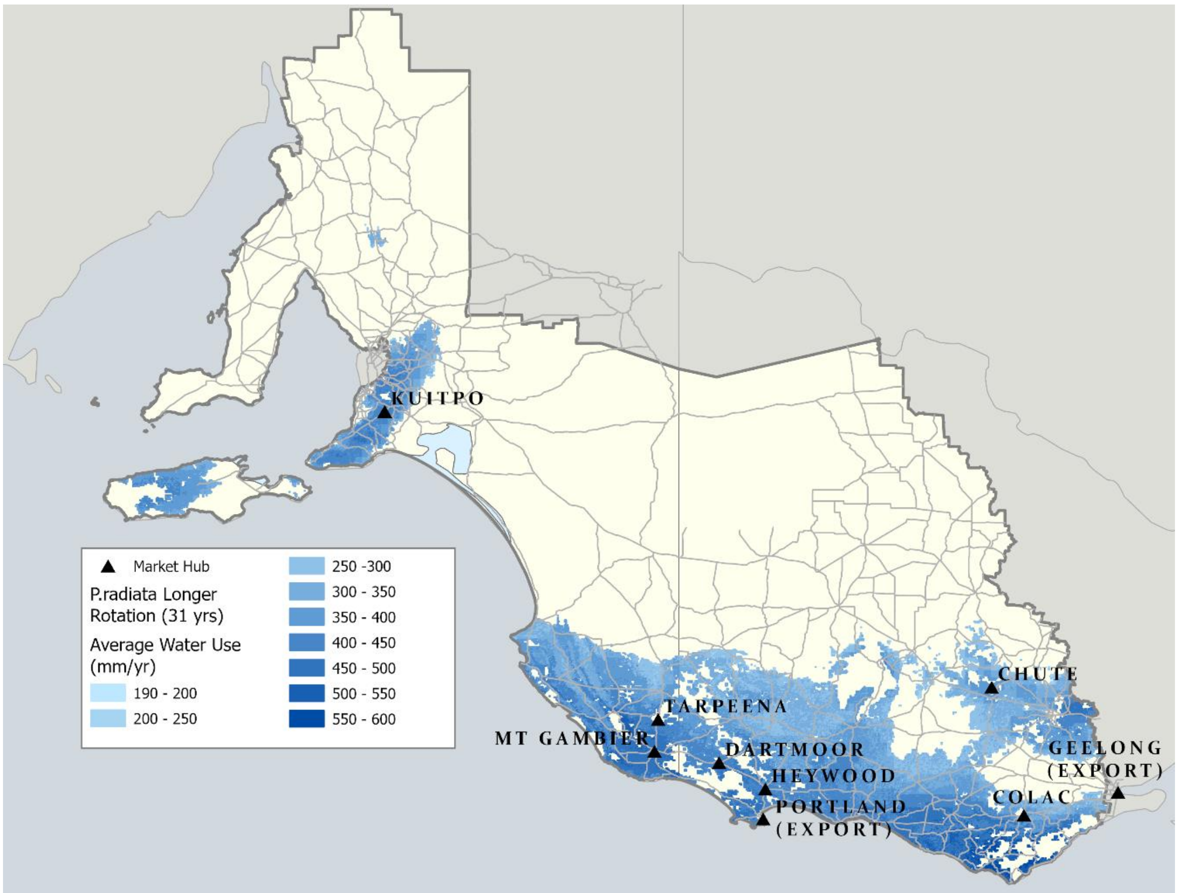

Figure 42: Average annual water usage reported by APSIM for the standard rotation Radiata Pine regime

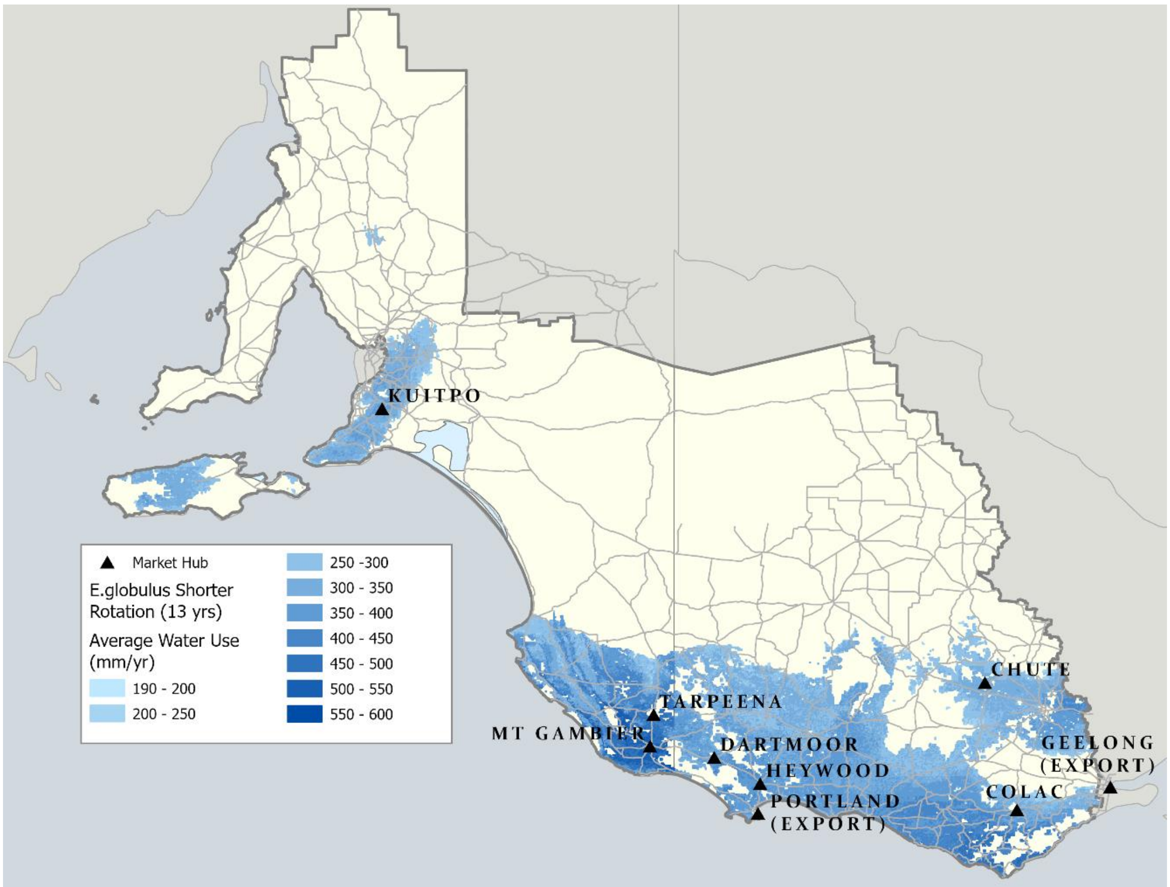

Figure 43: Average annual water usage reported by APSIM for the standard rotation Tasmanian Blue Gum regime

Carbon (ACCU) Model

Plantation Forestry ACCU Models

Figure 44, Figure 45, Figure 46 and Figure 47 show the Plantation Forestry ACCU model results for the four forest management regimes.

