Productivity of plantation hardwood tree species in north-eastern Australia: A report from the Forest Adaptation and Sequestration Alliance

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Productivity of plantation forest tree species in north-eastern Australia: A report from the Forest Adaptation and Sequestration Alliance[1]

By

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Disclaimer

Front cover: Nine year old *Corymbia citriodora* subsp. *variegata* trees near Miriam Vale (Wide Bay Burnett – coastal zone).

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[1] The Alliance comprises scientists from the three organisations listed above who have been working together over the last five years to develop tropical and subtropical hardwood species for production forestry applications in Northern Australia.

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EXECUTIVE SUMMARY

Purpose of this report

The report summarises data from a large number of trials of species with potential for use by the plantation forest industry in north-eastern Australia and provides information aimed at improving the understanding of growth rates, pest and disease risks and carbon sequestration. Data is summarised and presented at a regional level as opposed to individual trial or plot level. As well, nutritional impediments to tree growth and impacts on forest health are also reported.

This report is intended to contribute to policy deliberations about developing forestry opportunities that can that can be integrated into the landscape, with particular consideration given to lower rainfall regions. There are several examples in north-eastern Australia where production forests have developed sub-optimally; this has often been due to poor selection of tree species as little information has been available. This report helps address this deficiency.

Background

In north-eastern Australia approximately 130,000 ha of hardwood plantations have been established in the last 15 years. As a result of poor taxa selection, approximately 25,000 have failed due to drought, pest and disease or extreme weather events (mainly drought and cyclones). To proceed with any viable hardwood industry the growers need to know that their chosen taxa can sustain a viable plantation forest estate in the environments of north-eastern Australia. The results presented herein from taxa trials spread throughout Queensland and northern NSW are invaluable in providing greater certainty for industry and hopefully in future, avoiding mistakes made in the past.

Given the predicted impacts of climate change in north-eastern Australia (reduced rainfall, increased temperatures and an increase in extreme weather conditions, particularly drought, storms and cyclones) selection of the right taxa for plantation development is even more critical as the taxon planted needs to be able to perform well under the environments experienced at planting as well as those that may develop over in 30 years time as a result of altered climate.

The limited access to growth data and species risk assessment information on a regional scale as well as potential climate change impacts represent a major impediment to investment in commercial forestry in north-eastern Australia. The aim of this project was to improve the understanding of the suitability of sites and taxa for plantation establishment thereby increasing confidence in forestry investment

Methods

The FT Database was interrogated and 252 trials were identified that potentially could be included in this study. From the original experiment list, 37 taxa trials in Queensland were identified for inclusion in the project based on taxa linkage, stocking rate, and regional representation. Only one trial in New South Wales met the selection criteria and this trial was included in the project making a total of 38 taxa trials reported. Eleven trials in Queensland already had 10-year measures and assessments completed and this data was used for the analysis. Twenty seven taxa trials needed a 10-year measurement and assessment. This was undertaken with data captured for: growth (height and diameter at breast height); survival; borer infestation; and wood properties. For each trial site meteorological data and soil physical data were linked to the growth data prior to analysis.

A review of the 55 nutrition trials was undertaken and trials selected on the basis of taxon of interest, impact of pests and diseases and region. The six nutrition trials selected focused on the major commercial hardwood plantation areas in Queensland. Similar measurement and assessments to those undertaken for the taxa trials were completed prior to data analysis and reporting.

Results and Discussion

The taxa trials evaluated across the study regions showed significant differences at age 10 years in survival, height, diameter, basal area, volume MAI, stem borer incidence, carbon sequestration rates and pulp productivity. Across all sites the rainfall was 88% of the long-term average. Similarly the average maximum temperature was 0.6 °C higher than the long-term average. The lower than average rainfall and higher than average temperature experienced by most trials means that the trials experienced climate somewhat similar to the predicted climate of the future.

Of the 65 taxa included in the current study, those that were the most robust (based on volume growth, survival and carbon sequestration rates) under the drought conditions experienced in north-eastern Australia, during the study period were *Corymbia citriodora* subsp. *variegata* (CCV), *Eucalyptus dunnii*, *E. longirostrata* and *E. argophloia*. Of these species only CCV and *E. argophloia* had low borer attack, making them potentially suitable for solid wood production.

Across all regions evaluated, the best performing taxa in terms of volume MAI were:

- CCV, (range 3.9 to 10.3 m^3/ha/year), which ranked in the top five taxa in six regions;
- *E. longirostrata* (range 4.6 to 10.6 m^3/ha/year), which ranked in the top five taxa in five regions;
- *E. dunnii* (range 4.0 to 24.4 m^3/ha/year), which ranked in the top five taxa in five regions;
- *E. grandis* (range 4.1 to 10.5 m^3/ha/year), which ranked in the top five taxa in four regions;
- *E. argophloia* (range 4.5 to 8.2 m^3/year) which ranked in the top five taxa in three regions; and
- *C. citriodora* subsp. *citriodora* (range 4.8 to 9.9 m^3/year), which ranked in the top five taxa in three regions.

Across all regions the maximum volume increment was achieved by *E. pellita* in the North Tropical Coast and Tablelands region (volume MAI of 30 m^3/ha/year). This species also had the largest average height (20.3 m) and basal area (34.5 m^2/ha) at age 10 years. The largest average diameter at age 10 years was recorded for *E. dunnii* in the Northern Rivers region (19.6 cm). It should be emphasised at this point that thinning undertaken in the majority of these trials was in order to mimic the silviculture required for the development of logs suitable for the production of solid wood products.

The application of boron was found to reduce susceptibility to longicorn beetles (*Phoracantha solida)* and improved tree's apical dominance thus increasing potential product recovery. The application of phosphorus and potassium was also found to improve growth in the trials assessed.

These results were presented to the forest industry in a workshop on the 10th May 2011.

Recommendations

- In north-eastern Australia the taxa recommended for inclusion in on-going tree improvement programs (based on growth, adaptation and pest and disease resistance/tolerance) are CCV, *Corymbia* hybrids, *E. cloeziana E. longirostrata and E. argophloia*. These taxa should be further tested in a new suite of large block taxa trials in promising regions of north-eastern Australia to allow reliable long-term growth data capture and provide for non-destructive and destructive sampling of wood properties.
- Further analysis of the climatic and edaphic drivers of growth is required to better identify the taxa that will be suitable under the range of climate change scenarios. The short timeline available for completing this project, where the major focus was on data collection and collation, limited the project partner's ability to undertake a comprehensive analysis of the drivers of growth for the top performing taxa.
- Now that data on the potential to produce wood based products, risks and growth rates is available, it is important that economic modeling of hardwood plantation options be undertaken for north eastern Australia to drive the future investment in the industry.

- Further work is needed on identifying and overcoming nutritional impediments to growth and reducing pest and disease susceptibility of trees by manipulating tree nutritional status.
- A suite of taxa trials in regions that did not meet the minimum age requirement for this project were not measured. It is important that data from these trials be captured in 2012/2013 when they reach a similar age to the trials analysed for this project to help further identify the best taxa and to improve the understanding of climatic and edaphic drivers of growth over a greater part of north eastern Australia.

ABBREVIATIONS AND TERMS USED

ANOV	Analysis of Variance
B =	Boron
BA	Basal Area
BOM =	Bureau of Meteorology
C	Carbon
^{o}C	Degrees centigrade
CCC	*Corymbia citriodora* subsp. *citriodora*
CCV	*Corymbia citriodora* subsp. *variegata*
cm	Centimetre
CO_2	Carbon Dioxide
CT	*C. torelliana*
CT × CCV	*C. torelliana* × *C. citriodora* subsp. *variegata* (control cross hybrid)
Cu	Copper
DEEDI	Department of Employment, Economic Development and Innovation (Queensland)
DBH	Diameter at Breast Height (1.3 m above ground level)
E.	*Eucalyptus*. All other species with the genus name beginning with the letter E are spelt out in full.
EG × EC	*E. grandis* × *E. camaldulensis*
EG × EU	*E. grandis* × *E. urophylla*
EG × ER	*E. grandis* × *E. resinifera*
Est	Estimate
FASA	Forest Adaptation and Sequestration Alliance
FT	Forest Technologies, (DEEDI)
G x E	Genotype by Environment interaction
ha	Hectare
HT	Height
K	Potassium
kg	kilogram
KPY	Kraft Pulp Yield
LSD	Least Significant Difference
m	metre
MAI	Mean Annual Increment
MAP	MonoAmmonium Phosphate
MAR	Mean Annual Rainfall
MaxT	Maximum Temperature (Mean daily maximum temperature)
MinT	Minimum Temperature (Mean daily minimum temperature)
mm	Millimetres
MoE	Modulus of Elasticity
N	Nitrogen
na	Not available
NIR	Near-InfraRed spectra
p	Statistical probability
P	Phosphorus
PCH	*Pinus caribaea* var. *hondurensis*
Pine hybrid	The F2 hybrid from *Pinus elliottii* × *Pinus caribaea* var. *hondurensis*
R^2	Coefficient of determination for a regression
Raindays	Average number of days in which rain fell (annual)
StdE	Standard Error
Taxon / Taxa	May include species, subspecies, varieties, clones and hybrids
Tmin	Extreme low temperature
μg/g	micrograms per gram
Vol	Volume
YFEL	Youngest Fully Expanded Leaves
Zn	Zinc

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INTRODUCTION

Purpose of this report

The purpose of this report is to identify tree species with potential for use in sustainable forest plantations, agroforestry systems and other natural resource management systems. The report summarises data from a large number of trials and provides information aimed at improving the understanding of growth rates, pest and disease risks and carbon sequestration rates of selected hardwood plantation species in north-eastern Australia. Data is summarised and discussed at an estate level as opposed to individual trial or plot level. Nutritional impediments to tree growth and health across regions are also reported.

This report is intended to contribute to policy and program deliberations about developing forestry opportunities that can contribute to alternative land-uses in lower rainfall regions. There are several examples in north-eastern Australia where forestry options have been sub-optimal for traditional commercial forestry and this has often been due to poor selection of tree species. This report helps address this deficiency.

Background

In north-eastern Australia approximately 130,000 ha of hardwood plantations have been established in the last 15 years. As a result of poor taxa selection approximately 25,000 ha has failed due to drought, pest and disease incursions and extreme weather events (mainly drought and cyclones). To proceed with any viable hardwood industry, the growers need to know that their chosen taxa can perform (and at what level) in the environments of north-eastern Australia. The results from taxa trials spread throughout Queensland and northern NSW are invaluable in providing greater certainty for industry and hopefully, avoid the mistakes made in the past. In southern Australia, mistakes were made with poor taxa selection in the progress to the current large hardwood estate growers settled on *E. globulus* subsp. *globulus* and *E. nitens* for colder areas. This study is a step towards identifying the best tree taxa for north-eastern Australia and bench-marking the potential growth rates and associated risks for these taxa at a plantation estate scale.

Given the predicted impacts of climate change in north-eastern Australia (reduced rainfall, increased temperatures and an increase in extreme weather conditions (drought, storms and cyclones) (Battaglia *et al,* 2009; Allen Consulting Group 2005) the selection of the right taxa for plantation development is even more critical as the taxon planted needs to be able to perform well under the environments experienced at planting as well as the environment that may prevail in 30 years time as a result of altered climate.

The limited access to growth data and species risk assessments on a regional scale as well as potential climate change impacts represent a major impediment to investment in commercial forestry in north-eastern Australia. The aim of this project was to improve the understanding of the suitability of sites and taxa for plantation establishment thereby increasing confidence in forestry investment. In the period between 1990 and 2003 over 250 replicated and linked taxa and nutrition trials were established (Lee *et al*. 2003) in the region from the tropics of Queensland through to northern New South Wales. The aim of these trials was to generate growth data across the range of soils and climatic conditions found in areas with potential for plantation forestry. Consolidating the knowledge from this investment in field trials and distributing the information to the forest industry are the key outcomes to be generated from this project. This interconnected series of trials included a diverse range of hardwood germplasm covering most likely candidates for plantation development within the region. The potential for these trials to provide baseline data has not yet been realised for the following factors: 1) genetic adaptability and plasticity; 2) stem growth and form; 3) carbon sequestration rates; 4) nutritional impediments to growth; and 5) nutrient-mitigation of pest and disease susceptibility associated with tree stress. The project will increase plantation forest investor's confidence by addressing some of the major knowledge gaps impacting on the successful establishment and management of Australia's north-eastern hardwood plantations.

A comprehensive review was undertaken of the taxa trials established by the Queensland and New South Wales governments and industry partners in the period from1990 to 2003 (over 250 genetically-linked large plot taxa trials; Lee *et al*. 2010). From within this large set of experiments a subset of 38 trials was identified for further study. These trials contain most of the taxa of interest and extend over a broad latitudinal (Port Douglas, Queensland to Kyogle, New South Wales), rainfall, site and edaphic range covering the core potential planting areas. All of the trials were established under previous government initiatives and results have been under-utilised due to changes in State Government funding priorities. Existing growth, climate and soil information previously captured in the Department of Employment, Economic Development and Innovation (DEEDI) Forest Technologies (FT) database has been supplemented with new measurement and assessment data during this project for 27 of the 38 selected trials. The data was captured directly onto hand held field computers with inbuilt data validation systems and all data has been securely stored in the FT database. A large genotype $\times$ environment (G $\times$ E) interaction analysis was undertaken to identify the most stable varieties across region at age ten ($\pm$ 1.9 years) using the 10 year data from the 38 trials (Table 1). Taxa with good growth, identified as being well-adapted to different regions had wood density data collected and stem measurements taken at a range of heights up the stem which allowed for the development of simple taxon specific volume equations. This facilitated detailed estimations of baseline carbon sequestration rates for key species across the range of environments sampled.

In a parallel study a subset of six of the 55 existing nutrition trials were measured and assessed to evaluate the effect of nutrient applications on growth and the incidence of pests and diseases (*e.g.* in a glasshouse trial, Smith and Pegg (2009) observed that boron reduced susceptibility of CCV to the fungus *Quambalaria*). Statistical analysis was undertaken to identify key nutritional interventions that can improve tree growth and form and increase the trees ability to cope with attacks from pests and diseases.

METHODS

Selection of trials

Taxa trials

The FT Database was interrogated and 252 trials were identified that met the criteria of being at least 10+/-1.9 years old and having at least one of the following taxa: CCC, CCV, *C. henryi*, *Eucalyptus argophloia*, *E. crebra*, *E. cloeziana*, *E. drepanophylla*, *E. longirostrata*, *E. pellita* or *E. siderophloia*, that linked the trial to other taxa trials. Trials without replication or blocking, stocking outside the range of 400-700 stems/ha or that had suffered significant external damage to all trees (such as cyclones) were rejected. In addition, trial location, connectivity (related taxa) and representativeness of the site (including soil profile characteristics) for the region were also evaluated. From the original experiment list, 37 taxa trials in Queensland were identified for inclusion in the project. Eleven trials already had 10-year measures and assessments completed and this data was used for the analysis. However the majority of trials (26) required the 10 year measurement and these were undertaken as described below. Only one trial in New South Wales met the selection criteria and this trial was included in the project, bringing the total to 38 taxa trials.

The target area (north-eastern Australia) was divided into seven regions based on Bureau of Meteorology (BOM) forecast regions (Map 1) and experiment selection aimed to sample these regions as fully as possible. The Wide Bay and Burnett region was divided into two distinct rainfall zones, a coastal zone with an average annual rainfall of 1125 mm and an inland zone with an average annual rainfall of 748mm which were considered separately

(Table 1). Across all sites the rainfall was 88% of the long-term average (35 trials were below average and three were above average). Similarly the maximum temperature was approximately 0.6°C higher than the long term average (35 trials experienced higher temperature and three trials experienced lower temperature than the long-term averages).

Table 1 - Locations and climatic variables for the 38 taxa trials

Bureau of Meteorology forecast regions[a]	Trial	Latitude (decimal degrees)	Longitude (decimal degrees)	Trial annual rainfall average (mm)	Long-term average annual rainfall (mm)[b]	Trial average daily maximum temperature (°C)	Long-term average maximum temperature (°C)[b]
Capricornia	505.A	23.5	150.3	649	816	28.6	27.5
	622.A	23.0	150.6	1066	1392	26.9	26.5
	622.B	23.2	150.7	874	1136	26.2	26.5
Central Coast – Whitsunday	494.C	21.6	149.1	1169	1192	27.2	26.9
	494.V	21.0	149.0	1626	1907	27.6	27.2
	494.W	21.0	148.9	1481	1782	27.8	27.2
Darling Downs and Granite Belt	475.G	27.3	152.1	773	916	23.2	22.7
	505.C	28.3	152.0	699	682	24.2	23.5
	505.D	28.1	149.9	525	554	27.5	26.9
	558	26.9	152.1	745	940	25.6	24.4
	595.B	28.5	151.9	707	791	21.1	20.6
	614	28.1	152.0	516	662	24.2	23.6
North Tropical Coast and Tablelands	503.A	17.1	145.4	769	925	28.3	27.1
	503.C	17.9	145.0	669	725	27.9	27.6
	863.A	16.4	145.4	2430	2253	29.9	29.5
Northern Rivers (NSW)	475.D[c]	28.6	153.1	1594	1172	21.9	25.8
Southeast Coast	475.C	27.5	152.3	727	797	26.5	26.7
	475.F	26.9	152.7	1015	1216	26.4	25.2
	570	27.7	152.3	689	872	26.0	23.6
	573	27.4	152.5	683	817	27.2	26.4
	615	27.8	152.0	686	656	27.3	23.9
Wide Bay and Burnett – coastal	363	25.9	152.8	1111	1195	26.6	26.4
	498.A	24.5	151.6	1009	1122	26.9	26.8
	500	24.4	151.2	686	971	27.9	25.6
	506.A	24.6	151.6	945	1227	27.5	26.9
	506.C	24.4	151.5	814	1128	26.7	26.4
	535.A	26.1	152.7	1092	1227	25.6	25.0
	584	26.5	152.6	1045	1124	26.3	26.1
	605	24.7	151.7	871	1010	27.5	26.9
Wide Bay and Burnett – inland	475.A	25.7	151.4	591	701	28.8	28.0
	480.G	26.8	152.0	679	819	25.0	24.7
	504.A	26.4	151.9	644	765	25.3	25.3
	504.B	26.6	151.9	649	795	25.3	24.3
	505.B	25.7	150.9	590	670	27.8	27.4
	523.A	26.6	151.9	649	790	26.3	24.5
	586	25.1	151.2	593	676	28.3	27.6
	592	24.9	151.1	663	724	28.0	27.4
	593	24.8	151.0	705	796	26.7	25.9

[a] See www.bom.gov.au
[b] Based on Department of Environment and Resource Management (Queensland) enhanced meteorological data set, Data Drill (which accesses grids of data interpolated from point observations by the Bureau of Meteorology).
[c] Referenced as GSPHN009 by Forests New South Wales.

Nutrition trials

A review of the 55 nutrition trials was undertaken with respect to taxon of interest, impact of pests and diseases and BOM region. The six nutrition trials selected focussed on the major commercial hardwood plantation areas in Queensland, namely the North Tropical Coast and Tablelands and Wide Bay and Burnett – inland (Table 2). The species of interest and soil types vary between regions, with emphasis in the North Tropical Coast and Tablelands focussing on *E. pellita* on gradational sands and duplex soils and in the Wide Bay and Burnett – inland focussing on the *Corymbia* species on Ferrosol soils.

In the North Tropical Coast and Tablelands region, trials testing phosphorus (P) and micronutrient (copper (Cu), zinc (Zn) and boron (B)) on a Kurosol soil were selected for inclusion in this study. Tree growth on the Ferrosol soils, that dominate the hardwoods plantation estate in the Wide Bay Burnett – inland region of Queensland, is limited by a few key nutrient deficiencies (*viz*. P and B). In addition, at specific parts of the soil catena, namely seepage zones with typically Brown Ferrosols, potassium (K) deficiencies and elevated salt concentrations can occur. These criteria were used to select four trials from this zone for inclusion in this study.

Table 2 - Location, soil type and test elements of nutrition trials

Bureau of Meteorology forecast regions	Trial	Latitude (decimal degrees)	Longitude (decimal degrees)	Soil type	Test elements
North Tropical Coast & Tablelands	795	18.1	145.9	Kurosol	Micro-nutrients and K
	796	18.1	145.9	Kurosol	P
Wide Bay Burnett – inland	729	25.5	151.4	Brown Ferrosol	K
	730	25.4	151.4	Snuffy Red Ferrosol	B
	748	26.1	151.6	Snuffy Red Ferrosol	P
	749	26.1	151.7	Eroded Red Ferrosol	P

Measurements and assessments

Taxa trials

Data from 38 taxa trials was included in the study. Twenty-seven taxa trials were measured during the project and existing 10-year data was used from an additional 11 trials. The following traits were measured in all 38 trials (in total 1925 blocks):

- DBH – diameter at breast height(1.3m) (cm)
- HT – total tree height (m)
- The following traits were derived from trial assessments:
  - BA - Basal Area at 1.3m = 3.14159 × (DBH/200)^2 (m^2)
  - Volume Index (hereafter called volume) = 1/3 × BA × HT (m^3)
  - Volume MAI - Volume Index Mean Annual Increment (m^3/ha/year) calculated from age 10 years data
  - Pulp Productivity - derived as: Volume MAI × predicted basic density × predicted percent pulp yield × 10 years
  - CO^2 equivalents sequestered (stem wood only) - derived as: Volume MAI × average predicted basic density [biomass] × 0.50 [biomass to C] × 10 years × 44/12 [C to CO_2]

Because many of the trials were actively managed for sawlog production there was also information available for early survival before thinning which generally occurred between 22 and 50 months after planting. Where data was available, estimates of the following traits were generated:

- Survival pre-thinning (%)
- Survival post-thinning at the 10 year measure (%). This is a measure of trees that have survived during the period post thinning to age 10 years (as opposed to mortality which is a measure of trees that died between thinning and age 10 years)
- When no thinning was undertaken survival pre-thinning was set as a missing value and survival at 10 years assessment was used as an estimate of survival post-thinning.

In most of the trials where measurements and assessments were completed as part of this project the following traits were also assessed:

- Borer: Counts of active stem boring insect holes per tree (0–3 scale, where 0, 1 and 2 were actual counts and 3 indicated 3 or more borer holes). For this report the percentage of trees with borer holes is reported
- Old borer: Where holes or wounds left from borer attacks prior to the current assessment were observed (absence (0) or presence (1). For this report 'Old borer' incidence is reported as a percentage.

Wood quality assessments:

- Density: Wood density derived from Near-InfraRed spectra (NIR) and is referred to as predicted basic density (kg/m^3).
- Kraft pulp yield: Predicted from NIR as the percentage recovery of pulp from a given volume of wood when using the Kraft pulping process:
    - Wood samples (woodmeal) were collected from the best performing six taxa (based on volume/hectare at the latest measure) in experiments measured during this study. Approximately five individuals from each taxon per replicate were sampled covering the diameter size range distribution for the taxon in each sampled plot. The samples were collected at approximately 1.3m (DBH height) using a 16mm spade bit in a hand-held drill. The woodmeal samples represented approximately 40mm of sapwood per tree, collected from directly under the bark, ensuring that the sample was free of bark. The woodmeal samples were placed in a labeled paper bags and air dried prior to NIR analysis. Holes in the trees were sealed using a doweling rod and sealant after sampling to avoid pathogen attack.
    - Near-InfraRed spectra were recorded on samples using a Bruker MPA FT-NIR instrument (Bruker Optik, Ettlingen, Germany). For all samples spectra were recorded on air-dried, ground (60-mesh) material. Spectra were recorded between 4,000 and 10,000cm^{-1} (1000–2500 nm) at 8cm^{-1} resolution. An average of 32 scans were acquired per spectrum to increase the signal-to-noise ratio. The samples from 19 trials (1440 sample trees) were acquired and subsequently used to predict tree wood density, Kraft pulp yield and chemical composition using existing NIR calibrations (Downes *et al.* 2009; Meder unpublished data).

Nutrition trials

Similar assessments as were carried out in the taxa trials were undertaken in the nutrition trials. In addition, field observations indicated that the nutrient treatments might have impacted on pest and disease incidence. Wood samples were collected from all trials to determine wood quality responses to treatments.

Data collation

Database programming

The meteorological data presented are summarised from the Department of Environment and Resource Management (Queensland) enhanced meteorological data set, Data Drill (which accesses grids of data interpolated from point observations by the Bureau of Meteorology), for the period from three months prior to planting through to the 10+/-1.9 year measure date used for each experiment.

The FT database was modified to facilitate the analysis of experiments selected for the project. A new schema was added to define information specific to this project and to allow batch processing of the data. It also includes the project taxa definitions and links to pedigree information to allow the output of consistent taxa treatment codes across all taxa trials.

Specialised software was developed to access the FT database, process data, output plot level data for the actual measure period of the individual plots within each trial and link output to summarized climatic and soil profile data. Enhancements to the software used to generate these data from the database have been made to simplify the analysis of groups of experiments as a single dataset, and to match the format requirements of the statistical packages being used in the project.

Volume equations

Volume equations are required if realistic estimates of standing stem volumes are to be made based on the commonly measured parameters of DBH and height. The FT group has been collecting sample tree data for key species being considered for hardwood plantations since early 2000. This is a destructive process where trees are felled and then overbark and underbark diameters are measured systematically along the length of the stem. Previous sampling work was generally limited to thinnings or when trees were being harvested for wood quality testing. However, within this project, there has been considerable effort to sample trees for the target species of interest, particularly in the larger size classes. The species primarily targeted for new sample trees were *E. argophloia* and *E. longirostrata* as there was little data previously collected. Some additional CCV data from previously un-sampled provenances and size classes was also collected. Twenty CCV trees, 16 *E. argophloia* trees and 20 *E. longirostrata* trees were sampled for this project.

The standard measure heights applied to sample trees were 0.2, 0.5, 0.8, 1.3, 2.0, 3.0, 5.0m and then at 2m intervals to a small end diameter of about 5cm. These may have been varied to avoid defect, where trees were being used for wood quality studies, or to coincide with other measure requirements. At each measure, height and diameter overbark were measured, the bark removed and diameter underbark was measured.

Volume equations are derived from sample tree data stored in the FT database. The total number sampled for key species to date is shown in Table 3.

Table 3 - Number of trees, DBH, height range for taxon sampled for volume table development

Taxon	Number of trees sampled	DBH range (cm)	Height range(m)
CCV	180	4.6–27.6	5.0–25.8
CCC	11	3.8–20.1	4.6–23.3
C. henryi	21	3.8–25.0	5.3–20.9
E. dunnii	166	2.5–32.5	3.5–28.5
E. longirostrata	42	5.2–30.5	5.9–26.1
E. argophloia	18	5.2–26.5	6.1–21.4
E. pellita	47	9.7–31.8	9.5–29.9
E. cloeziana	56	4.8–33.1	4.6–31.5

There remains a need for some larger trees (30cm + DBH) for most taxon to be sampled however, there are currently few of these in experiments so the potential for sampling is limited. Most taxon also have some gaps within the sampled distribution, generally in the 12–18cm range. Some taxa that were promising based on growth and survival (*e.g*. *E. moluccana*) did not have trees that meet the requirements for standard volume measurements (due to poor form) and therefore no data was available for these taxa.

Soils

Existing information of soil physical properties was collated for the majority of taxa trials and linked to measure data within the FT Database. There was variation in the number of soil descriptions completed on each trial. In most cases soil descriptions were completed for each replicate within the experiment. In all cases soil descriptions were completed to define the major soil type/s for the trial. Soil descriptions were allocated to individual plots within each experiment. The allocation was based on expert knowledge and site factors pertaining to the trial.

There was some variation in the level of soil descriptive detail that was recorded across this large suite of experiments. All soil descriptions had a minimum of depths of various horizons (generally soils had been described to no greater than 100cm deep), colour (Munsell 1994) and field texture (McDonald *et al.* 1990). Many soil descriptions also had information on soil layer boundaries, soil structure, inclusions and field pH, while some have soil chemical information. As far as practical the soil descriptive data was checked and soils classed according to the standard The Australian Soil Classification (Isbell 1996). All soils data was uploaded onto the FT Soils Relational Database.

Soil physical properties and values derived from these were used in the analysis of the measure data. The derived values were:

1. Clay percentage. A conversion of field texture to a mean percentage of clay weighted by layer depth. This is based on mean values for texture ranges with the clay percentage figures derived from values defined in McDonald *et al.* (1990).
2. Soil moisture availability index. The calculation of soil moisture availability index was based on Williams (1983) and Gardner (1988). This soil moisture availability index has been successfully used in work in native eucalypt forest studies by Lewis *et al*. (2010). The index uses soil texture and structure to estimate the amount of water that can be retained to a given depth for a given textural class. The index was calculated to a maximum depth of 80cm because there was little available soil data beyond this depth.
3. Colour index. A conversion of the soil colour categories from the Munsell Soil Colour Chart (Munsell 1994) to a continuous variable was made using an index derived by Buntley and Westin (1965). This index attributes a numeric value to the soil hue and this value is multiplied by the chroma giving an index where higher values are attributed to brighter colours.

Data analysis

Taxa evaluation trials

A mixed model was used to analyse the trial data at the plot level using data that was compiled to provide one estimate for each plot within each replication of each experiment. Most experiments were assessed near 10 years of age, nevertheless, growth related traits (HT, DBH, BA, volume MAI) were adjusted to better approximate age 10 data by multiplying each plot estimate by the ratio of assessment age to the target age of 10 years. For the purposes of this project, data was analysed at the taxon or hybrid level rather than at the provenance or family level. When a taxon was represented by numerous provenances, these provenances were aggregated at the taxon level.

The statistical model used for the across-site analysis of all trials was:

$$y_{ijklm} = \mu + R_i + E_{ij} + B_{ijk} + T_l + RT_{il} + ET_{ijl} + e_{ijkl}$$

where: μ = overall mean; R_i is the fixed effect of the i^{th} Region; E_{ij} is the random effect of the j^{th} Experiment within the i^{th} Region ($E(E_{ij})=0$, $Var(E_{ij}=\sigma^2_{ij})$; B_{ijk} is the random effect of the k^{th} Block (or replication) within the j^{th} Experiment of the i^{th} Region ($E(B_{ijk})=0$, $Var(B_{ijk}=\sigma^2_k)$; T_l is the fixed effect of the l^{th} taxon; RT_{il} is the fixed interaction between the i^{th} Region and the l^{th} taxon; ET_{ijl} is the random effect of the interaction between the j^{th} Experiment within the i^{th} Region and l^{th} Taxon ($E(ET_{ijl})=0$, $Var(ET_{ijl}=\sigma^2_{ijl})$; and e_{ijklm} is a pooled error term containing the Taxon by Replication interaction, within Taxon variance caused by taxa aggregation and any other within-plot variance ($E(E_{ijkl})=0$, $Var(E_{ijkl}=\sigma^2_e)$).

Least square means estimated for the region by taxon fixed effects are presented in the appendices for each assessment trait. Where estimates were implausible (*i.e.* survival less than 0%) due to scaling of variances and imbalance of data, estimates were constrained to fall within the theoretically feasible range.

Multiple linear regression was used to determine the significance of climatic and edaphic drivers of growth (MAI) and then develop a model to predict MAI given these drivers. The 'stepwise' process was used to select variables to be included in the model, which was compiled using fixed effect estimates for taxa within each experiment ($\mu + T_l + E_{ij} + ET_{ijl}$) using a model that did not include regional effects. Starting with the most significant effect, with a model entry criterion of $p<0.05$, the next most significant site-specific climatic or soil parameter accounting for variation in the response was included in the model with additional terms being added from the highest to the lowest significance level. After any effect was added, all model effects were then reviewed to ensure they remained significant ($p<0.05$) and removed from the model if found to be insignificant. Models were first built using main effects alone and any effects found to be significant in this analysis were forced to be included in an expanded model, which included all two way interactions as well as main effects.

Nutrition trials

The nutrition trials assessed for this report had randomised complete block designs. Statistical analysis of data was conducted with the aid of GenStat Eleventh Edition (Copyright 2008, VSN International Ltd). One-way and two-way analysis of variance (ANOVA) and Least Significant Difference at 5% probability ($LSD_{P=0.05}$) were used to determine the significance of treatment effects.

RESULTS

Taxa trials

Growth

The five best performing taxa (based on volume MAI) in each region at age 10 years are shown in Table 4. The full list of taxon performance across regions is presented in Appendix 1. Across all regions evaluated, the best performing taxa in terms of growth were: 1) CCV, (range 3.9 to 10.3m^3/ha/year), which ranked in the top five taxa in six regions; 2) *E. longirostrata* (range 4.6 to 10.6m^3/ha/year), which ranked in the top five taxa in five regions; 3) *E. dunnii* (range 4.0 to 24.4m^3/ha/year), which ranked in the top five taxa in five regions; 4) *E. grandis* (range 4.1 to 10.5m^3/ha/year), which ranked in the top five taxa in four regions; and 5) *E. argophloia* (range 4.5 to 8.2m^3/year) and 6) CCC range 4.8 to 9.9m^3/year), which ranked in the top five taxa in three regions (Table 4). Across all regions the maximum volume increment was achieved by *E. pellita* in the North Tropical Coast and Tablelands region (volume MAI of 30m^3/ha/year). This species also had the largest average height (20.3m) and basal area (34.5m^2/ha) at age 10 years. The largest average diameter at age 10 years was recorded for *E. dunnii* in the Northern Rivers region (19.6cm).

If the readers wish to evaluate whether the growth of taxon in a region are significantly different, they can use the method for testing for significant differences between taxa detailed in Appendix 4.

Survival and borer damage

The level of old borer incidence was always lower than that for current borer incidence when they were assessed as part of this study (Table 5, Appendix 2). Therefore, it was considered that the assessment of recent activity gave a better indication of taxon stress and susceptibility to borers. Subsequently only the current borer incidence assessed during the project is discussed, and is presented as proportion of trees affected.