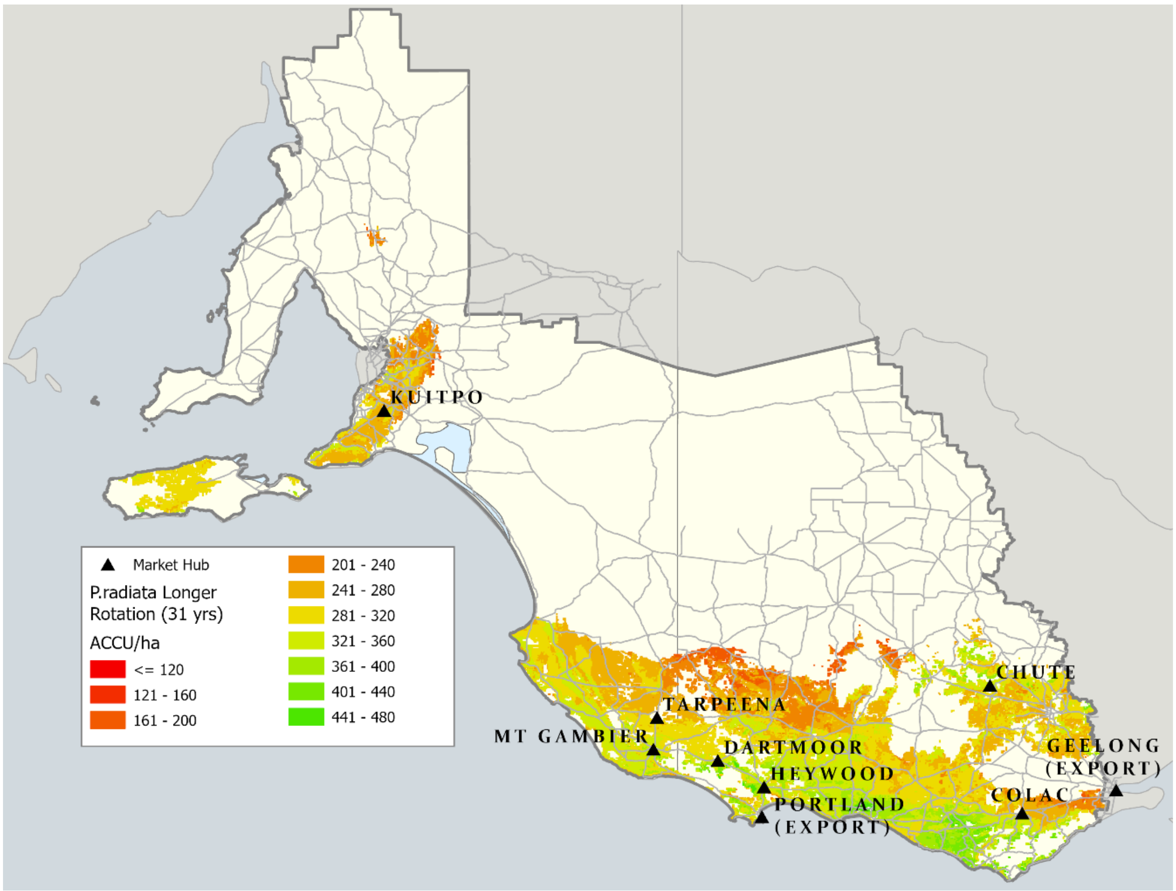

Figure 44: Plantation Forestry ACCU Model for the standard rotation Radiata Pine regime as generated by FullCAM