The taxa with the best survival and lowest incidence of borer damage in each region are shown in Table 5 with the full list of taxon survival and borer damage across regions presented in Appendix 2. Across all regions, taxa with the best survival and lowest incidence of borer infestation were CCV (post-thinning survival range 85 to 95%; borer incidence range 1 to 9% and *E. argophloia* (post-thinning survival range 96 to 100%; borer incidence range 0 to 29%). Other species with good survival and low borer incidence across multiple zones were *E. siderophloia*, *E. sideroxylon* and CCC.

The post-thinning survival ranged from 0% for *E. macarthurii* to 100% for 12 taxon including *Casuarina cristata* CCC, *C. torelliana*, *E. argophloia*, *E. camaldulensis*, *E. cambageana*, *E. crebra*, *E. longirostrata*, *E. moluccana*, *E. sideroxylon*, *G. robusta* and *Melalueca linarifolia*.

Species with less than 5% borer damage in one or more trials include: *Araucaria cunninghamii*, CT × CCV, CCC, CCV, *C. henryi*, *Elaeocarpus grandis*, *E. argophloia*, *E. camaldulensis*, *E. cambageana*, *E. cloeziana*, *E. crebra, E. dunnii*, *E. globulus* subsp. *maidenii*, *E. pellita*, *E. raveretiana*, *E. sideroxylon*, *E. sphaerocarpa*, *E. tereticornis* and *Khaya senegalensis* (Appendix 2).

Species that had high levels of borer attack (greater than 50% of trees attacked) across several trials included: *Acacia glaucocarpa*, many *Eucalyptus* hybrids, *E. camaldulensis*, *E. dunnii*, *E. globulus* subsp. *maidenii*, *E. grandis*, *E. longirostrata*, *E. moluccana*, *E. pilularis* and *E. tereticornis* (Appendix 2).

The taxa that sequestered the largest amount of CO_2 per hectare over a ten year period varied across regions with CCV in the top three taxa in six regions, *E. dunnii* in the top three taxa in four regions and *E. longirostrata* in the top three in three regions. Other taxon which sequestered large amounts of CO_2 (greater than 150 tonnes CO_2/ha over ten years) in at least one region were *E. grandis* and CCC (Table 6 and Appendix 3).

The pulp productivity at age 10 years for those taxa sampled for this trait ranged from 1.2 tonnes/ha for *E. tereticornis* in the Darling Downs and Granite belt region to 74 tonnes/ha for *E. dunnii* in the Northern Rivers region (Table 6 and Appendix 3).

Table 4 - Growth of the best five taxa in each region based on volume MA

Region	Taxon [a]	Volume MAI (m^3/ha/year)		Diameter breast height (cm)		Total height (m)		Basal area (m^2/ha)	
		Estimate	StdErr	Est	StdEr	Est	StdEr	Est	StdEr
Capricornia	*E. longirostrata*	8.83	2.49	14.94	4.20	15.19	3.40	14.83	3.90
	E. argophloia	8.82	2.14	18.34	3.47	16.81	2.83	16.31	3.35
	CCV	8.49	1.82	15.5	2.75	17.19	2.32	14.17	2.86
	E. moluccana	7.58	2.46	18.77	4.13	16.39	3.35	15.04	3.86
	CCC	4.85	2.60	14.84	4.44	14.76	3.56	10.58	4.07
Central Coast – Whitsunday	*E. grandis*	10.53	2.07	14.26	3.31	13.95	2.73	15.89	3.25
	E. cloeziana	10.31	1.80	18.09	2.71	17.17	2.30	15.86	2.84
	E. dunnii	9.97	1.85	16.53	2.83	17.15	2.37	14.76	2.91
	CCC	9.88	1.85	15.64	2.82	16.67	2.37	15.52	2.91
	CCV	9.34	2.09	14.61	3.35	17.49	2.76	13.14	3.28
Darling Downs and Granite Belt	*E. longirostrata*	4.62	2.23	15.79	3.93	12.64	3.13	11.28	3.50
	E. globulus subsp. *maidenii*	4.41	1.52	14.9	2.45	10.49	2.02	9.78	2.39
	E. sideroxylon	4.14	2.23	16.17	3.93	10.96	3.13	11.34	3.50
	E. grandis	4.09	1.72	13.47	2.88	11.11	2.35	8.72	2.71
	E. dunnii	4.02	1.33	14.28	2.05	10.77	1.72	8.67	2.10
North Tropical Coast and Tablelands	*E. pellita*	29.98	2.72	18.74	4.48	20.31	3.67	34.50	4.28
	Elaeocarpus grandis	7.92	2.72	14.32	4.48	11.39	3.67	14.16	4.28
	CCV	6.69	2.50	13.12	4.17	14.63	3.40	13.59	3.93
	EG × EC	5.32	2.55	10.73	4.28	12.62	3.47	11.96	4.00
	CCC	5.20	2.04	11.35	3.18	13.11	2.66	11.52	3.21
Northern Rivers	*E. dunnii*	24.39	3.12	19.62	4.71	19.74	3.98	33.72	4.91
	E. globulus subsp. *maidenii*	12.30	3.12	16.59	4.71	16.46	3.98	20.74	4.91
	CCV	10.28	3.05	14.55	4.52	16.31	3.86	16.98	4.80
	E. grandis	6.08	3.02	13.63	4.46	14.9	3.82	10.78	4.76
	EG × EU	5.15	3.12	14.08	4.71	12.28	3.98	10.23	4.91
Southeast Coast	*E. longirostrata*	5.35	1.37	16.50	2.03	13.69	1.73	10.73	2.15
	E. dunnii	5.28	1.56	16.18	2.46	12.69	2.05	9.88	2.45
	E. argophloia	4.94	1.54	16.16	2.43	13.28	2.02	10.67	2.43
	E. sideroxylon	4.20	2.21	17.37	3.83	11.38	3.08	10.94	3.47
	C. henryi	3.94	2.27	17.21	3.93	13.63	3.17	7.41	3.57
Wide Bay and Burnett – coastal	*E. longirostrata*	10.59	1.45	18.21	2.41	17.55	1.96	15.82	2.27
	Pinus caribaea var. *hondurensis*	9.94	2.21	17.47	3.96	12.01	3.13	19.89	3.46
	CCV	7.91	1.08	15.81	1.61	16.70	1.37	12.09	1.70
	E. dunnii	7.72	1.19	17.91	1.85	15.66	1.54	12.34	1.87
	E. grandis	7.60	1.12	16.09	1.69	14.41	1.44	11.11	1.77
Wide Bay and Burnett –inland	*E. argophloia*	4.49	1.09	16.65	1.67	13.63	1.41	9.96	1.71
	E. longirostrata	3.56	1.13	16.06	1.76	12.95	1.47	7.93	1.77
	E. moluccana	3.53	1.25	14.77	2.04	12.18	1.68	8.33	1.97
	CCV	3.50	1.05	14.93	1.58	13.92	1.34	7.26	1.65
	EG × ER	3.27	1.30	16.02	2.14	10.63	1.75	7.59	2.04

[a] Taxon abbreviations CCC = *C. citriodora* subsp. *citriodora*, CCV = *C. citriodora* subsp. *variegata*, EG × EU = *E. grandis* × *E. urophylla*, EG × ER = *E. grandis* × *E. resinifera*

Table 5 - Survival and borer incidence of the best[a] taxa within regions

Region	Taxon [b]	Pre-thin survival		Post-thin survival		Stem borer incidence		Old borer incidence	
		Estimate	StdErr	Est	StdErr	Est	StdErr	Est	StdErr
Capricornia	CCV	0.95	0.13	0.92	0.15	0.09	0.41	0.00	0.17
	E. argophloia	0.94	0.16	1.00	0.19	0.10	0.65	0.00	0.29
	E. camaldulensis	1.00	0.16	0.94	0.19	0.02	0.65	0.05	0.29
Central Coast – Whitsunday[c]	CCC	na[d]	na	0.64	0.16	0.00	0.35	0.00	0.15
	CCV	na	na	0.53	0.19	0.08	0.42	0.02	0.18
	E. cloeziana	na	na	0.48	0.15	0.07	0.33	0.00	0.14
	E. dunnii	na	na	0.49	0.16	0.45	0.35	0.19	0.15
	E. pellita	na	na	0.52	0.17	0.24	0.39	0.12	0.16
Darling Downs and Granite Belt	*E. argophloia*	0.98	0.11	0.99	0.11	0.00	0.57	0.00	0.23
	E. cambageana	1.00	0.18	1.00	0.22	0.16	0.57	0.07	0.23
	E. sideroxylon	1.00	0.18	1.00	0.22	0.00	0.57	0.00	0.23
North Tropical Coast and Tablelands[c]	*E. pellita*	na	na	0.56	0.25	0.03	0.56	0.03	0.23
	EG×EC	na	na	0.88	0.24	0.05	0.55	0.11	0.23
	CCC	na	na	0.70	0.18	0.11	0.40	0.09	0.16
	CCV	na	na	0.66	0.23	0.06	0.54	0.11	0.22
Northern Rivers	CCV	na	na	0.85	0.25	0.01	0.55	0.00	0.22
	E. dunnii	na	na	0.90	0.26	0.00	0.58	0.00	0.24
	E. globulus subsp. *maidenii*	na	na	0.81	0.26	0.00	0.58	0.00	0.24
Southeast Coast	CCV	0.86	0.10	0.85	0.11	0.01	0.39	0.00	0.18
	E. argophloia	0.96	0.12	1.00	0.14	0.00	0.52	0.01	0.22
	E. cloeziana	0.57	0.18	0.91	0.22	0.00	0.52	0.00	0.22
	E. crebra	0.97	0.18	1.00	0.22	0.00	0.52	0.00	0.22
	E. siderophloia	0.93	0.18	0.86	0.23	0.37	0.55	na	na
	E. sideroxylon	0.98	0.18	1.00	0.22	0.00	0.52	0.00	0.22
Wide Bay and Burnett – coastal	CCC	0.85	0.18	0.85	0.12	0.10	0.32	0.07	0.13
	CCV	0.90	0.10	0.90	0.09	0.06	0.32	0.06	0.13
	E. argophloia	0.80	0.18	0.96	0.22	0.13	0.53	0.08	0.21
	E. longirostrata	0.93	0.18	0.81	0.14	0.28	0.33	0.19	0.14
	Pinus caribaea var. *hondurensis*	na	na	0.88	0.22	0.29	0.54	0.09	0.22
	Pine hybrid	na	na	0.85	0.22	0.29	0.54	0.09	0.22
Wide Bay and Burnett – inland	*A. cunninghamii*	0.83	0.10	0.91	0.12	0.00	0.53	0.00	0.22
	CCC	0.86	0.08	0.95	0.10	0.02	0.31	0.00	0.12
	CCV	0.85	0.08	0.95	0.09	0.02	0.27	0.02	0.11
	C. henryi	0.83	0.10	0.85	0.12	0.00	0.37	0.00	0.15
	E. argophloia	0.95	0.08	1.00	0.09	0.29	0.28	0.16	0.11
	E. moluccana	1.00	0.10	0.98	0.12	0.36	0.31	0.13	0.12
	E. siderophloia	0.87	0.11	0.96	0.13	0.00	0.53	0.00	0.22
	E. sideroxylon	0.92	0.18	0.87	0.22	0.30	0.53	0.07	0.22

[a] Best taxa was defined as taxa that had >80+% post-thinning survival and <50% of trees recently damaged by borers.

[b] Taxon abbreviations CCC = *C. citriodora* subsp. *citriodora*, CCV = *C. citriodora* subsp. *variegata*, EG × EC = *E. grandis* × *E. camaldulensis*, Pine hybrid = the F2 hybrid from *Pinus elliottii* × *Pinus caribaea* var. *hondurensis*

[c] Trials were not thinned but were damaged by cyclones. In these regions taxon that had greater than 48% survival and good volume growth were included here.

[d] Not available.

Wood density, carbon sequestration and pulp productivity

Across all trials, 19 taxa were sampled during the term of this project for wood property traits (wood density and Kraft pulp yield) (Table 6 and Appendix 3). Values for density and Kraft pulp yield (KPY) were predicted from existing near infrared (NIR) calibrations for hardwoods (Downes *et al*. 2009, Meder unpublished data). The error in the relationship between breast height sampling for NIR and actual whole tree value had been determined previously as being <1% for KPY and about 3% for density (Downes *et al*. 2009). Carbon sequestered, evaluated as CO_2 equivalents, was calculated for stem wood only, based on wood density and volume (assuming stem biomass contained 50% C). Pulp Productivity was estimated using volume, density and KPY.

The highest wood density observed in this study was for the *Corymbia* hybrids (CT × CCV) in the Wide Bay and Burnett – inland region with a predicted wood density of 816kg/m^3 (Table 6). The predicted wood density for taxon sampled across multiple sites was fairly consistent for some taxon *e.g.* density of CCC sampled across six regions ranged from 715 to 770 kg/m^3, CCV sampled across six regions ranged from 701 to 777kg/m^3. Other species were reactive to the regions with a large variation in wood densities *e.g*. the density of *E. dunnii* sampled across five regions ranged from 572 to 697kg/m^3 (Appendix 3).

Table 6 - Wood density, volume, CO_2 sequestered and pulp productivity of selected taxa[a] in each region

Region	Taxon[c]	Wood density (kg/m^3)		Volume MAI (m^3/ha/year)		CO_2 [b] sequestered (tonnes/ha)		Pulp productivity (tonnes/ha)	
		Estimate	StdErr	Est	StdErr	Est	StdErr	Est	StdErr
Capricornia	*E. argophloia*	664	20.7	8.82	2.14	100.6	25.70	26.0	6.98
	E. longirostrata	614	24.5	8.83	2.49	108.2	32.70	27.0	8.80
	CCV	740	15.4	8.49	1.82	115.3	19.45	32.2	5.30
Central Coast – Whitsunday	*E. cloeziana*	681	15.1	10.31	1.80	130.1	19.20	34.3	5.24
	E. grandis	633	20.3	10.53	2.07	159.0	25.45	40.0	6.88
	CCV	701	19.5	9.34	2.09	159.1	24.87	45.9	6.72
Darling Downs and Granite Belt	*E. dunnii*	697	18.0	4.02	1.33	65.1	23.26	16.5	6.32
	E. grandis	689	25.2	4.09	1.72	65.8	32.97	16.3	8.92
	E. globulus subsp. *maidenii*	687	23.6	4.41	1.52	72.0	31.61	18.5	8.56
Northern Rivers	CCV	717	24.7	10.28	3.05	135.1	31.91	37.6	8.71
	E. dunnii	614	26.2	24.39	3.12	273.6	33.24	73.9	9.06
	E. globulus subsp. *maidenii*	621	26.2	12.30	3.12	138.9	33.24	37.5	9.06
Southeast Coast	CCV	768	17.6	3.41	1.35	56.2	22.93	14.9	6.23
	E. longirostrata	675	15.0	5.35	1.37	79.6	19.08	20.0	5.21
	E. dunnii	617	23.0	5.28	1.56	126.0	31.44	33.1	8.46
Wide Bay Burnett – coastal	CCC	726	26.2	5.05	1.30	152.0	33.23	43.6	9.06
	CCV	729	27.9	7.91	1.08	184.5	34.67	54.5	9.45
	E. longirostrata	649	26.2	10.59	1.45	235.2	33.23	60.7	9.06
Wide Bay Burnett – inland	*E. dunnii*	649	16.9	2.20	1.09	62.4	22.88	15.9	6.12
	CT × CCV	816	29.4	3.05	2.17	62.6	37.37	15.3	9.97
	EG × ER	699	25.1	3.27	1.30	68.4	33.64	16.0	8.97

[a] Taxa were selected as the top three taxa in each region, based on CO_2 sequestered at age 10 years.
[b] CO^2 equivalents sequestered (stem wood only) - derived as: Volume MAI × average predicted basic density [biomass] × 0.50 [biomass to C] ×10 years × 44/12 [C to CO_2]
[c] Taxon abbreviations CCC = *C. citriodora* subsp. *citriodora*, CCV = *C. citriodora* subsp. *variegata,* CT × CCV = hybrids seedlings between C. torelliana × *C. citriodora* subsp. *variegata*, EG × ER = *E. grandis* × *E. resinifera*

Volume equations

Volumes of individual sample trees were estimated by treating the section between consecutive measures as the frustum of a cone, and the section between the highest measure and the tip as a cone. Individual section volumes were calculated and summed to estimate the volume of the stem.

The calculated volumes for the eight taxa were plotted against BA × HT to determine the form of the relationship and investigate how well the calculated volumes fitted the model, where:

BA is tree basal area at breast height (1.3 m) in m^2; and
HT is total tree height in meters.

In all cases the relationship was linear over the range of tree sizes sampled. The simple linear regression module of GenStat Eleventh Edition (Copyright 2008, VSN International Ltd.) was used to fit an equation for each taxon (Appendix 5). As the constant term was found to be non significant for all species a regression through the origin was fitted to ensure that negative volumes could not result from using the fitted models. A model of the form:

$$VOL = C \times BA \times HT$$

Where:

VOL is volume in m^3; and
C is a constant (coefficient) for a given taxon (Table 7).