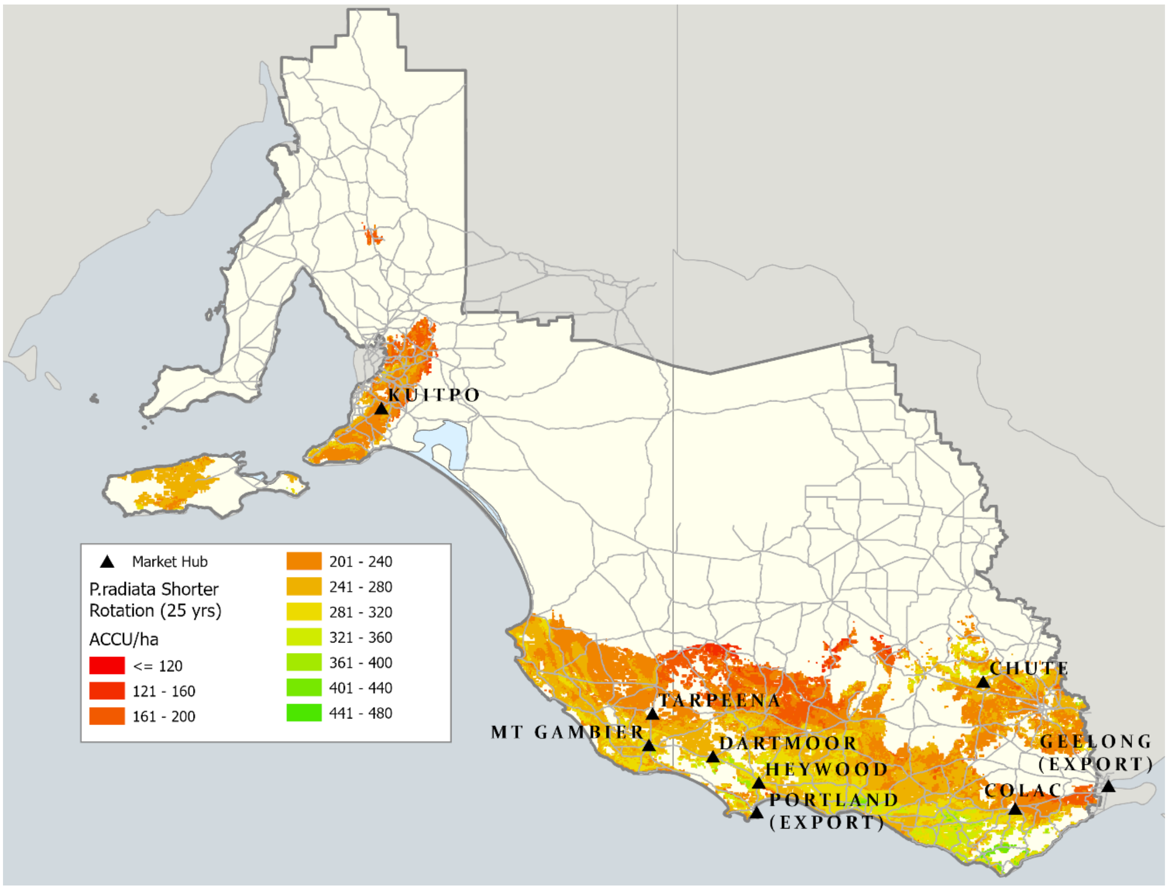

Figure 45: Plantation Forestry ACCU Model for the shorter rotation Radiata Pine regime as generated by FullCAM

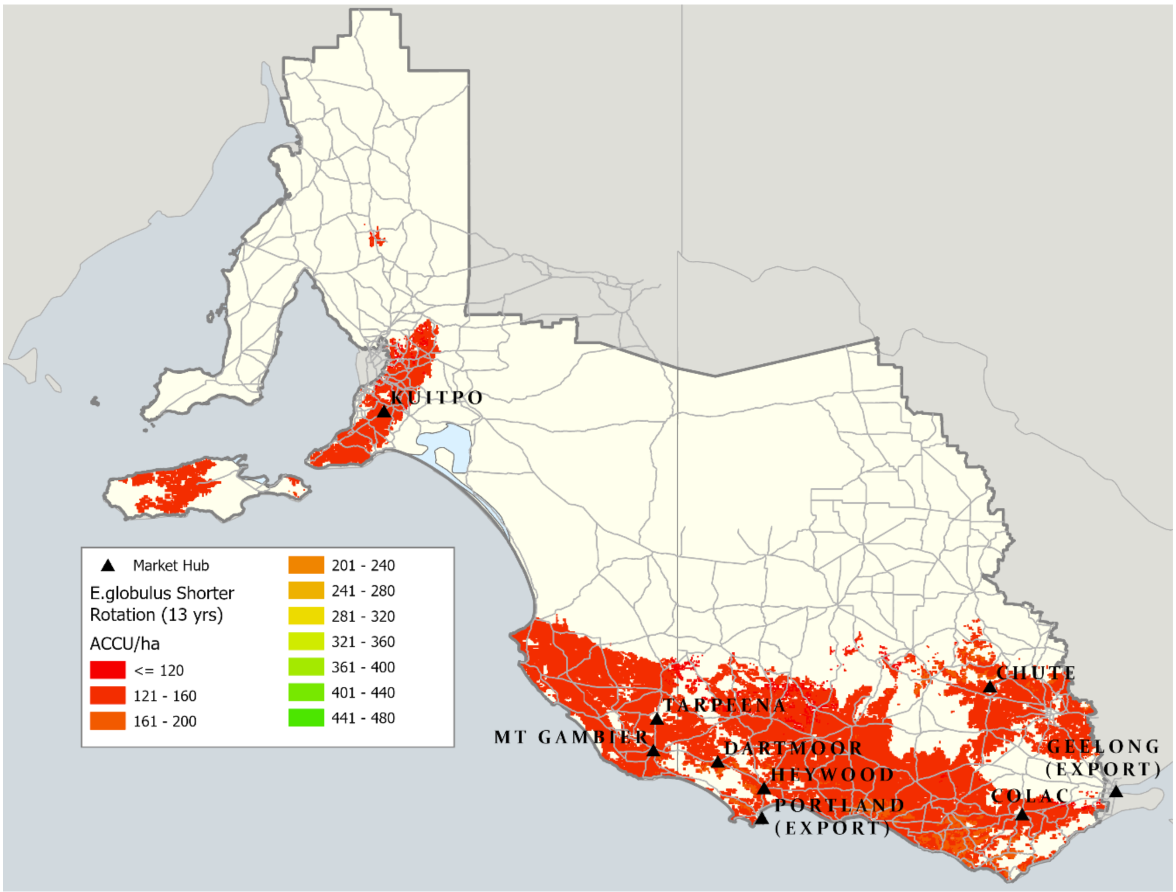

Figure 46: Plantation Forestry ACCU Model for the standard rotation Tasmanian Blue Gum regime as generated from FullCAM

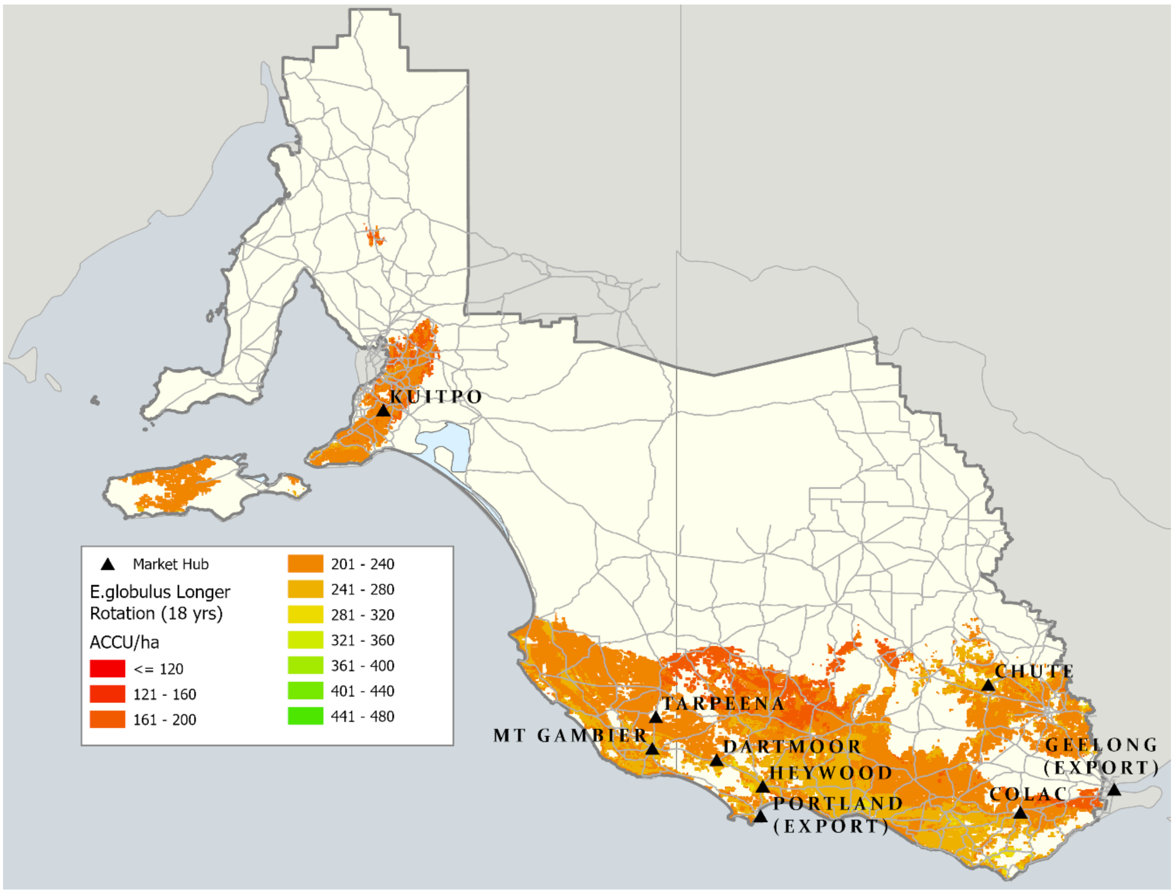

Figure 47: Plantation Forestry ACCU Model for the longer rotation Tasmanian Blue Gum regime as generated from FullCAM

Environmental Planting ACCU Model

The Environmental Planting ACCU Model is displayed in Figure 48 below.

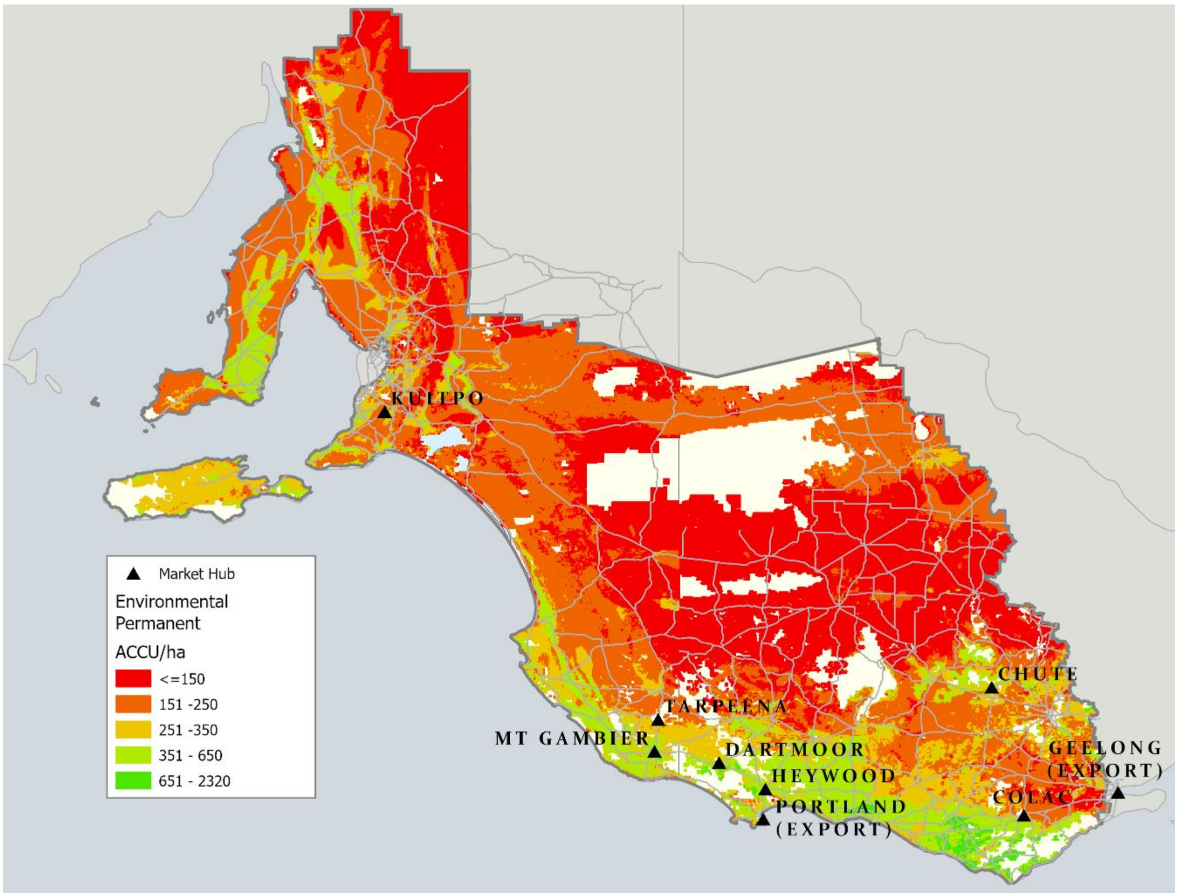

Figure 48: Environmental Planting ACCU Model as generated from FullCAM

Cartage Distance Model

Market Hubs

A cartage distance model was developed within the project to provide a high-level indication of market accessibility across the project AOI. Individual processing facilities & export destinations were located from a range of sources[25] and aggregated based on geographic proximity to form the key Market Hubs (refer Figure 49) used in this report, namely:

- Chute
- Colac
- Dartmoor
- Geelong (Export only)
- Heywood
- Kuitpo
- Mount Gambier
- Portland (Export only)
- Tarpeena

During the aggregation process, emphasis was placed on processing/export facilities with significant scale, so some smaller isolated processor locations were not represented in the final Market Hubs.