The details of the analysis for each taxon are shown in Table 7. There is only limited data available for some taxon, but in all cases the data appear to fit well. There is a particular need for more data for CCC, *C. henryi* and *E. argophloia*. There is some variation in the coefficient (which can be considered as a form factor) of the BA × HT term. However, it should be noted that the two extreme values are for taxon that had few samples (*C. henryi* with 21 samples had the lowest value, and CCC with 11 values had the highest). The two taxa with the most samples (CCV and *E. dunnii*) actually had very similar (and intermediate) values for the coefficient of the BA × HT term. These models should not be applied to trees outside the diameter and height ranges shown in Table 7.

Table 7 - Volume equation coefficients for eight key species

Taxon	No. of samples	DBH range (cm)	Ht range (m)	Underbark			Overbark		
				Coefficient	R^2	SE of obs	Coefficient	R^2	SE of obs
CCV	197	4.6–27.6	5.0–25.8	0.3150	97.8	0.0138	0.3995	97.9	0.0170
CCC	11	3.8–20.1	4.6–23.3	0.3459	100.0	0.0018	0.4479	100.0	0.0021
C. henryi	21	3.8–25.0	5.3–20.9	0.2829	98.8	0.0095	0.3860	99.0	0.0114
E. argophloia	18	5.2–26.5	6.1–21.4	0.3135	96.1	0.0196	0.4125	96.5	0.0237
E. cloeziana	56	5.9–33.1	4.8–31.5	0.2957	99.6	0.0134	0.4027	99.7	0.0148
E. dunnii	166	12.2–32.9	10.7–28.6	0.3189	98.9	0.0171	0.3984	99.2	0.0180
E. longirostrata	42	5.2–30.5	5.9–26.1	0.2980	99.1	0.0142	0.3918	99.4	0.0146
E. pellita	48	9.7–31.8	9.5–29.9	0.3267	96.8	0.0342	0.4422	97.3	0.0424

Productivity drivers of plantation growth in north-eastern Australia

The ability to predict productivity using the environmental characteristics that have been experienced by these trials was evaluated using linear regression to model volume MAI. The model summarised in Appendix 6 points to the major drivers (main effects) of volume MAI over the life of the experiments sampled as being: Wetness index (mean annual rainfall/Evaporation); MinT (Extreme low temperature); Rain (mean annual rainfall); Raindays (average number of raindays per year); MaxT (mean daily maximum temperature); and Water(soil water holding potential). Overall, analysis of variance (Tables A6.1and A6.2) indicates that simple linear regression model accounts for a significant ($p<0.001$) amount of the variation in the data, therefore, the environmental variables evaluated for this project are predictive of growth. Given the extreme variation in the environments sampled, the model appears to fit well (Figure A6.1) with an adjusted R^2 implying just over 52% of the variation in the predicted taxa performance can be accounted for using site characteristics. A better understanding of how each environmental variable impacts volume MAI can be under taken through inspection of Table A6.2. Clearly water is a critical driver with all three variables associated with water availability appearing in the model. All model terms were included in the model once interactions were included. While significant as a main effect, the average daily minimum temperature failed to account for a significant amount of variance as two-way interactions (when solar radiation, evaporation, maximum recorded temperature, and soil water holding capacity) were included in the model. Graphical representation of the inter-relationships between variables identified by the linear model detailed in Table A6.2 provides more detailed descriptions of the impact of environment on productivity. While the inclusion of interactions between variables improved the model, transformations of environmental variables to allow for non-linear relationships should be explored to provide more explicative models. The ability to better describe volume MAI with non-linear functions of the environmental variables, splines or other pattern analysis methods is evident for some of the variables, particularly environmental variables that are related to productivity though their impact on survival.

The suitability of taxon-specific models (when taxa were represented more than 10 times in at least 5 experiments) varied widely: CCV R^2=0.72, *E. dunnii* R^2=0.81, *E. grandis* R^2=0.81, *E. tereticornis* R^2=0.65, *E. pellita* R^2=0.87, *E. moluccana* R^2=0.39, CCC R^2=0.91, *E. camaldulensis* R^2=0.14, *E. cloeziana* R^2=0.57, *E. grandis* x *E. urophylla* R^2=0.30, *E. longirostrata* R^2=0.93, *E .grandis* x *E. camaldulensis* R^2=0.09, *E. resinifera* R^2=0.72, *E. grandis* x *E*. *tereticornis* R^2=022, *E. globulus* subsp. *maidenii* R^2=0.77, *E. argophloia* R^2=0.50. Productivity of each taxon was influenced by a different set of variables with some similarities between sets of taxa indicating more generalised models could be generated for some groups of taxa.

Nutrition trials

Tree growth

In the North Tropical Coast and Tablelands region, a P trial was measured to examine the optimum rate of P to apply on a Kurosol soil and the best time of application for establishment and tree growth of *E. pellita*. At age 15 months, treatments had a significant impact on DBH and stem volume, but not tree height. Growth responses have shown significant differences to the rates of P applied, but not to time of application of P. An application of 60kg/ha P at planting increased DBH by 13.3% and stem volume index by 33.7%, compared to nil P controls.

Two P trials were measured in the Wide Bay and Burnett – inland region to determine the requirement for P at establishment to improve the growth of CCV on a snuffy Red Ferrosol soil and a degraded Red Ferrosol soil. On the snuffy Red Ferrosol soil, 30kg/ha P applied as mono-ammonium phosphate (MAP) with basal N applied as urea to supply 55kg/ha N resulted in a 256% increase in stem volume at 3.1 years, compared to the nil P plus N treatment. On the degraded Red Ferrosol, there was a similar trend of increasing stem volume (21.5%) at 3.1 years with a P application of 30 kg/ha P although treatment effects were not significant.

Also in the Wide Bay and Burnett – inland region a K trial was measured to determine the requirement for K of CCV in a failed plantation area. The difference between the well established surrounding area and the failed plantation area was associated with a change in soil type from a Red Ferrosol to a Brown Ferrosol. Stem volume at age seven years (after thinning to 500 stems/ha) was increased by 22.8% with the application of 75kg/ha K at establishment, compared to the nil K control.

Tree form

A rate of B trial was established in the Wide Bay Burnett – inland region, on a snuffy Red Ferrosol testing CCV and two families of *C. torelliana* × CCV hybrids. Trees were rated for stem form at six years using a subjective 1–5 scoring system (score of 1 having no evidence of incidences of loss of apical dominance and score of 5 having several incidences of loss of dominance evident). Boron treatment improved tree form *i.e.* improved apical dominance. There were also taxon differences in stem form with CCV having the best apical dominance (3.4) < CT×CCV9 (3.7) < CT×CCV3 (4.0).

Wood quality

Increases in wood volume through increasing P to adequate levels for plant growth did not result in any change in wood quality in two of the three P trials included in this study. However, in the P trial with CCV on a snuffy Red Ferrosol in the Wide Bay and Burnett - inland region, wood density increased (by 10%) and Modulus of Elasticity (MoE) decreased (by 5%) with the application of 60kg/ha P compared to the nil P control treatment. In the micronutrient trial (North Tropical Coast and Tablelands region), density and pulp yield increased by 7.5% and 3.5% respectively, in the nil copper treatment due to slower tree growth.

Pest susceptibility

In the B trial on a snuffy Red Ferrosol in the Wide Bay Burnett – inland region, B treatments decreased the severity of longicorn beetle (*Phoracantha solida*) attack. The CCV was the least affected with a severity (number of borer holes per tree) of 0.02, compared to 0.62 for CT × CCV3 and 0.27 for CT × CCV9.

DISCUSSION

The estate of commercial hardwood plantations in north-eastern Australia is small relative to some parts of Australia, with over 115,000 ha established in the subtropics (Nichols *et al*., 2010) and approximately 15,000 ha established in the tropics, compared to approximately 900,000 ha of hardwood plantations in southern Australia (ABARES 2011). The main constraints to expansion of the industry in north-eastern Australia are inadequate knowledge about the most suitable taxa, the limited supply of improved seed of preferred taxa, lack of information on growth rates over the range of environments, the risks associated with growing trees (pests, diseases, frost, drought, climate change, etc) and uncertainty around potential products and markets. Many of these constraints do not apply to established hardwood plantation industries in southern Australia (*e.g.* Green Triangle, Southern West Australia and Tasmania). There is a need for a clear government policy to promote hardwood production forestry in north-eastern Australia and this report provides summarised data which will aid in this policy development.

Given the rather recent nature of the hardwood plantation research relevant to the region, it is not surprising that the selection of many of the taxa planted in the recent rapid expansion of the commercial hardwood plantations was based on overseas experience (Lee *et al.* 2010) and the limited published information from young trials in the region (Johnson and Stanton 1993; Lee *et al.* 2001, Lee *et al.* 2003). As a result of poor taxon selection and subsequent pest and disease incursions combined with cyclones and drought, approximately 25,000 ha of the hardwood plantations in north-eastern Australia have failed.

The results from trials reported in this project provide a better basis for taxon/site matching to guide industry investment. Examining taxon growth and risks at a regional level reflects potential plantation scale performance, and helps inform tree improvement programs in northern Australia of the most suitable taxa for different regions. In addition to growth rate and silvicultural risks, growing costs, wood properties and potential products and markets need to be considered in selecting species for broad scale plantation investment. This study will also help focus the tree improvement programs in northern Australia on taxa that are currently showing the greatest potential value for the region.

Increasing the understanding of taxon performance under a range of climatic, edaphic and nutrient conditions (as this report has done) will allow more confident prediction of taxon behaviour as the impacts of climate change take effect.

Possible impacts from climate change.

The possible impacts and implications of climate change are covered by several current publications including Pinkard *et al.* (2010). A summary of the main impacts and outcomes are included in Table 8.

Table 8 - Summary of possible impacts and outcomes of climate change on forest productivity in Australia
(Adapted from Table 4 in Pinkard *et al.* 2010)

Impact	Outcome
Warmer mean annual temperature	• Change in seasonality of growth and increase in length of growing season.[a] • Potential for increased pest damage if pest phenology changes alongside tree phenology. • Increased potential distribution of species currently restricted by mean minimum temperatures e.g. *E. globulus.* • Reduced frost hardening and increased susceptibility to frost that may result in more severe damage when frosts occur. • Increased transpiration and greater evaporation from soil resulting in increased water stress. • Increased rates of photosynthesis that may increase growth rate. • Increased vapour pressure deficit that may increase plant water stress.
Increased frequency of heatwaves	• Tissue damage, protein denaturation and mortality, particularly if combined with drought. • Greater soil evaporation leading to increased plant water stress. • Greater post-establishment mortality.
Reduced precipitation	• Reduced leaf area index and therefore decreased growth rates. • Tissue damage and mortality. • Greater susceptibility to some pests e.g. stem borers. • Greater post-establishment mortality.[b]
Elevated atmospheric CO_2	• Increased growth where water and nutrients are non-limiting, but likely to be restricted to young, actively-growing stands. • Increased allocation of biomass belowground meaning increased growth may not result in improved yield. • Greater water-use efficiency that may reduce drought effects.

[a] In north-eastern Australia this may not apply as water is the main limiting factor and the temperatures are higher year round.
[b] As shown below the models for north-eastern Australia are not clear on the amount of precipitation likely to occur.

Taxa performance by region

The taxa planted in 38 taxa trials reported from across the study regions showed significant differences at age 10 years in survival, height, diameter, basal area, volume MAI, stem borer incidence, carbon sequestration rates and pulp productivity. Across all sites the rainfall was 88% of the long-term average (35 trials were below average and three were above average). Similarly the average maximum temperature was 0.6 °C higher than the long-term average (35 trials experience higher temperature and three trials experienced lower temperature than the long-term averages; Table 1). The lower than average rainfall and higher than average temperature experienced by most trials means that the trials experienced climate somewhat similar to the predicted climate of the future.

In the Capricornia region, three taxa had volume MAI over 8m^3/ha/year at age 10 years (*E. longirostrata*, *E. argophloia* and CCV; Table 4) despite the region suffering a severe drought. Of these taxa, only *E. argophloia* and CCV also exhibited good survival and low borer damage (Table 5). All three taxa sequestered over 100 tonnes of CO_2 equivalents/ha over ten years trial period. Only 77% of the average rainfall falling during the measure period and the average daily temperature in this region was 0.4°C higher than the long-term average.

For the Central Coast – Whitsunday region, five taxa had volume MAI over 9m^3/ha/year (*E. grandis, E. cloeziana, E. dunnii*, CCC and CCV - Table 4) despite the region suffering a severe drought. Of the five taxa mention above, those which had good survival and low borer attack were CCC, CCV and *E. cloeziana*. Lawson (2003a, b) considered levels of over 15% of trees attacked by borers to be 'very high' and would preclude the use of the taxon for solid wood products. Based on this, *E. pellita* and *E. dunnii* would not be suitable for solid wood products in this region. All species evaluated for CO_2 sequestration captured over 100 tonnes of CO_2 equivalents/ha over the ten years trial period, with CCV and *E. grandis* sequestering the most CO_2 (both sequestering 159 tonnes/ha over 10 years - Table 6, Appendix 3). Only 88% of the average rainfall falling during the measure period. The average daily temperature in this region was 0.4°C warmer than long-term average. The trials in this region also suffered cyclone damage during several cyclones including category-three Cyclone Ului in March 2010.

In the Darling Downs and Granite Belt region no taxon had a volume MAI over 5m^3/ha/year, with five taxa, *E. longirostrata*, *E. globulus* subsp. *maidenii, E. sideroxylon, E. grandis and E. dunnii* growing between 4 m^3 and 5 m^3/ha/year (Table 4, Appendix 1). Of the five taxa with the fastest growth, only *E. sideroxylon* exhibited good survival and low borer damage (Table 5). The only other taxon that showed potential for this region is *E. argophloia* which had a lower volume growth of 3.5m^3/ha/year (Appendix 2) but good survival and low borer attack (Table 5). Carbon sequestration in this region was also low with the top three species (*E. dunnii*, *E. grandis* and *E. globulus* subsp. *maidenii* sequestering between 65 and 72 tonnes of CO_2 equivalents over the -year trial period (Table 6). This region had a mean annual rainfall of 87% of its long-term average during the 10-year trial period and the average daily temperature in this region was 0.7°C higher than the long-term average.

Growth in the North Tropical Coast and Tablelands region reflected the higher rainfall of this area with the fastest growing taxon, *E. pellita* having a predicted volume MAI of 30m^3/ha/year. On the wet coastal area no other species came near the growth of *E. pellita* (Table 4, Appendix 1). On the drier tablelands, other taxa showing potential included CCV, EG $\times$ EC and CCC which had volume MAI of 5.2 to 6.7m^3/ha/year (Table 4). *Eucalyptus pellita*, CCC, CCV and EG $\times$ EC hybrids all had good survival and low borer attack in this region (Table 5, Appendix 2). All of these taxa could therefore be suitable for solid wood production based on the low incidence of borers if growth rates are considered satisfactory. Wood density and CO_2 sequestration data is a not currently available for this region, however, samples have been collected and data is available for analysis. During the trial period 1999–2011 the North Tropical Coast and Tablelands region experienced seven cyclones (www.bom.gov.au) so growing trees in plantations is highly risky. The two trials on the tablelands had 87% of their long-term average rainfall whereas the coastal trial in this region had 108% of its long-term annual average during the trial period. In the region, the average daily temperature was 0.6°C warmer than long-term average.

Only one trial was available for measurement and assessment in the Northern Rivers region. In this trial the standout species was *E. dunnii* with a volume MAI of 24.4 m^3/ha/year. Other taxa with good growth included *E. globulus* subsp*. maidenii* (volume MAI of 12.3 m^3/ha/year) and CCV (volume MAI of 10.3 m^3/ha/year) (Table 5, Appendix 2). This un-thinned trial experienced low borer damage (< 1% of trees affected) for the faster growing trees *E. dunnii*, *E. globulus* subsp. *maidenii* and CCV (Table 5, Appendix 2). Based on this, these three taxa could be suitable for solid wood production. The carbon sequestration rate in this region was also high with the four taxa sampled sequestering between 97 and 274 tonnes of CO_2 over 10 years (Table 6, Appendix 3). This trial's annual rainfall was higher than the long-term average (by 36%) and the trial average daily temperature was -3.9°C cooler than long-term average for the site.

In the Southeast Coast, the top five volume growth taxa with volume MAI ranging from 5.3 to 3.9m^3/ha/year were *E. longirostrata, E. dunnii, E. moluccana, E. sideroxylon* and *C. henryi* (Table 4; Appendix 1). In this region a different suite of taxa had good survival and low borer damage. These taxon were CCV*, E. argophloia, E. cloeziana, E. crebra, E. siderophloia* and *E. sideroxylon*. Of the five taxa with the fastest growth, only *E. sideroxylon* exhibited good survival and low borer damage (Table 5). The other taxon that might have potential for this region is *E. argophloia* which had low volume growth (3.5 m^3 /ha/year) (Appendix 2) but good survival and low borer attack (Table 5). Carbon sequestration was generally low with the top three species (*E. dunnii*, *E. grandis* and *E. globulus* subsp. *maidenii*) sequestering between 65 and 72 tonnes of CO_2 equivalents over the 10-year trial period (Table 6, Appendix 3). Trials in this relatively dry coastal region (MAR = 872 mm) experienced only 87% of their long-term average rainfall during the 10-year trial period. In this region, the average daily temperature was also 1.5°C higher than the long-term average. This is the largest increase in temperature documented in this study.