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[25] GTFIH provided a summary of processors as part of their 5-yearly supply to ABARES for national reporting purposes, which were compared and updated from the Australia and New Zealand Forest Products Industry Map 2022 (FIEA, 2022) and the AgInsight South Australia web map)

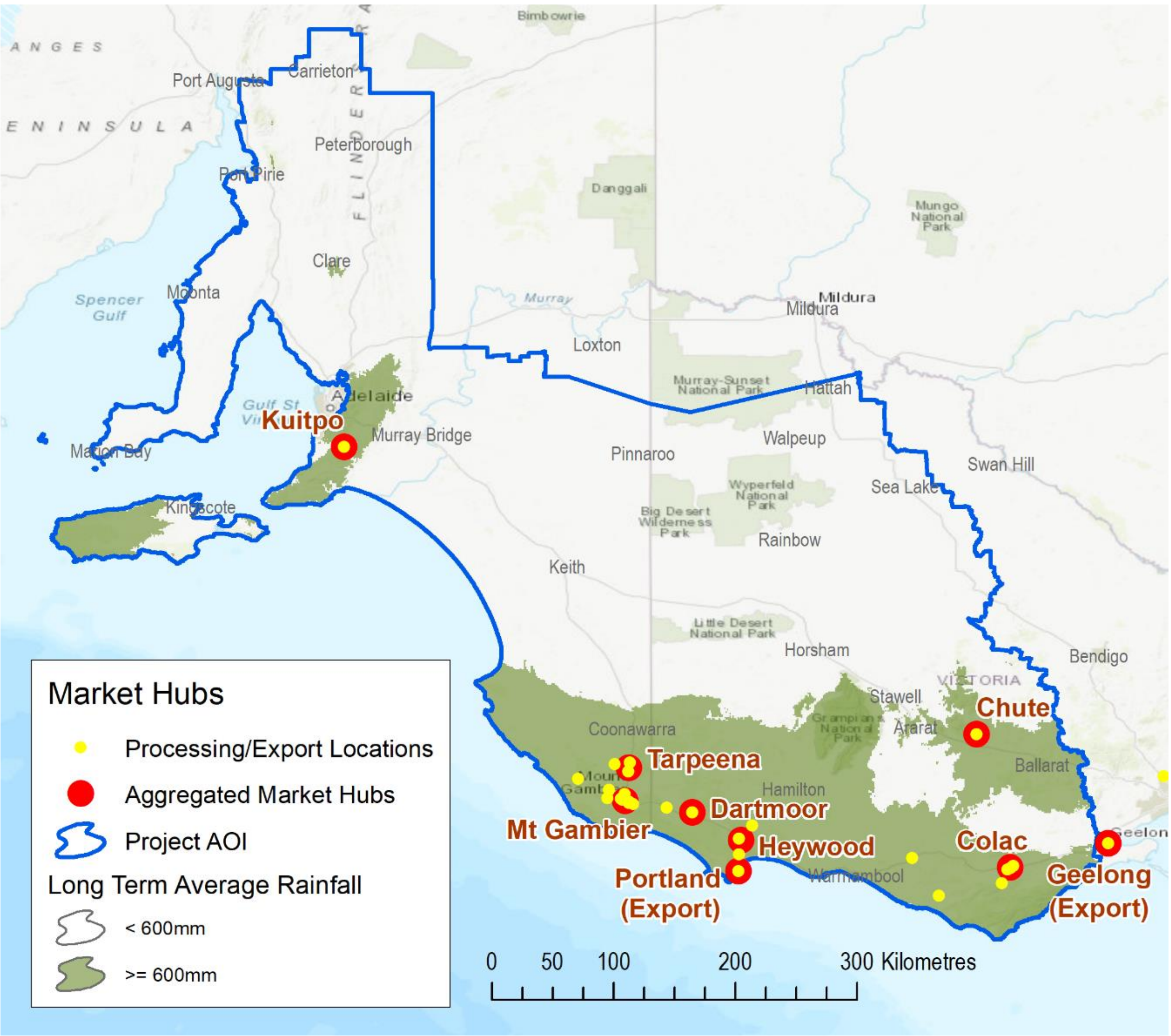

Figure 49: Processing locations and export facilities aggregated into key Market Hubs for Cartage Distance Modelling

Cartage Model

Using a networked roads layer combined from publicly available South Australia and Victoria statewide transport layers, the travel distance from the centre of each grid location to each Market hub was modelled. The centre point of each grid was snapped to the nearest road on the network, this became the snap point, the distance from this snap point to the grid centre was called the snap distance. The total travelled distance from any grid point was calculated as the sum of its snap distance and the travel distance along the network from its snap point to the destination hub.

Assumptions made for the modelling include:

- Network modelling was only undertaken for the 600 mm grid points as there is no harvestable wood products derived from the 300-600 mm grid points.
- Kangaroo island was not included in the transport network modelling.
- Only major roads were modelled, which included highways and state roads, (A, B and C roads).

No road speed limits were modelled, only length travelled. An example output for the cartage distance model, based on the Geelong Market Hub, is shown in Figure 50 below.

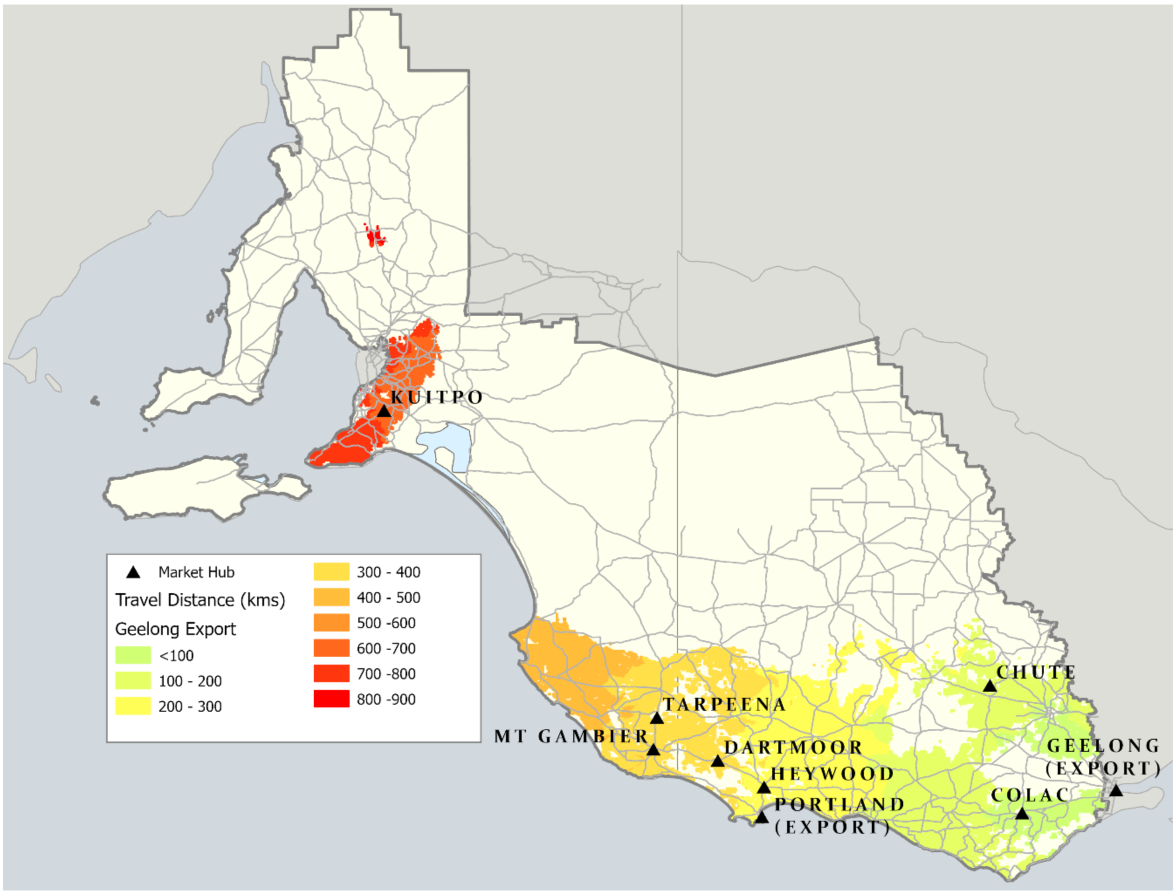

Figure 50: Example Cartage Distance Model output for Geelong Market Hub

Web Map

The web map was developed using ESRI's ArcGIS Online software and is available for free access from the GTFIH website. The outputs from this project were uploaded as layers that can be viewed by the user from any web browser. When interrogated a composite base layer summarising all the relevant model outputs returns the attributes described in Table 11 below.

Table 11: Wood Productivity, Carbon Productivity and Cartage Distance Model attributes presented in the Web Map

Source	Regime	Web Map Attribute	Description
Wood Productivity Model (APSIM)	Radiata Pine Standard Rotation	P. radiata Std Rotation Harvest MAI (m^3/ha/yr)	Estimated mean annual increment (average cubic metres per hectare per annum) at harvest (accounts for volume from any historic thinning and clearfell) under a standard Radiata Pine plantation management regime
		P. radiata Std Rotation CF Harvest Vol (m^3/ha)	Estimated volume (cubic metres) of wood products available from final clearfell harvest under a standard Radiata Pine plantation management regime
		P. radiata Std Rotation T3 Harvest Vol (m^3/ha)	Estimated volume of wood products available from 3rd thinning harvest under a standard Radiata Pine plantation management regime
		P. radiata Std Rotation T2 Harvest Vol (m^3/ha)	Estimated volume of wood products available from 2nd thinning harvest under a standard Radiata Pine plantation management regime
		P. radiata Std Rotation T1 Harvest Vol (m^3/ha)	Estimated volume of wood products available from 1st thinning harvest under a standard Radiata Pine plantation management regime
		Max Annual Water Usage (mm/ha)	Estimated maximum annual amount of water used per hectare in the year of peak plantation growth under a standard Radiata Pine plantation management regime
		Average Annual Water Usage (mm/ha/annum)	Estimated average annual amount of water used per hectare over the full rotation of a standard Radiata Pine plantation management regime
	Radiata Pine Shorter Rotation	P. radiata Shorter Rotation Harvest MAI (m^3/ha/yr)	Estimated mean annual increment (average cubic metres per hectare per annum) at harvest (accounts for volume from any historic thinning and clearfell) under a shorter rotation Radiata Pine plantation management regime
		P. radiata Shorter Rotation CF Harvest Vol (m^3/ha)	Estimated volume (cubic metres) of wood products available from final clearfell harvest under a shorter rotation Radiata Pine plantation management regime
		P. radiata Shorter Rotation T2 Harvest Vol (m^3/ha)	Estimated volume of wood products available from 2nd thinning harvest under a shorter rotation Radiata Pine plantation management regime

		P. radiata Shorter Rotation T1 Harvest Vol (m^3/ha)	Estimated volume of wood products available from 1st thinning harvest under a shorter rotation Radiata Pine plantation management regime
		P. radiata Shorter Rotation Max Annual Water Use (mm/ha)	Estimated maximum annual amount of water used per hectare in the year of peak plantation growth under a shorter rotation Radiata Pine plantation management regime
		P. radiata Shorter Rotation Average Annual Water Usage (mm/ha/annum)	Estimated average annual amount of water used per hectare over the full rotation of a shorter rotation Radiata Pine plantation management regime
	Tasmanian Blue Gum Standard Rotation	E. globulus Std Rotation Harvest MAI (m^3/ha/yr)	Estimated mean annual increment (average cubic metres per hectare per annum) at harvest (accounts for volume from any historic thinning and clearfell) under a standard Tasmanian Blue Gum plantation management regime
		E. globulus Std Rotation CF Harvest Vol (m^3/ha)	Estimated volume (cubic metres) of wood products available from final clearfell harvest under a standard Tasmanian Blue Gum plantation management regime
		E. globulus Std Rotation Max Annual Water Use (mm/ha)	Estimated maximum annual amount of water used per hectare in the year of peak plantation growth under a standard Tasmanian Blue Gum plantation management regime
		E. globulus Std Rotation Average Annual Water Usage (mm/ha/annum)	Estimated average annual amount of water used per hectare over the full rotation of a standard Tasmanian Blue Gum plantation management regime
	Tasmanian Blue Gum Standard Rotation	E. globulus Longer Rotation Harvest MAI (m^3/ha/yr)	Estimated mean annual increment (average cubic metres per hectare per annum) at harvest (accounts for volume from any historic thinning and clearfell) under a longer rotation Tasmanian Blue Gum plantation management regime
		E. globulus Longer Rotation CF Harvest Vol (m^3/ha)	Estimated volume (cubic metres) of wood products available from final clearfell harvest under a longer rotation Tasmanian Blue Gum plantation management regime
		E. globulus Longer Rotation T1 Harvest Vol (m^3/ha)	Estimated volume of wood products available from 1st thinning harvest under a longer rotation Tasmanian Blue Gum plantation management regime
		E. globulus Longer Rotation Max Annual Water Use (mm/ha)	Estimated maximum annual amount of water used per hectare in the year of peak plantation growth under a longer rotation Tasmanian Blue Gum plantation management regime
		E. globulus Longer Rotation Average Annual Water Usage (mm/ha/annum)	Estimated average annual amount of water used per hectare over the rotation under a longer rotation Tasmanian Blue Gum plantation management regime
Carbon Productivity Model (FullCAM)	Environmental Planting	Environmental Planting Carbon Credits (ACCU/ha)	Total carbon credits in the form of ACCUs estimated to be issued over 25-year crediting period under the Reforestation by Environmental or Mallee Planting 2014 method