For the Wide Bay and Burnett – coastal region, six taxa had MAI over 7m^3/ha/year (*E. longirostrata, Pinus caribaea* var. *hondurensis*, CCV, *E. dunnii*, *E. grandis* and *E. Cloeziana* - Table 4, Appendix 1) despite the region suffering a severe drought. Of the six best performing taxa, those which had good survival and low borer attack were CCV and *E. cloeziana.* These are the only taxon that could be considered for production of solid wood products. All taxa evaluated for wood properties in this region sequestered over 100 tonnes of CO_2 equivalents/ha over the 10-year trial period, with *E. longirostrata* and CCV sequestering the most CO_2 (235 and 184 tonnes/ha over 10 years respectively - Table 6, Appendix 3). In this region, 84% of the average rainfall falling during the measure period and the average daily temperature in this region was 0.6°C warmer than long-term average.

The Wide Bay and Burnett – inland region had low growth with the best performing taxa (*E. argophloia*) growing at only 4.5m^3/ha/year (Table 4, Appendix 1). Other taxa with similar growth were *E. longirostrata*, *E. moluccana*, CCV and the EG × ER hybrid. Of these faster growing taxa, those that also had good survival and low borer damage, were CCV*, E. argophloia* and *E. moluccana* (Table 5, Appendix 2). Other taxa with low borer damage and good survival were *A. cunninghamii,* CCC*, C. henryi, E. siderophloia* and *E. sideroxylon*. Carbon sequestration in this region was also low with the top three taxa (*E. dunnii*, CT × CCV and EG × ER sequestering between 62 and 68 tonnes of CO_2 equivalents over the 10-year trial period (Table 6, Appendix 3). The average rainfall across the trials in the inland section of the Wide Bay Burnett region is 784mm/year, however during the 10-year trial period only 86% of the average annual rainfall fell. Trials in this region experienced average daily temperature for the trial period of 0.7°C higher than the long-term average.

Taxa suitability across regions and products

Sustainable plantation expansion and growth in north-eastern Australia requires optimal choice of taxon in regards to site (soil, topography and location) and potential risks associated with climate change (both anthropomorphic and natural). Battaglia *et al.* (2009) discussed how global climate models for north-eastern Australia vary in predictions of the percentage change in annual rainfall, with some models predicting increases and others decreases by 2030 or 2070. However, all models do predict increases in temperature and more intense severe weather events. The two of these models that seem most relevant to this study are:

- Hadley Mk2 A1Fi model. This model is based on rapid economic and population growth (declining in the second half of the century), is a high CO_2 emission scenario focussed on fossil fuel usage. This model predicts an increase of annual average temperatures (1–2°C by 2030 and 4–5°C by 2070) and a reduction of annual rainfall (0 to –15% in annual rainfall by 2030 and between –15% and –29% by 2070) relative to the current climate in north-eastern Australia.

- CSIRO Mk3 A2 model. This model is based on an increasing population with fragmented technological change and some reductions or mitigation of CO_2 emissions. Predictions from this model are that annual average temperatures will increase (0–1°C by 2030 and 1–2°C by 2070) and a range of potential changes in rainfall across the region of between 0 to –15% in annual rainfall by 2030 and between –15% and +25% by 2070, relative to the current climate in north-eastern Australia.

Given that there is some uncertainty about the future climate in north-eastern Australia the taxon chosen for commercial deployment need to be adapted to a large range of soils and climatic conditions as well as elevated CO_2 concentrations. The 38 taxa trials included in this study were generally subject to lower-than-average rainfall, higher annual average temperatures and many severe weather events (storms, drought and cyclones). They are also sited on typical soils for the regions. Therefore, the taxon performances reported here should be a good indicator of their potential under the conditions of the two climate change models describe above. Of the 65 taxa included in the current study, those that were the most robust (based on volume growth, survival and carbon sequestration rates) under both the drought conditions experienced by most of the trials and the above average rainfall in other regions were CCV, *E. dunnii*, *E. longirostrata* and *E. argophloia*. The growth achieved for CCV (volume MAI range of 3.5 to 10.3m^3/ha/year for unimproved germplasm) and *E. longirostrata* (volume MAI range of 3.6 to 10.6m^3/ha/year for unimproved germplasm) in north-eastern Australia confirm the findings of Lee *et al.* (2001; 2010) in Australia and Gardner *et al.* (2007) in South Africa of the high potential of these taxa for plantation development. *Eucalyptus dunnii* and *E. argophloia* were also identified as having potential for some regions of north-eastern Australia.

In five of the seven regions evaluated in this study, the growth rates of the better performing taxa (managed for sawlog production) were similar or better than those observed for *E. globulus* subsp. *globulus* in 338 permanent growth plots in Victoria (Green triangle to Gippsland, managed for wood chip production). At a mean age of 5.8 years *E. globulus* subsp. *globulus,* managed for woodchip production had an average standing volume of 63.3 m^3 equating to a volume MAI of 10.9 m^3/ha/year (Wang and Baker, 2007).

While it is important to match taxa to sites and regions across north-eastern Australia to achieve an acceptable growth rate, it is equally important to consider what products can be produced. The potential products that could be produced from trees grown in north-eastern Australia include solid wood products, pulp and environmental services such as carbon capture or sequestration. Solid wood products such as sawlogs, poles or veneer logs require trees to have minimal borer defect. Lawson (2003a & b) considered borer attack to more than 15% of trees to be 'very high' and would preclude usage for solid wood products. Pook and Forrester (1984) indicated that changes in rainfall and particularly drought may influence insect-host interactions with; for example, stem borers attracted to trees suffering from drought. Most trials included in this project suffered drought and only a few taxa showed the potential for both good growth and low borer attack. These were CCV and *E. argophloia* in particular, with CCC*, E. cloeziana* and several ironbark species (*E. siderophloia* and *E. sideroxylon*) also showing potential in some regions. The long-term potential of these species for solid wood production is however still uncertain as it is expected that they will experience a significant change in climate within a single rotation. The taxa planted for solid wood production need to be able to cope with today's climate as well as that expected in 30 years time (Booth *et al.* 2010). The species listed above, are currently the best bets for solid wood production in north-eastern Australia for plantations established both now and in the future. In the coastal section of the Northern Tropical Coast and Tableland region *E. pellita* grew well and had low borer attack, similarly in the Northern Rivers region *E. dunnii* grew well and was not attacked by borers. Both of these taxa may therefore be suitable for solid wood production under optimal growing conditions.

Venn (2005) investigated the financial and economic potential of growing hardwood plantations for sawlog production. He found that where high growth rates are achievable (volume MAI of 20–25m^3/ha/year), long-rotation hardwood plantations were profitable if the land could be purchased for <$2300/ha. At intermediate or low growth rates (volume MAI of 15 m^3/ha/year or 5–10m^3/ha/year), hardwood sawlog plantations were only viable under optimistic assumptions or when carbon sequestration, salinity amelioration and other ecosystem service values were also considered. In the current study the growth of best taxa across most regions was in the low to intermediate growth rates with the high growth rates of Venn (2005) only being achieved by *E. pellita* in the North Tropical Coast and Tablelands region of Queensland and *E. dunnii* in the Northern Rivers region of New South Wales. Now that longer term growth data has been collected and secured; and with the introduction of new processing technologies such as the spindless lathe and a price is being set for carbon capture, the economics of growing hardwood plantations in north-eastern Australia needs to be re-visited.

In north-eastern Australia, the taxa that consistently had the highest estimated pulp productivities were CCV and *E. dunnii* (pulp productivity of over 30tonnes/ha/year); (Table 6, Appendix 3). Other taxa that showed potential in at least one region were: CCC, *E. cloeziana*, *E. globulus* subsp. *maidenii*, *E. grandis* and *E. longirostrata*. Gardner *et al.* (2007) reported that both *C. henryi* and CCC (taxa with very similar wood properties to CCV) had similar growth and pulp yields at age seven years to those of commercial pulp wood hybrid clones in trials in South Africa. Clark and Hicks (2003) also found that when 13 species were tested for Kraft pulp yield in Australia, the 12-year-old CCV (called *C. maculata*) from the Gympie region had a higher pulpwood quality index than 10-year-old plantation grown *E. globulus* from Tasmania. The potential of *Corymbia* species and hybrids and many of the taxa in this study for pulp wood production in Australia needs further study.

If trees are grown to sequester carbon then the most consistent species were CCV, *E. longirostrata* and *E. dunnii*. As indicated by Johnson and Coburn (2010), one tonne of carbon sequestered is equivalent to 3.67 tonnes of atmospheric CO_2. In this study CCV sequestered over 100 tonnes of CO_2 in four regions (Capricornia, Central Coast–Whitsunday, Northern Rivers and Wide Bay and Burnett – coastal region). Existing data on partitioning of biomass from a Queensland Government, Below Ground Carbon in CCV project, in the subtropics indicated that approximately 50% of the carbon in a tree is in the stem wood and the reminder is in bark, branches, leaves and roots (Bristow *et al.* unpub). For CCV this indicates that the CO_2 equivalents estimate presented under-estimate whole tree CO_2 sequestration by about 50% (the sequestration number reported in this study therefore could be doubled). Similar work needs to be undertaken for the other taxa identified in this study as having potential for north-eastern Australia.

Issues with the dataset and data analysis

In the current dataset, an imbalance in taxon representation across trials has in some circumstances biased the output from the analysis. For example in the Capricornia region, *E. longirostrata* is represented in only one trial whereas CCV is in all three trials. In the trial where both taxon occur (the wettest site) the growth is very similar; however, in the other two sites where overall trial performance was worse, CCV also had poorer growth but was one of the best taxa in each of these trials. Similarly, the breadth of the genetic base and therefore the provenance range varied by taxa. For example, CCV is represented by 12 provenances representing the full range of provenance growth potential from Presho (poor) through to Woondum (good) (Lee 2007) whereas *E. longirostrata* is represented by three provenances, with most of the trees from the best growth provenances identified by Warburton *et al.* (2009). Hence the potential performance of CCV, if the best provenances only were included, may be underestimated in this study. This leads to the recommendation below that a new suite of very large block, taxa trials should be established to assess the adaptation, growth, wood properties and carbon sequestration potential of the best available germplasm of the top performing taxa identified in this study.

Another issue not clear from the data is the susceptibility of *E. pellita* to cyclone damage. *Eucalyptus pellita* was one of the species planted in the three trials in the Central Coast – Whitsundays region. Following the category three cyclone Ului that hit this region in March 2010, most of the *E. pellita* in the trials was badly damaged (tipped over or snapped off between 0.3 m and 3.0 m). In the two experiments most affected by the cyclone, the taxa that best withstood cyclone damage (most trees standing and undamaged) were CCC, CCV and *E. cloeziana*. This may indicate that these are better species to deploy if wind or cyclone damage may be an issue for the plantation area. This is supported by anecdotal observations in the North Tropical Coast and Tablelands region where trials affected by category 5 cyclone Yasi in 2011 containing *E. pellita* had more than 90% of trees either snapped off or tipped over whereas an adjoining three year old CCV planting had fewer trees damaged.

Variation in wood properties across regions

The predicted wood density for those taxa sampled across multiple sites at age 10 years was fairly consistent for some taxon while others were quite reactive to location. For example, the density of CCC sampled across six regions ranged from 715 to 770kg/m^3 and CCV sampled across six regions ranged from 701 to 777kg/m^3. In contrast *E. dunnii* sampled across five regions ranged from 572 to 697kg/m^3 (Appendix 3). In this study CCC, CCV and *E. argophloia* had low levels of variation in wood density across regions.

Wood density did however vary across regions, with lower wood density generally being associated with faster growth and higher wood density associated with slower growth. This is consistent with the observation of Pinkard *et al.* (2010). Unfortunately the current study did not allow us to evaluate the ideas of Pinkard *et al.* (2010) that increased temperature led to reduction in wood density and decreased rainfall leads to an increase in wood density. Similarly in a study in the subtropics of KwaZulu-Natal, South Africa, Drew and Pammenter (2007), found that *E. grandis* × *E. camaldulensis* and *E. grandis* × *E. urophylla* hybrid clones that experienced comparatively higher levels of environmental stress had greater variation in wood properties than those in a less stressful environment, and hence different site-types should be managed accordingly. Therefore, it is recommended that a suite of trials of the best bet taxon (including any improved varieties from the tree improvement programs in north-eastern Australia) be established to gain a better understanding of the effect of site type on wood properties.

Estimated pulp productivity also varied between regions with some moderate growth regions e.g. CCV in the Wide Bay and Burnett – coastal and Central Coast – Whitsunday regions having higher predicted pulp productivity than the high growth regions (e.g. Northern Rivers; Appendix 3). The reason for this variation is unknown and needs further investigation. Schimleck *et al.* (2000) found that there was lower variation in wood properties for plantation grown *E. globulus* and *E. nitens* trees on better quality sites possibly due to better quality site allowing the trees to grow more steadily than poorer sites thus reducing wood variability. This finding was not supported in the current study in the tropics and subtropics where variability was higher on the better sites.

Refocussing the tree improvement programs in north-eastern Australia

Given the diversity of taxa that could become commercially relevant for developing a hardwood plantation forest industry in the tropics and subtropics, a necessary first step in directing resources into tree improvement is the screening of a wide range of taxa across many site types. Tree improvement is a long-term activity that requires consistency in funding and capability maintenance in order to generate improved populations for industry utilisation. The considerable expense involved in developing superior germplasm should therefore be guided by results from field trials and take into account predicted future market requirements. Extensive breeding programs can be designed to ensure a modest level of improvement for developing industries so that populations are available as industries move into new areas and new climatic situations develop. The empirical data collected during this study provides direct evidence on taxon performance under a range of climatic regimes and therefore provides an indication as to which taxa may become more important as future climate change takes effect.

To date, the vast majority of studies of climate change and forests have focused on impact, although there is a growing awareness of the need to build adaptation into forest management (Seppala *et al*. 2009). The Allen Consulting Group (2005) further stress that plantation forestry needs a high adaptive capacity and because of the long planning horizons, it needs to take climate change into account through better selection of species and management planning to reduce risk. Based on these and other studies, Pinkard *et al*. (2010) suggested the need to select taxa with greater resilience to increased transpiration, water stress, vapour deficit and heatwaves caused by climate change. Battaglia *et al.* (2009) also highlighted that breeding for future climates needs to address tolerance and resistance to pests and diseases assuming that the incidence, distribution and activity of these may alter with climate.

This study, while not being able to directly investigate the impact of increased atmospheric CO_2 on tree growth, has been able identify taxa that are most suited to the regions of north-eastern Australia. The taxon that appears most adaptive and which can produce the widest product range (based on growth, survival resistance to borers, density CO_2 sequestrated and pulp productivity) is CCV. Another taxon with good potential in this region based on other studies is the *Corymbia* hybrid (Lee 2007; Lee *et al.*, 2009). The relative poor performance of this later taxon in the current study is not unexpected as only a few *Corymbia* hybrid families were planted in the taxa trials that met the age profile prescribed by this study. As discussed in Lee *et al.* (2009) the performance of *Corymbia* hybrid families ranges from poor through to outstanding and only the better performing of these hybrids would be commercialised.

Other species that performed well in particular regions and should have active tree breeding programs based on their adaptability and projected industry demand include:
- *E. longirostrata* in the Capricornia and Wide Bay and Burnett – coastal region;
- *E. argophloia* for the Capricornia and low rainfall regions of north-eastern Australia; and
- *E. cloeziana* for the Central Coast – Whitsunday region and possibly the Wide Bay and Burnett – coastal region - based on its good growth in this study and excellent wood properties. (Bailleres *et al.* 2008).

Eucalyptus dunnii performed well in the single trial in the Northern Rivers. It is considered that the existing tree improvement work involving *E. dunnii* seed orchards and progeny trials in New South Wales (Smith and Henson 2007) should cater for future industry requirements without the need for further expansion of existing tree breeding programs.

Volume equations

During this project volume equations, which consist of a form factor applied to BA $\times$ HT, were developed for a limited HT and DBH range for eight taxa with potential for plantation forestry in north-eastern Australia. The limited spread of the raw data limits the confident extrapolation of the volume equations outside the range of data used to compile the equations. The under bark form factors had values of between 0.2829 and 0.3454; however, the two extreme values were for two of the taxon with fewer sample trees (11 and 21). If these two taxon were ignored the range was from 0.2980 to 0.3267. Stem volumes (and therefore volume MAI) calculated for this report used the volume of a cone which has a 'form factor' of 0.3333. Therefore, based on the data for those taxa with more than 40 sample trees, it is likely that the volume MAI has been overestimated by up to 12%. There is an ongoing need to collect more sample tree data to improve volume estimates. Future collection of sample tree data should be particularly targeted towards larger and older trees as they become available.