	Radiata Pine Standard Rotation	P. radiata Std Rotation Carbon Credits (ACCU/ha)	Total carbon credits in the form of ACCUs estimated to be issued over 25-year crediting period under the Plantation Forestry 2022 – Schedule 1 method
	Radiata Pine Shorter Rotation	P. radiata Short Rotation Carbon Credits (ACCU/ha)	Total carbon credits in the form of ACCUs estimated to be issued over 25-year crediting period under the Plantation Forestry 2022 – Schedule 1 method
	Tasmanian Blue Gum Standard Rotation	E. globulus Std Rotation Carbon Credits (ACCU/ha)	Total carbon credits in the form of ACCUs estimated to be issued over 25-year crediting period under the Plantation Forestry 2022 – Schedule 1 method
	Tasmanian Blue Gum Longer Rotation	E. globulus Long Rotation Carbon Credits (ACCU/ha)	Total carbon credits in the form of ACCUs estimated to be issued over 25-year crediting period under the Plantation Forestry 2022 – Schedule 1 method
Network Analysis	NA	Chute (km)	Estimated road distance to the Chute Market Hub (km)
		Colac (km)	Estimated road distance to the Colac Market Hub (km)
		Dartmoor (km)	Estimated road distance to the Dartmoor Market Hub (km)
		Geelong Export (km)	Estimated road distance to the Geelong Market Hub (km)
		Heywood (km)	Estimated road distance to the Heywood Market Hub (km)
		Kuitpo (km)	Estimated road distance to the Kuitpo Market Hub (km)
		Mount Gambier (km)	Estimated road distance to the Mount Gambier Market Hub (km)
		Portland Export (kms)	Estimated road distance to the Portland Export Market Hub (km)
		Tarpeena (km)	Estimated road distance to the Tarpeena Market Hub (km)

Discussion

APSIM Inputs

In terms of available data to pre-populate the model inputs, climatic data of good resolution, distribution and representativeness was readily available for the project AOI, but the digital soil data accessible was less complete for any given source and required much more effort to manipulate to achieve an acceptable growing simulation of Radiata Pine and Tasmanian Blue Gum, particularly by extending soil depths to at least 2 m, and deeper if a water table (unconfined aquifer) was known to be present. These changes affected assumed of soil water storage and water availability to trees in this project. Most soil datasets currently available are designed for agricultural crops that do not require as deep soils and do not take account of a water table, requiring significant modification to represent local conditions relevant to plantation growth.

In terms of the cultivars chosen in the project, there were other *Eucalyptus spp*. cultivars in the APSIM model (three others for *E. globulus* and two for *E. nitens*) that were better fitted to data from other regions, but some of those could have been as useful or more useful than the cultivar we chose. Similarly, there were another two cultivars in the model for Radiata Pine, but these were better fitted to data from NZ and Tasmania. As biomass development and stem metrics are integral to cultivar definitions, choice of cultivar would have affected our analysis to some extent, but the importance is unknown, as the value of choosing another cultivar was not explored for this project.

APSIM Models

In general, the APSIM model for Radiata Pine appeared to be fit for purpose for the local conditions, though did require some adjustments to account for observed bias that became positive (i.e., over-predicted), and increased, as age increased, particularly around the time of the third thinning, apparently driven by the tree basal area model.

Similar can be said for the APSIM Tasmanian Blue Gum model, i.e., the tree basal area model slowly became more negatively biased with age, though it was concerning to observe such a large consistent positive bias in tree height across all ages.

For both Radiata Pine and Tasmanian Blue Gum, tree volume presented less bias than basal area or height alone.

The test of the APSIM models here was quite thorough because it was based on real-world plantation data from the AOI, the use of national climate and soils databases, conducted by users who were mainly trained within the project, and the models were not re-calibrated within APSIM prior to or during the project. The project showed how these models can be used currently to provide realistic estimates of plantation productivities across large areas without further modification of the models in APSIM. However, results also show that some adjustments of outputs were required to better match observed data, and that both models within APSIM would benefit from further empirical calibration of stem metrics (diameters, heights, basal areas, and volumes) to better represent the AOI of this study and the regimes used, and thereby reduce the need for adjustments to APSIM outputs.

APSIM for the Grower

Feedback was sought from the GTFIH on the utility of APSIM in terms of a system that could be used by an existing or new plantation grower, and this project provided a good opportunity to gain such an understanding. Esk Spatial have a long history and depth of experience with a large range of industry standard forest modelling software and have developed and scripted software components and automated models in this space for a range of application platforms but had only ever used APSIM on a limited scale prior to this engagement. From this relatively low starting base we were in a good position to provide the following feedback from a new users' perspective.

The APSIM model is complex as it is attempting to simulate all the significant climate, genotype, soil and management factors that drive each of the biological and physical processes within a crop, and then report all the significant chemical, nutritional and physical outcomes that arise both within the crop and environment during each time step in the simulation. APSIM can do this simultaneously for an endless number of scenarios should you wish and has powerful reporting tools to help you dig into the smallest detail of the modelling process. To attempt to capture such complexity into a single interface is a significant feat, and overall APSIM delivers this well, combining an interactive interface for standard simulation runs with scripting (C# & Python) for advanced functionality.