Productivity drivers of plantation growth in north-eastern Australia

Given the extreme variation in the environments sampled from the North Tropical Coast and Tablelands to the Northern Rivers in NSW, a model using environmental drivers of plantation growth which accounts for over 52% of the variation in the predicted taxa performance across the environments sampled is encouraging (Appendix 6). This result needs further development and refinement via inclusion of additional data (both taxa trial and environmental) as it becomes available. Further exploration of the links between these empirical models and process based models is a recommended area of further research.

Potential of the study to guide process based model development for plantations in north-eastern Australia

Medlyn *et al.* (2011) point out some of the many knowledge gaps for forestry in Australia, including: the need for credible predictions of the impacts of climate change for most of the Australian forest estate, climate projections, ecosystem scale data, process understanding and research integration and modelling. They also point out that researchers around the world use data sets to develop and test ideas about controls on forest productivity, however this critical data is not available for large parts of Australia. This project has partially addressed this issue by providing for the first time baseline data on taxa productivity in north-eastern Australia at a plantation estate level. The data can be used to truth and calibrate growth models (*e.g*. Cabala and 3PG) for taxa in north-eastern Australia. As pointed out by Booth (2005) and Battaglia *et al.* (2009) a large number of plots (or trials in the case of this study) will need to be measured to provide reasonable accuracy for predicting plantation estate yield variation. The results from the 38 taxa trials provided here is the first step to addressing this issue.

Nutritional impacts on growth and performance

Information gained from trials on Ferrosol soils in the Wide Bay Burnett – inland region was that 30kg/ha P as MAP and 10kg/ha B at establishment was required to optimise growth, health and form of CCV. On of the brown Ferrosol soils in this region, 75kg/ha K was also required for optimum growth. Increasing foliar B status from deficient (9–12 µg/g YFEL B) to sufficient B status (22–24 µg/g YFEL B) lowers CCV and CT × CCV susceptibility to borers and should therefore increase the ability of these taxa to cope with the some of the predicted stresses resulting from climate change such as drought, increased temperatures and evaporation. It is therefore recommended that the foliar B concentrations of plantation be monitored and maintained in the adequate range to minimise the impact of outbreaks of stem borer pests particularly *Phorocantha solida*.

In the Tropical Coast and Tablelands region, results from trials included in this study show that 60 kg/ha P at planting improved early tree growth of *E. pellita* on an ex-pasture, Kurosol soil and delaying P application for six months after planting was not detrimental to tree growth on this marginally P deficient site.

This study has shown that addressing nutrient deficiencies of tree crops growing on the various soils in Queensland improves tree growth, health and quality of plantations as well as potential carbon capture.

RECOMENDATIONS

1. This study has brought to attention some of the deficiencies in the 38 taxa trials assessed such as the lack of adequate isolation in some trials. In order to be able to collect relevant, reliable long term data in the future, it is proposed that six replicated large block (100 to 150-tree blocks) trials be established in the Central Coast – Whitsundays, both the Wide Bay Burnett coastal and inland regions as well as the Northern Rivers region. These trials should include only the better performing taxa to allow reliable long-term growth data capture and provide for non-destructive and destructive sampling to allow investigation of the impact of climate change on the wood properties. Ideally these trials should include plots of at least three different stockings for each taxon so the impact of stocking rate on growth and wood properties can be assessed.

2. Further analysis of the climatic and edaphic drivers of growth is required to better identify the taxa that will be suitable under the range of climate change scenarios. The short timeline available for completing this project, where the major focus was on data collection and collation, limited the project partners ability to undertake a comprehensive analysis of the data investigating the drivers of growth for the top performing taxa.

3. While the empirical data from the taxa trials has clarified how some taxon respond to various environmental drivers, the taxon and spatial coverage are both limited. The understanding gained from extensive field trial data can be made more widely applicable and useful through interpreting it within a process-based framework. Physiological models not only allow this broader interpretation but permit changing climate to be considered through a scenario testing approach. Currently, physiological models have been parameterised for very few taxa due to cost and complexity. By bringing together the strengths of the two modelling approaches and applying them in a spatially explicit way, tools developed in this project will contribute to an understanding of risk, integration of plantations into primary production systems and thus increased business confidence. It is recommended that further research is undertaken to integrate empirical data and process based models in order to allow communities to respond more effectively and rapidly to climate change.

4. Taxon recommended for inclusion in tree improvement programs for north-eastern Australia (based on growth, adaptation and pest and disease resistance / tolerance) from this study in decreasing priority order are CCV, *Corymbia* hybrids, *E. cloeziana E. longirostrata and E. argophloia*.

5. Further work is needed on identifying and overcoming nutritional impediments to growth and reducing pest and disease susceptibility of trees by manipulating tree nutrient status.

6. A suite of taxa trials in the Central Highlands Coalfield region and young trials in other regions that did not meet the minimum age requirement for this a project were not measured during this project. It is important that data from these trials be captured when they reach a similar age to those trials analysed here to help identify the best taxon for these regions and improve the understanding of climatic and edaphic drivers of growth. Widening the scope of this study will also improve plantation grower confidence about some of the taxon showing promise in this study.

7. In north-eastern Australia very little is known about the quality and suitability of the plantation or agroforestry-system grown wood from some species. Testing of the wood properties of the better performing taxa grown to produce solid wood, veneers and pulp is required. Evaluation of non-timber products supplied by plantations (energy source, carbon sequestered, environmental values, etc) is also required.

This is expensive and currently resources are not available to do this at the scale required.

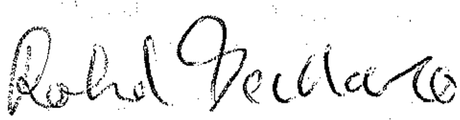
8. This study has highlighted the need to collect additional sample tree data for construction of volume equations, with particular emphasis on larger and older trees as they become available.

9. Now that data on the potential to produce wood based products, risks and growth rates is available (based on the data from this project), it is important that economic modeling of the hardwood plantations be undertaken for north eastern Australia in order to instill confidence in future investment in the industry.

10. Given the potential benefits that can arise from the use of fertilisers in establishing and growing hardwood plantations, investigations into managing the nutritional status of hardwood plantations needs to be continued and the benefits promoted to growers.

CERTIFICATION

I certify this as being an accurate statement of the matters specified in the Final Report.



Professor Roland De Marco
Pro Vice-Chancellor (Research)
31 May 2011

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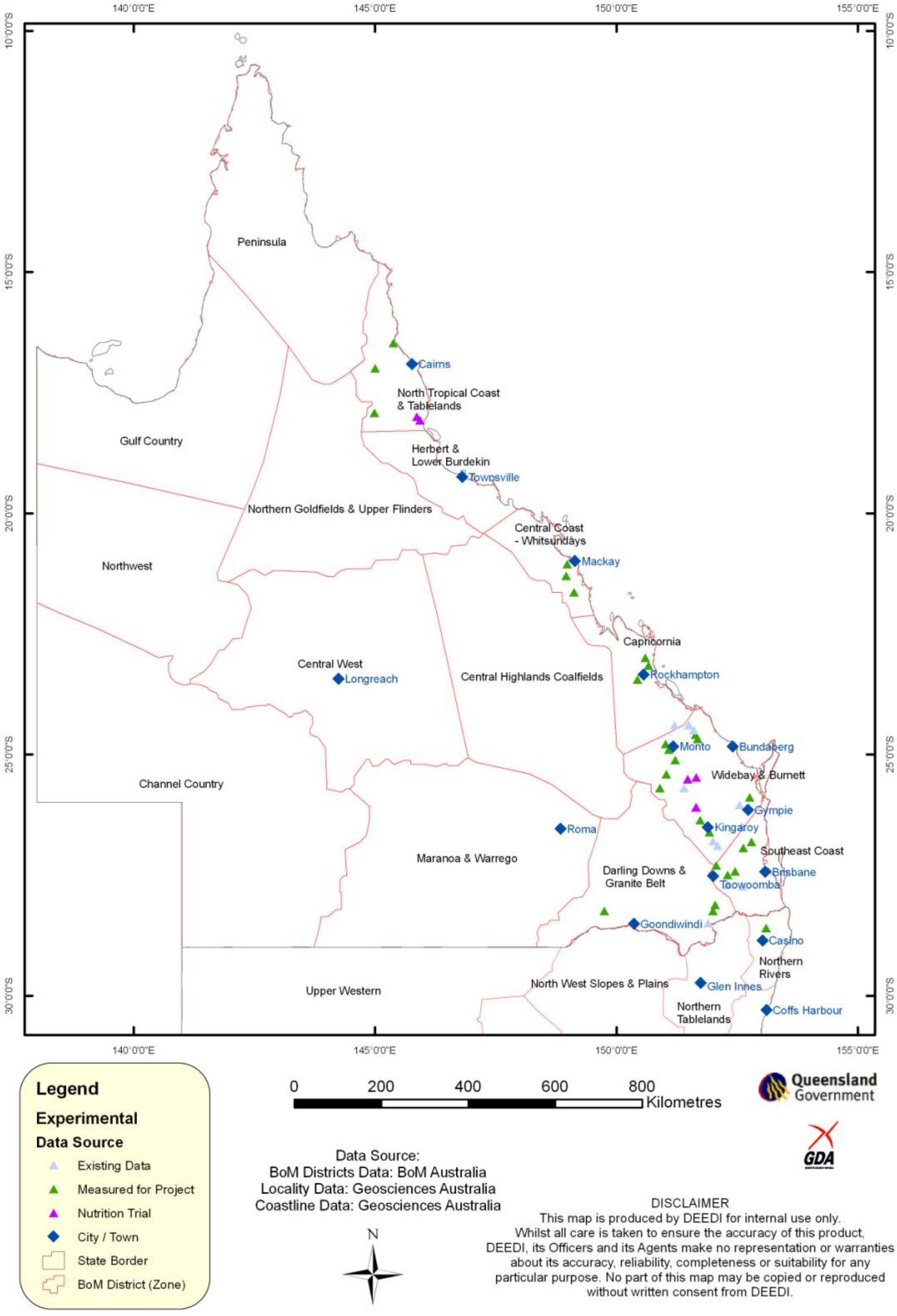
Map 1 - Bureau of Meteorology Forecast Regions and locations of trials assessed for this study



Appendix 1 - Growth at age 10 years for each taxon in taxa comparison field trials

Taxon	BOM region	Volume MAI (m^3)		Diameter at breast height (cm)		Total height (m)		Basal area (m^2)	
		Estimate	StdE	Estimate	StdE	Estimate	StdE	Estimate	StdE
Acacia aulacocarpa	Wide Bay and Burnett – inland	0.46	2.31	5.05	4.20	3.94	3.30	0.64	3.62
	Capricornia	1.05	2.60	0.31	4.44	6.53	3.56	2.20	4.07
	Darling Downs and Granite Belt	0.95	1.83	1.72	3.13	3.95	2.51	1.73	2.87
Acacia deanei	Wide Bay and Burnett – inland	1.01	2.57	3.57	4.74	2.95	3.68	2.02	4.02
Acacia glaucocarpa	Wide Bay and Burnett – inland	1.01	2.57	3.57	4.74	2.95	3.68	2.02	4.02
	Capricornia	4.23	2.49	15.07	4.20	11.70	3.40	9.81	3.90
	Darling Downs and Granite Belt	1.89	2.33	14.92	4.11	9.93	3.28	5.01	3.66
	Southeast Coast	2.61	1.78	15.16	2.94	10.57	2.40	6.71	2.80
	Wide Bay and Burnett – coastal	5.67	2.17	16.78	3.87	12.26	3.07	9.96	3.39
Acacia mangium	Wide Bay and Burnett – inland	0.44	2.31	0.77	4.20	1.23	3.30	0.50	3.62
	Capricornia	1.05	2.60	0.31	4.44	1.48	3.56	2.20	4.07
	Darling Downs and Granite Belt	0.95	1.83	1.72	3.13	1.97	2.51	1.73	2.87
Acacia melanoxylon	Wide Bay and Burnett – inland	0.43	2.17	0.76	3.88	1.25	3.08	0.44	3.39
	Capricornia	1.16	2.46	0.33	4.13	1.52	3.35	2.33	3.86
	Darling Downs and Granite Belt	0.91	1.73	1.68	2.91	3.28	2.36	1.66	2.72
Araucaria cunninghamii	Wide Bay and Burnett – inland	0.71	1.28	8.57	2.09	6.24	1.71	2.73	2.01
Brachychiton rupestris	Wide Bay and Burnett – inland	0.44	2.31	0.77	4.20	2.77	3.30	0.50	3.62
	Capricornia	1.05	2.60	0.31	4.44	3.28	3.56	2.20	4.07
	Darling Downs and Granite Belt	0.95	1.83	1.72	3.13	2.11	2.51	1.73	2.87
Callistemon salignus	Wide Bay and Burnett – inland	0.44	2.31	2.23	4.20	2.97	3.30	0.52	3.62
	Capricornia	1.05	2.60	0.31	4.44	4.25	3.56	2.20	4.07
	Darling Downs and Granite Belt	0.95	1.83	1.72	3.13	3.26	2.51	1.73	2.87
Callistemon viminalis	Wide Bay and Burnett–inland	0.44	2.31	2.36	4.20	2.73	3.30	0.56	3.62
	Capricornia	1.05	2.60	0.31	4.44	2.82	3.56	2.20	4.07
	Darling Downs and Granite Belt	0.95	1.83	1.72	3.13	2.57	2.51	1.73	2.87
Casuarina cristata	Wide Bay and Burnett – inland	0.47	2.31	4.51	4.20	4.97	3.30	0.61	3.62
	Capricornia	2.58	2.60	10.59	4.44	10.96	3.56	6.43	4.07
	Darling Downs and Granite Belt	0.95	1.83	1.72	3.13	3.98	2.51	1.73	2.87
Casuarina cunninghamiana	Wide Bay and Burnett – inland	1.07	2.17	10.21	3.88	8.79	3.08	2.61	3.39
	Capricornia	2.68	2.46	11.09	4.13	10.74	3.35	6.76	3.86
	Darling Downs and Granite Belt	1.69	1.73	7.30	2.91	5.70	2.36	4.07	2.72
CT × CCV[2]	Wide Bay and Burnett– inland	3.05	2.17	15.22	3.92	11.19	3.09	6.68	3.40
Corymbia citriodora subsp. *citriodora*	Wide Bay and Burnett– inland	2.64	1.13	13.45	1.76	12.49	1.47	6.10	1.77
	Central Coast – Whitsunday	9.88	1.85	15.64	2.82	16.67	2.37	15.52	2.91
	Capricornia	4.85	2.60	14.84	4.44	14.76	3.56	10.58	4.07

[2] CT × CCV = *Corymbia torelliana* × *Corymbia citriodora* subsp. *variegata*

Taxon	BOM region	Volume MAI (m^3)		Diameter at breast height (cm)		Total height (m)		Basal area (m^2)	
		Estimate	StdE	Estimate	StdE	Estimate	StdE	Estimate	StdE
Corymbia citriodora subsp. *citriodora*	Darling Downs and Granite Belt	2.26	1.83	11.59	3.13	10.74	2.51	5.44	2.87
	Far North Queensland	5.20	2.04	11.35	3.18	13.11	2.66	11.52	3.21
	Southeast Coast	1.72	1.74	10.38	2.86	9.94	2.34	3.75	2.74
	Wide Bay and Burnett – coastal	5.05	1.30	12.71	2.10	13.99	1.73	8.62	2.04
Corymbia citriodora subsp. *variegata*	Wide Bay and Burnett– inland	3.50	1.05	14.93	1.58	13.92	1.34	7.26	1.65
	Central Coast – Whitsunday	9.34	2.09	14.61	3.35	17.49	2.76	13.14	3.28
	Capricornia	8.49	1.82	15.50	2.75	17.19	2.32	14.17	2.86
	Darling Downs and Granite Belt	2.14	1.32	10.55	2.03	9.42	1.71	4.53	2.08
	North Tropical Coast and Tablelands	6.69	2.50	13.12	4.17	14.63	3.40	13.59	3.93
	Northern Rivers	10.28	3.05	14.55	4.52	16.31	3.86	16.98	4.80
	Southeast Coast	3.41	1.35	13.25	1.98	12.59	1.70	6.81	2.12
	Wide Bay and Burnett – coastal	7.91	1.08	15.81	1.61	16.70	1.37	12.09	1.70
Corymbia henryi	Wide Bay and Burnett – inland	3.08	1.26	15.33	2.04	13.40	1.68	6.83	1.97
	Darling Downs and Granite Belt	1.45	2.23	11.80	3.93	10.27	3.13	3.46	3.50
	Southeast Coast	3.94	2.27	17.21	3.93	13.63	3.17	7.41	3.57
	Wide Bay and Burnett – coastal	6.04	1.63	15.53	2.78	14.34	2.24	10.52	2.55
Corymbia nesophila	North Tropical Coast and Tablelands	2.97	2.55	9.51	4.28	9.48	3.47	7.48	4.00
Corymbia torelliana	Wide Bay and Burnett – inland	0.44	2.31	0.77	4.20	1.23	3.30	0.50	3.62
	Capricornia	2.20	2.60	11.66	4.44	8.28	3.56	7.08	4.07
	Darling Downs and Granite Belt	1.01	1.83	5.52	3.13	3.88	2.51	2.13	2.87
EG × EC[3]	Wide Bay and Burnett – inland	1.27	1.18	10.26	1.89	7.90	1.56	3.40	1.86
	Capricornia	1.63	2.86	11.97	4.97	9.66	3.94	4.10	4.46
	North Tropical Coast and Tablelands	5.32	2.55	10.73	4.28	12.62	3.47	11.96	4.00
	Northern Rivers	0.56	3.12	9.79	4.71	8.80	3.98	1.37	4.91
	Southeast Coast	2.09	2.33	13.54	4.08	10.53	3.26	4.69	3.66
	Wide Bay and Burnett – coastal	3.31	1.23	13.59	1.96	12.69	1.62	5.09	1.94
EG × EP[4]	Central Coast – Whitsunday	4.52	2.62	17.25	4.47	13.54	3.60	7.87	4.11
	Capricornia	2.21	1.99	14.22	3.13	10.25	2.60	5.90	3.12
	North Tropical Coast and Tablelands	2.41	2.55	12.53	4.28	9.17	3.47	5.94	4.00
	Wide Bay and Burnett – coastal	5.84	1.45	13.75	2.43	11.68	1.97	9.49	2.28
EG × ER[5]	Wide Bay and Burnett – inland	3.27	1.30	16.02	2.14	10.63	1.75	7.59	2.04
	Capricornia	1.41	2.86	16.97	4.97	11.10	3.94	3.42	4.46
	Darling Downs and Granite Belt	1.41	2.39	8.40	4.25	6.06	3.37	2.93	3.74
	Southeast Coast	1.85	2.26	9.73	3.94	7.37	3.16	2.74	3.55
	Wide Bay and Burnett – Coastal	4.12	1.68	10.57	2.89	7.76	2.32	7.11	2.63
EG × ET[6]	Wide Bay and Burnett – inland	1.46	1.11	11.28	1.74	8.48	1.45	3.82	1.75
	Central Coast – Whitsunday	2.57	2.62	9.47	4.47	10.46	3.60	3.52	4.11
	Capricornia	2.49	2.86	11.45	4.97	10.19	3.94	6.73	4.46
	Darling Downs and Granite Belt	1.69	1.56	11.12	2.54	8.34	2.08	4.73	2.45