Despite this, there is still a steep learning curve to this interface as it is simply so extensive (and powerful), and to make most sense of it, and to understand which variables have the most effect when manipulated, requires a very deep understanding of the science that drives the growth of the target crop you are simulating. It would not be recommended at all for a casual user and even with our experience in the software programming space we would recommend that it is learned with the help of a pre-existing user to get you understanding the key concepts in approaching the simulation.

Templates for the key tree species we were modelling were publicly available, but again, without the assistance of a pre-existing user, they were difficult to navigate at first, and understanding how mechanisms like mortality and thinning were achieved were not straightforward.

Modelling at the regional scale added further complexity as the computation power required to simulate each location under each scenario was considerable, and the sheer size of the output data could be overwhelming given the multitude of parameters it could optionally report on. Typically, APSIM at this scale is run via cloud-hosted supercomputers, which overcome these issues we faced running on (many and powerful) desktop computers, and had we needed to model a larger area, or a high resolution, we would have been forced to use such facilities to achieve outputs in reasonable timeframes.

As part of our regional modelling process, we did build a set of Python scripts which could be called by passing through a set of parameters to a controlling script, which would form the core of a more automated system, around which a user-friendly interface could be built. The list of parameters it could handle were by no means exhaustive but were invaluable in editing and bulk updating APSIM inputs & variables during this project, so would likely be a good start on the path to a more ‘forestry’ intuitive but locked down interface, should it ever be needed.

As mentioned earlier, the modelling here was for a 1 km grid across the AOI. However, farm-level decisions about placement of plantations within a farm, their management, and expected productivities are likely to be needed on a much fine scale. Farm-level or sub-farm-level productivity maps could be produced using the same methods used in this project, except using a smaller grid size to make use of finer scale data that might be available, e.g. (1) SLGA data are current at 90 m and going to 30 m in some places), (2) farmers or consultants often have access to other useful information like soil analyses, soil depth, rock content, drainage characteristics, and more local weather experience than the 5 km interpolations from LongPaddock.

ACCU Models

The FullCAM-based modelling presented in this project is relatively clear cut, the ACCU estimates presented are those likely to be available for any actual carbon project for any given location on the grid for the specified species and plantation management regime as the FullCAM model cannot be calibrated or adjusted by the user for the exact local conditions, no matter how close or far they might appear to predict from actual growth rates. The main flexibility you have over ACCU generation for a site is via manipulation of the species, thinning regime and clearfell age of the modelled plantation. Growth calibration and adjustment for FullCAM is typically made at the national and regional levels, and such an exercise was completed during the transition from the 2016 version of FullCAM to the 2020 and 2023 versions of the software.

Obviously, the estimate of ACCU generation provided in this project is one of many considerations required for appropriate due diligence prior to entering the ERF, and it is recommended that the user of such data ensure they also understand the timeline over which those ACCUs are issued, the administrative costs for entry, details of the eligibility requirements, the permanence obligations, the skills needed to report and monitor the project, and the external support available, before entering such a project.

Although some in the forestry industry have had misgivings about the relatively locked down nature of the FullCAM modelling, in that it might not represent their own modelling or not match actual yields observed on ground for a specific location, the beauty of it is that it achieves national coverage, and it is consistent for any given location now and (updates to the models permitting) into the future. This avoids the need for a deep statistical understanding of forest modeling to use it, avoids the need to produce complex future growth assumptions to build financial modelling around it, avoids the costs associated with field measurements to build or prove a model and it can be applied anywhere in Australia. This approach also does not need data from a pre-existing forest in that area to calibrate growth, which often reduces the utility of standard empirical models and process-based models.

This approach does obviously put a lot of pressure on the Australian Government to manage any growth model updates released such that they do not provide undue uncertainty for those within or wanting to enter the carbon sequestration project space, requiring significant care in their related stakeholder review and release process.

Web Map

In terms of effective delivery of the outputs from this project, the Web Map, although interactive and fit for scope, is currently rather simplistic in that it only presents values stored in spatial layers, requiring the user to have the appropriate background or experience to interpret them. Wrapping the layers in some form of customisation which would query and report the data in a more intelligent manner via a simple to use interface, with links to relevant reference information on how to interpret such data, would provide significant value to any grower using the system. The models generated in this project provide a solid basis to support entry into the plantation growing business and would really shine if delivered in a more readily interpretable manner for the grower, especially those without a solid forestry background.

Conclusions / Recommendations

Overall, the APSIM model behaved reasonably well within the Green Triangle region, though some aspects of the growth models would benefit from an improved calibration within APSIM, as some bias was being displayed in the basal area models, and a significant bias was observed in the Tasmanian Blue Gum tree height model.

To release APSIM to a plantation grower for on-farm plantation simulation would require provision of a much more simplified interface, with many of the inputs hidden such that only those with most significance to growing the target crop are readily available. The approach taken by FullCAM is probably a good example of how this could be achieved. Provision of a preset suite of standard management activities from a drop-down list which are relevant to the practices the grower employs in a daily fashion would be provided. Each management activity chosen would then modify the underlying inputs and assumptions to suit, avoiding the need for the user to modify a range of inputs directly into a complex set of tables. Manual overrides for key parameters would be accessible to the grower for any given management regime, reflecting those decisions made throughout the life of a plantation about how much to thin or fertilise, or when to harvest, say, would be readily accessible as part of this process. As mentioned in the previous section, some of the underlying automation building blocks for such a system were developed as part of this project, so it would not be a stretch to build such an interface.

Specific ‘plantation forest’ digital soil datasets, and a way to easily access these via the APSIM interface, would also be required. Given most of the viable suitable plantation area is readily known in Australia, setting up such a soils dataset on a national scale, but with reasonable modifications to factor in the likely limitations within any local region, would not be unrealistic, and with all the research and projects the various Forestry Hubs are supporting around the country at present to promote plantation expansion, it is likely that many of the key inputs and limitations are already well documented in most. Development of these soil datasets for each plantation region in Australia would be a very useful long-term asset for the industry.

To better enhance the delivery of the outputs of this project to a grower with little forestry experience, it would be recommended that some form of customised interface be developed that can report the outputs of each layer in a more descriptive and interpreted manner, with relevant links to supporting information.

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