[3] EG × EC = *E. grandis ×E. camaldulensis*
[4] EG × EP = *E. grandis ×E. pellita*
[5] EG × ER = *E. grandis ×E. resinifera*
[6] EG x× ET = *E. grandis ×E . tereticornis*

Taxon	BOM region	Volume MAI (m^3)		Diameter at breast height (cm)		Total height (m)		Basal area (m^2)	
		Estimate	StdE	Estimate	StdE	Estimate	StdE	Estimate	StdE
EG × ET	North Tropical Coast and Tablelands	2.03	2.90	0.66	5.03	2.45	4.00	4.10	4.54
	Northern Rivers	1.85	3.12	9.51	4.71	9.93	3.98	4.28	4.91
	Southeast Coast	2.12	1.79	12.50	2.97	9.71	2.42	4.76	2.81
	Wide Bay and Burnett – coastal	1.02	1.44	10.65	2.41	8.32	1.96	2.49	2.27
EG × EU[7]	Wide Bay and Burnett – inland	1.36	1.28	11.68	2.11	7.95	1.73	3.36	2.02
	Central Coast – Whitsunday	5.78	2.62	20.56	4.47	16.24	3.60	9.92	4.11
	Capricornia	1.82	2.04	13.34	3.23	9.97	2.68	4.73	3.20
	Darling Downs and Granite Belt	2.54	1.81	9.09	3.07	6.04	2.47	5.77	2.84
	North Tropical Coast and Tablelands	2.12	2.50	8.71	4.17	7.70	3.40	5.02	3.93
	Northern Rivers	5.15	3.12	14.08	4.71	12.28	3.98	10.23	4.91
	Southeast Coast	1.75	1.59	13.10	2.54	8.84	2.10	3.27	2.50
	Wide Bay and Burnett – coastal	4.60	1.23	16.29	1.93	12.88	1.61	8.18	1.93
ES × ET[8]	Wide Bay and Burnett – coastal	5.66	2.33	19.33	4.21	16.76	3.31	9.52	3.65
ET × EP[9]	Capricornia	3.30	2.86	13.64	4.97	9.95	3.94	8.84	4.46
EU × EC[10]	Wide Bay and Burnett – inland	1.82	2.60	14.33	4.77	10.10	3.71	4.59	4.06
	Central Coast – Whitsunday	3.86	2.62	18.04	4.47	13.20	3.60	7.02	4.11
	North Tropical Coast and Tablelands	2.03	2.55	6.37	4.28	5.73	3.47	4.28	4.00
	Wide Bay and Burnett – coastal	3.65	1.72	19.51	2.98	16.05	2.38	6.16	2.69
EU × ET[11]	Wide Bay and Burnett – inland	1.06	2.60	14.25	4.77	11.31	3.71	2.40	4.06
	Central Coast – Whitsunday	6.26	2.62	16.68	4.47	14.81	3.60	11.29	4.11
	Capricornia	1.06	2.86	12.54	4.97	8.95	3.94	2.87	4.46
	Wide Bay and Burnett – coastal	4.93	1.68	17.74	2.89	14.36	2.32	8.74	2.63
Elaeocarpus grandis	North Tropical Caost and Tablelands	7.92	2.72	14.32	4.48	11.39	3.67	14.16	4.28
Eucalyptus acmenoides	Wide Bay and Burnett – inland	0.41	2.07	5.48	3.69	3.40	2.94	1.10	3.24
	Wide Bay and Burnett – coastal	2.27	1.64	12.29	2.81	9.23	2.26	7.83	2.57
Eucalyptus argophloia	Wide Bay and Burnett – inland	4.49	1.09	16.65	1.67	13.63	1.41	9.96	1.71
	Capricornia	8.82	2.14	18.34	3.47	16.81	2.83	16.31	3.35
	Darling Downs and Granite Belt	3.54	1.33	14.26	2.04	11.43	1.72	8.79	2.09
	Southeast Coast	4.94	1.54	16.16	2.43	13.28	2.02	10.67	2.43
	Wide Bay and Burnett – coastal	6.30	2.17	16.55	3.87	15.45	3.07	11.36	3.39
Eucalyptus camaldulensis	Wide Bay and Burnett – inland	2.45	1.37	13.93	2.28	10.26	1.86	7.10	2.15
	Capricornia	3.91	2.08	13.79	3.34	11.82	2.75	9.85	3.27
	Darling Downs and Granite Belt	1.42	1.40	7.41	2.19	6.08	1.82	3.62	2.20
	North Tropical Coast and Tablelands	3.68	2.02	9.87	3.14	9.96	2.64	9.71	3.19
	Wide Bay and Burnett – coastal	2.97	1.70	11.44	2.93	11.46	2.35	6.29	2.66
Eucalyptus cambageana	Wide Bay and Burnett – inland	2.64	2.10	13.52	3.75	12.19	2.99	5.99	3.30

[7] EG × EU = *E. grandis* × *E. urophylla*
[8] ES × ET = *E. saligna* × *E. tereticornis*
[9] ET × EP = *E. tereticornis* × *E. pellita*
[10] EU × EC = *E. urophylla* × *E. camaldulensis*
[11] EU × ET = *E. urophylla* × *E. tereticornis*

Taxon	BOM region	Volume MAI (m^3)		Diameter at breast height (cm)		Total height (m)		Basal area (m^2)	
		Estimate	**StdE**	**Estimate**	**StdE**	**Estimate**	**StdE**	**Estimate**	**StdE**
Eucalyptus cambageana	Darling Downs and Granite Belt	3.99	2.23	14.52	3.93	12.09	3.13	10.05	3.50
Eucalyptus cloeziana	Wide Bay and Burnett – inland	2.73	1.13	13.27	1.77	9.60	1.48	6.25	1.78
	Central Coast – Whitsunday	10.31	1.80	18.09	2.71	17.17	2.30	15.86	2.84
	Capricornia	1.48	2.60	5.39	4.44	6.89	3.56	3.52	4.07
	Darling Downs and Granite Belt	2.80	1.56	11.07	2.54	8.80	2.09	5.43	2.45
	Far North Queensland	3.28	2.04	12.39	3.18	9.95	2.66	8.42	3.21
	Southeast Coast	2.34	2.21	13.14	3.83	9.30	3.08	5.08	3.47
	Wide Bay and Burnett – coastal	7.39	1.17	18.80	1.80	16.16	1.51	12.71	1.83
Eucalyptus crebra	Wide Bay and Burnett – inland	2.25	2.31	13.75	4.20	9.14	3.30	7.19	3.62
	Capricornia	2.66	2.60	12.13	4.44	9.15	3.56	8.01	4.07
	Darling Downs and Granite Belt	1.24	1.83	6.00	3.13	4.61	2.51	3.21	2.87
	Southeast Coast	2.56	2.21	13.07	3.83	9.27	3.08	6.42	3.47
Eucalyptus dunnii	Wide Bay and Burnett – inland	2.20	1.09	8.97	1.69	6.99	1.42	4.41	1.72
	Central Coast – Whitsunday	9.97	1.85	16.53	2.83	17.15	2.37	14.76	2.91
	Capricornia	2.04	1.82	12.53	2.75	10.51	2.32	4.44	2.86
	Darling Downs and Granite Belt	4.02	1.33	14.28	2.05	10.77	1.72	8.67	2.10
	Northern Rivers	24.39	3.12	19.62	4.71	19.74	3.98	33.72	4.91
	Southeast Coast	5.28	1.56	16.18	2.46	12.69	2.05	9.88	2.45
	Wide Bay and Burnett – coastal	7.72	1.19	17.91	1.85	15.66	1.54	12.34	1.87
Eucalyptus globulus subsp. *bicostata*	Darling Downs and Granite Belt	1.75	2.38	14.84	4.24	9.38	3.36	5.18	3.73
	Southeast Coast	1.16	2.23	5.80	3.86	4.34	3.11	2.13	3.50
Eucalyptus globulus subsp. globulus	Darling Downs and Granite Belt	2.35	2.38	15.10	4.24	11.60	3.36	5.54	3.73
Eucalyptus globulus subsp. *maidenii*	Wide Bay and Burnett – inland	1.83	1.18	11.07	1.89	8.02	1.56	4.41	1.86
	Darling Downs and Granite Belt	4.41	1.52	14.90	2.45	10.49	2.02	9.78	2.39
	Northern Rivers	12.30	3.12	16.59	4.71	16.46	3.98	20.74	4.91
	Southeast Coast	2.35	1.56	13.03	2.47	10.11	2.05	5.41	2.46
	Wide Bay and Burnett – coastal	1.80	1.43	15.34	2.37	11.16	1.93	5.94	2.24
Eucalyptus grandis	Wide Bay and Burnett – inland	1.53	2.07	10.91	3.69	9.14	2.94	3.39	3.24
	Central Coast – Whitsunday	10.53	2.07	14.26	3.31	13.95	2.73	15.89	3.25
	Capricornia	1.56	1.91	12.84	2.93	9.89	2.47	4.11	3.00
	Darling Downs and Granite Belt	4.09	1.72	13.47	2.88	11.11	2.35	8.72	2.71
	Northern Rivers	6.08	3.02	13.63	4.46	14.90	3.82	10.78	4.76
	Southeast Coast	1.90	2.17	13.11	3.73	9.93	3.01	3.77	3.41
	Wide Bay and Burnett – coastal	7.60	1.12	16.09	1.69	14.41	1.44	11.11	1.77
Eucalyptus longirostrata	Wide Bay and Burnett – inland	3.56	1.13	16.06	1.76	12.95	1.47	7.93	1.77
	Capricornia	8.83	2.49	14.94	4.20	15.19	3.40	14.83	3.90
	Darling Downs and Granite Belt	4.62	2.23	15.79	3.93	12.64	3.13	11.28	3.50
	Southeast Coast	5.35	1.37	16.50	2.03	13.69	1.73	10.73	2.15
	Wide Bay and Burnett – Coastal	10.59	1.45	18.21	2.41	17.55	1.96	15.82	2.27
Eucalyptus macarthurii	Wide Bay and Burnett – inland	0.23	2.17	9.88	3.92	3.76	3.09	0.87	3.40
	Darling Downs and Granite Belt	1.12	2.23	1.28	3.93	1.66	3.13	2.01	3.50
	Southeast Coast	0.00	2.33	2.40	4.08	0.17	3.25	0.00	3.65
Eucalyptus melliodora	Wide Bay and Burnett – inland	2.36	2.31	13.76	4.20	9.78	3.30	6.95	3.62
	Capricornia	4.49	2.60	16.96	4.44	11.48	3.56	12.54	4.07

Taxon	BOM region	Volume MAI (m^3)		Diameter at breast height (cm)		Total height (m)		Basal area (m^2)	
		Estimate	StdE	Estimate	StdE	Estimate	StdE	Estimate	StdE
Eucalyptus melliodora	Darling Downs and Granite Belt	2.28	1.83	9.35	3.13	6.53	2.51	5.98	2.87
Eucalyptus microcorys	Wide Bay and Burnett – inland	1.34	2.31	11.14	4.20	8.26	3.30	4.01	3.62
	Capricornia	1.41	2.60	7.60	4.44	5.09	3.56	3.41	4.07
	Darling Downs and Granite Belt	0.95	1.83	1.72	3.13	2.95	2.51	1.73	2.87
	Wide Bay and Burnett – coastal	5.42	2.34	18.03	4.23	13.98	3.33	11.53	3.66
Eucalyptus moluccana	Wide Bay and Burnett – inland	3.53	1.25	14.77	2.04	12.18	1.68	8.33	1.97
	Capricornia	7.58	2.46	18.77	4.13	16.39	3.35	15.04	3.86
	Darling Downs and Granite Belt	1.79	1.40	9.07	2.19	7.66	1.82	4.59	2.20
	Far North Queensland	3.14	2.90	10.18	5.03	10.52	4.00	7.87	4.54
	Southeast Coast	3.67	1.73	15.37	2.84	11.98	2.33	8.59	2.73
Eucalyptus pellita	Wide Bay and Burnett – inland	1.38	2.31	12.50	4.20	6.95	3.30	4.47	3.62
	Central Coast – Whitsunday	8.83	1.98	16.39	3.11	16.92	2.59	14.42	3.12
	Capricornia	2.98	1.78	11.74	2.66	8.74	2.26	8.08	2.80
	Darling Downs and Granite Belt	1.19	1.83	6.08	3.13	4.31	2.51	2.81	2.87
	North Tropical Caost and Tablelands	29.98	2.72	18.74	4.48	20.31	3.67	34.50	4.28
	Southeast Coast	1.90	2.33	15.11	4.08	10.05	3.26	4.38	3.66
	Wide Bay and Burnett – coastal	6.17	1.67	17.41	2.88	13.72	2.31	11.94	2.62
Eucalyptus pilularis	Wide Bay and Burnett – inland	0.66	1.57	5.00	2.70	3.68	2.18	1.34	2.47
	Darling Downs and Granite Belt	3.37	2.26	15.20	3.90	9.44	3.15	8.72	3.55
	Wide Bay and Burnett – coastal	2.97	1.33	12.34	2.17	10.20	1.78	6.34	2.09
Eucalyptus raveretiana	Wide Bay and Burnett – inland	1.06	1.68	13.44	2.92	8.06	2.34	4.17	2.63
	Capricornia	2.23	2.60	11.71	4.44	8.35	3.56	6.79	4.07
	Darling Downs and Granite Belt	1.15	1.83	5.90	3.13	4.28	2.51	2.85	2.87
Eucalyptus reducta	Wide Bay and Burnett – Coastal	0.00	2.21	10.63	3.96	7.91	3.13	3.46	3.46
Eucalyptus resinifera	Wide Bay and Burnett – inland	1.28	1.64	11.36	2.85	7.52	2.28	3.97	2.57
	Capricornia	1.10	2.60	4.44	4.44	4.16	3.56	2.46	4.07
	Darling Downs and Granite Belt	1.15	1.83	4.04	3.13	3.55	2.51	2.59	2.87
	Wide Bay and Burnett – coastal	5.10	1.45	16.57	2.43	11.70	1.97	11.68	2.28
Eucalyptus robusta	Wide Bay and Burnett – inland	0.48	2.31	10.00	4.20	3.93	3.30	0.91	3.62
	Capricornia	1.05	2.60	0.31	4.44	1.48	3.56	2.20	4.07
	Darling Downs and Granite Belt	1.10	1.83	4.07	3.13	3.37	2.51	2.54	2.87
	Wide Bay and Burnett – coastal	3.61	2.17	8.45	3.87	7.45	3.07	6.08	3.39
Eucalyptus siderophloia	Wide Bay and Burnett – inland	2.65	1.39	14.29	2.34	9.98	1.90	7.34	2.19
	Southeast Coast	2.34	2.33	13.00	4.08	9.23	3.25	7.43	3.65
Eucalyptus sideroxylon	Wide Bay and Burnett – inland	2.52	2.17	13.50	3.92	8.23	3.09	7.51	3.40
	Darling Downs and Granite Belt	4.14	2.23	16.17	3.93	10.96	3.13	11.34	3.50
	Southeast Coast	4.20	2.21	17.37	3.83	11.38	3.08	10.94	3.47
Eucalyptus sphaerocarpa	Wide Bay and Burnett – coastal	1.83	1.68	11.16	2.89	8.81	2.32	7.32	2.63
Eucalyptus tereticornis	Wide Bay and Burnett – inland	2.33	1.27	12.77	2.08	10.10	1.71	6.33	2.00
	Central Coast – Whitsunday	3.92	2.62	10.46	4.47	9.67	3.60	8.00	4.11
	Capricornia	3.96	1.97	13.54	3.11	11.89	2.59	9.61	3.11

Taxon	BOM region	Volume MAI (m^3)		Diameter at breast height (cm)		Total height (m)		Basal area (m^2)	
		Estimate	StdE	Estimate	StdE	Estimate	StdE	Estimate	StdE
Eucalyptus tereticornis	Darling Downs and Granite Belt	1.00	1.35	7.45	2.08	6.44	1.74	2.88	2.12
	North Tropical Coast and Tablelands	3.57	2.06	10.10	3.22	9.72	2.69	9.46	3.23
	Southeast Coast	1.47	1.37	11.06	2.03	8.37	1.73	4.31	2.15
	Wide Bay and Burnett – coastal	2.28	1.43	10.72	2.37	10.77	1.93	5.25	2.24
Eucalyptus tetrodonta	Wide Bay and Burnett – inalnd	1.05	2.07	3.56	3.70	2.93	2.94	2.10	3.25
	North Tropical Coast and Tablelands	2.41	2.14	9.99	3.42	7.65	2.83	5.78	3.37
Eucalyptus urophylla	Wide Bay and Burnett – coastal	0.00	1.44	8.30	2.39	5.71	1.95	0.72	2.26
Flindersia australis	Wide Bay and Burnett – inland	0.44	2.31	0.77	4.20	2.08	3.30	0.50	3.62
	Capricornia	1.05	2.60	0.31	4.44	2.98	3.56	2.20	4.07
	Darling Downs and Granite Belt	0.95	1.83	1.72	3.13	2.08	2.51	1.73	2.87
Grevillea robusta	Wide Bay and Burnett – inland	0.44	2.31	2.34	4.20	2.56	3.30	0.52	3.62
	Capricornia	1.06	2.60	1.89	4.44	3.84	3.56	2.28	4.07
	Darling Downs and Granite Belt	0.95	1.83	1.72	3.13	2.50	2.51	1.73	2.87
Khaya senegalensis	North Tropical Caost and Tablelands	3.56	1.80	8.71	2.72	5.75	2.30	9.16	2.84
Melaleuca armillaris	Wide Bay and Burnett – inland	0.44	2.31	0.77	4.20	5.23	3.30	0.50	3.62
	Capricornia	1.05	2.60	0.31	4.44	1.48	3.56	2.20	4.07
	Darling Downs and Granite Belt	0.95	1.83	1.72	3.13	3.14	2.51	1.73	2.87
Melaleuca bracteata	Wide Bay and Burnett – inland	0.44	2.31	0.77	4.20	2.93	3.30	0.50	3.62
	Capricornia	1.05	2.60	0.31	4.44	3.31	3.56	2.20	4.07
	Darling Downs and Granite Belt	0.95	1.83	1.72	3.13	3.81	2.51	1.73	2.87
Melaleuca linarifolia	Wide Bay and Burnett – inland	0.59	2.31	6.06	4.20	5.24	3.30	1.53	3.62
	Capricornia	1.05	2.60	0.31	4.44	3.53	3.56	2.20	4.07
	Darling Downs and Granite Belt	1.06	1.83	3.84	3.13	4.46	2.51	2.40	2.87
Pinus caribaea var. hondurensis	Wide Bay and Burnett – coastal	9.94	2.21	17.47	3.96	12.01	3.13	19.89	3.46
Pine hybrid[12]	Wide Bay and Burnett – coastal	5.08	2.21	15.62	3.96	9.56	3.13	14.84	3.46
Tipuana tipu	Wide Bay and Burnett – inland	0.55	2.17	5.04	3.88	4.63	3.08	1.19	3.39
	Capricornia	1.16	2.46	0.33	4.13	7.31	3.35	2.33	3.86
	Darling Downs and Granite Belt	0.91	1.73	1.68	2.91	3.86	2.36	1.66	2.72

[12] Pine hybrid = the F2 hybrid from *Pinus elliottii* × *Pinus caribaea* var. *hondurensis*

Appendix 2 - Survival and borer performance at age 10 years for each taxon

Taxon	BOM Region	Pre-thin Survival		Post-thin Survival		Stem Borer Incidence		Old Borer Incidence	
		Estimate	StdE	Est	StdE	Est	StdE	Est	StdE
Acacia aulacocarpa	Wide Bay and Burnett – inland	0.98	0.19	0.08	0.24	na	na	na	na
	Capricornia	1.00	0.20	0.89	0.25	na	na	na	na
	Darling Downs and Granite Belt	0.67	0.15	0.51	0.17	na	na	na	na
Acacia deanei	Wide Bay and Burnett – inland	0.29	0.20	0.21	0.26	na	na	na	na
Acacia glaucocarpa	Wide Bay and Burnett – inland	0.53	0.20	0.21	0.26	na	na	na	na
	Capricornia	0.75	0.19	0.70	0.24	2.57	0.55	0.02	0.23
	Darling Downs and Granite Belt	0.65	0.19	0.42	0.23	na	na	na	na
	Southeast Coast	0.86	0.14	0.69	0.17	1.23	0.55	na	na
	Wide Bay and Burnett – coastal	0.60	0.18	0.43	0.22	1.41	0.54	0.93	0.22
Acacia mangium	Wide Bay and Burnett – inland	0.06	0.19	0.03	0.24	na	na	na	na
	Capricornia	0.17	0.20	0.09	0.27	na	na	na	na
	Darling Downs and Darling Downs	0.21	0.15	0.08	0.17	na	na	na	na
Acacia melanoxylon	Wide Bay and Burnett – inland	0.22	0.17	0.03	0.22	na	na	na	na
	Capricornia	0.17	0.19	0.03	0.23	na	na	na	na
	Darling Downs and Granite Belt	0.67	0.14	0.20	0.16	na	na	na	na
Araucaria cunninghamii	Wide Bay and Burnett – inland	0.83	0.10	0.91	0.12	0.00	0.53	0.00	0.22
Brachychiton rupestris	Wide Bay and Burnett – inland	0.88	0.19	0.27	0.24	na	na	na	na
	Capricornia	1.00	0.20	0.94	0.25	na	na	na	na
	Darling Downs and Granite Belt	0.56	0.15	0.25	0.17	na	na	na	na
Callistemon salignus	Wide Bay and Burnett – inland	0.34	0.18	0.77	0.22	0.00	0.53	0.00	0.22
	Capricornia	0.86	0.08	0.95	0.10	0.02	0.31	0.00	0.12
	Darling Downs and Granite Belt	na	na	0.64	0.16	0.00	0.35	0.00	0.15
Callistemon viminalis	Wide Bay and Burnett – inland	1.00	0.20	0.99	0.25	na	na	na	na
	Capricornia	0.62	0.15	1.00	0.17	na	na	na	na
	Darling Downs and Granite Belt	na	na	0.70	0.18	0.11	0.40	0.09	0.16
Casuarina cristata	Wide Bay and Burnett– inland	0.82	0.13	0.67	0.16	0.01	0.39	0.00	0.22
	Capricornia	0.85	0.18	0.85	0.12	0.10	0.32	0.07	0.13
	Darling Downs and Granite Belt	0.85	0.08	0.95	0.09	0.02	0.27	0.02	0.11
Casuarina cunninghamiana	Wide Bay and Burnett – inland	na	na	0.53	0.19	0.08	0.42	0.02	0.18
	Capricornia	0.95	0.13	0.92	0.15	0.09	0.41	0.00	0.17
	Darling Downs and Granite Belt	0.43	0.11	0.67	0.11	na	na	na	na
CT × CCV[13]	Wide Bay and Burnett – inland	na	na	0.66	0.23	0.06	0.54	0.11	0.22
Corymbia citriodora subsp. *citriodora*	Wide Bay and Burnett – inland	na	na	0.85	0.25	0.01	0.55	0.00	0.22
	Central Coast – Whitsunday	0.86	0.10	0.85	0.11	0.01	0.39	0.00	0.18
	Capricornia	0.90	0.10	0.90	0.09	0.06	0.32	0.06	0.13
	Darling Downs and Granite Belt	0.96	0.19	0.08	0.24	na	na	na	na

[13] CT × CCV = *Corymbia torelliana* × *Corymbia citriodora* subsp. *variegata*

Taxon	BOM Region	Pre-thin Survival		Post-thin Survival		Stem Borer Incidence		Old Borer Incidence	
		Estimate	StdE	Est	StdE	Est	StdE	Est	StdE
Corymbia citriodora subsp. *citriodora*	North Tropical Coast and Tablelands	1.00	0.20	1.00	0.25	na	na	na	na
	Southeast Coast	0.94	0.15	0.15	0.17	na	na	na	na
	Wide Bay and Burnett – coastal	1.00	0T.17	0.57	0.22	na	na	na	na
Corymbia citriodora subsp. *variegata*	Wide Bay and Burnett	1.00	0.19	0.98	0.23	na	na	na	na
	Central Coast – Whitsunday	0.98	0.14	0.55	0.16	na	na	na	na
	Capricornia	0.83	0.10	0.85	0.12	0.00	0.37	0.00	0.15
	Darling Downs and Granite Belt	na	na	0.49	0.22	na	na	na	na
	North Tropical Coast and Tablelands	0.52	0.18	0.83	0.22	na	na	na	na
	Northern Rivers	0.85	0.18	0.75	0.16	0.21	0.38	0.09	0.15
	Southeast Coast	na	na	0.49	0.24	0.05	0.55	0.11	0.23
	Wide Bay and Burnett – coastal	0.82	0.19	0.08	0.24	na	na	na	na
Corymbia henryi	Wide Bay and Burnett – inland	0.41	0.20	0.61	0.25	na	na	na	na
	Darling Downs and Granite Belt	0.79	0.15	0.33	0.17	na	na	na	na
	Southeast Coast	0.98	0.19	0.03	0.24	na	na	na	na
	Wide Bay and Burnett – coastal	1.00	0.20	1.00	0.25	na	na	na	na
Corymbia nesophila	North Tropical Coast and Tablelands	0.86	0.15	0.40	0.17	na	na	na	na
Corymbia torelliana	Wide Bay and Burnett– inland	1.00	0.19	0.15	0.24	na	na	na	na
	Capricornia	1.00	0.20	0.58	0.25	na	na	na	na
	Darling Downs and Granite Belt	0.90	0.15	0.18	0.17	na	na	na	na
EG × EC[14]	Wide Bay and Burnett – inland	0.71	0.09	0.53	0.11	0.93	0.42	0.01	0.18
	Capricornia	0.72	0.22	0.45	0.27	2.07	0.65	0.37	0.29
	North Tropical Coast and Tablelands	na	na	0.88	0.24	0.05	0.55	0.11	0.23
	Northern Rivers	na	na	0.25	0.26	0.11	0.58	0.00	0.24
	Southeast Coast	0.87	0.19	0.54	0.23	na	na	na	na
	Wide Bay and Burnett – coastal	0.56	0.14	0.40	0.11	0.86	0.39	0.49	0.16
EG × EP[15]	Central Coast – Whitsunday	na	na	0.28	0.25	0.95	0.57	0.36	0.24
	Capricornia	0.84	0.15	0.42	0.17	2.31	0.40	0.65	0.17
	North Tropical Coast and Tablelands	na	na	0.12	0.24	0.23	0.55	0.70	0.23
	Wide Bay and Burnett – coastal	0.39	0.19	0.48	0.14	1.12	0.39	0.67	0.16
EG × ER[16]	Wide Bay and Burnett – inland	0.84	0.10	0.61	0.12	2.12	0.53	0.69	0.22
	Capricornia	0.60	0.22	0.24	0.27	1.27	0.65	0.00	0.29
	Darling Downs and Granite Belt	0.33	0.19	0.29	0.24	1.47	0.67	0.49	0.30
	Southeast Coast	0.81	0.18	0.16	0.22	2.63	0.58	1.00	0.25
	Wide Bay and Burnett – coastal	0.37	0.19	0.35	0.16	1.54	0.54	0.84	0.22
EG × ET[17]	Wide Bay and Burnett – inland	0.76	0.08	0.57	0.10	1.65	0.34	0.28	0.14
	Central Coast – Whitsunday	na	na	0.14	0.25	0.07	0.57	2.19	0.24
	Capricornia	0.78	0.22	0.81	0.27	1.07	0.65	0.27	0.29
	Darling Downs and Granite Belt	0.72	0.14	0.65	0.14	1.83	0.58	0.70	0.24
	North Tropical Coast and Tablelands	na	na	0.04	0.28	na	na	na	na
	Northern Rivers	na	na	0.50	0.26	0.23	0.58	0.08	0.24

[14] EG × EC = *E. grandis* × *E. camaldulensis*
[15] EG × EP = *E. grandis* × *E. pellita*
[16] EG × ER = *E. grandis* × *E. resinifera*
[17] EG × ET = *E. grandis* × *E . tereticornis*

Taxon	BOM Region	Pre-thin Survival		Post-thin Survival		Stem Borer Incidence		Old Borer Incidence	
		Estimate	StdE	Est	StdE	Est	StdE	Est	StdE
EG × ET	Southeast Coast	0.92	0.14	0.72	0.17	2.06	0.54	0.90	0.23
	Wide Bay and Burnett – coastal	0.79	0.18	0.33	0.14	1.32	0.54	0.64	0.22
EG × EU[18]	Wide Bay and Burnett – inland	0.73	0.10	0.33	0.12	1.34	0.56	0.09	0.24
	Central Coast – Whitsunday	na	na	0.24	0.25	2.45	0.57	0.82	0.24
	Capricornia	0.87	0.15	0.35	0.18	2.20	0.42	0.72	0.18
	Darling Downs and Granite Belt	0.42	0.14	0.38	0.17	na	na	na	na
	North Tropical Coast and Tablelands	na	na	0.04	0.23	0.06	0.55	0.53	0.23
	Northern Rivers	na	na	0.57	0.26	2.11	0.58	0.35	0.24
	Southeast Coast	0.70	0.12	0.25	0.14	2.48	0.42	1.00	0.25
	Wide Bay and Burnett – coastal	0.55	0.14	0.42	0.11	1.66	0.38	0.89	0.15
ES × ET[19]	Wide Bay and Burnett – coastal	0.80	0.19	0.54	0.24	na	na	na	na
ET × EP[20]	Capricornia	0.85	0.22	0.68	0.27	2.50	0.65	0.88	0.29
EU × EC[21]	Wide Bay and Burnett – inland	0.90	0.21	0.60	0.26	2.61	0.63	0.06	0.28
	Central Coast – Whitsunday	na	na	0.21	0.25	2.32	0.57	0.69	0.24
	North Tropical Coast and Tablelands	na	na	0.05	0.24	0.11	0.57	0.41	0.24
	Wide Bay and Burnett – coastal	0.52	0.19	0.35	0.17	na	na	na	na
EU × ET[22]	Wide Bay and Burnett	0.79	0.21	0.22	0.26	0.12	0.63	0.06	0.28
	Central Coast – Whitsunday	na	na	0.44	0.25	2.41	0.57	0.73	0.24
	Capricornia	0.83	0.22	0.22	0.27	2.12	0.65	0.72	0.29
	Wide Bay and Burnett – coastal	0.51	0.18	0.44	0.16	na	na	na	na
Elaeocarpus grandis	North Tropical Coast and Tablelands	na	na	0.45	0.25	0.00	0.56	0.00	0.23
Eucalyptus acmenoides	Wide Bay and Burnett– inland	0.23	0.17	0.29	0.21	0.73	0.53	0.08	0.22
	Wide Bay and Burnett – coastal	na	na	0.71	0.16	0.11	0.39	0.10	0.16
Eucalyptus argophloia	Wide Bay and Burnett – inland	0.95	0.08	1.00	0.09	0.29	0.28	0.16	0.11
	Capricornia	0.94	0.16	1.00	0.19	0.10	0.65	0.00	0.29
	Darling Downs and Granite Belt	0.98	0.11	0.99	0.11	0.00	0.57	0.00	0.23
	Southeast Coast	0.96	0.12	1.00	0.14	0.00	0.52	0.01	0.22
	Wide Bay and Burnett – coastal	0.80	0.18	0.96	0.22	0.13	0.53	0.08	0.21
Eucalyptus camaldulensis	Wide Bay and Burnett – inland	1.00	0.11	1.00	0.13	1.11	0.36	0.09	0.14
	Capricornia	1.00	0.16	0.94	0.19	0.02	0.65	0.05	0.29
	Darling Downs and Granite Belt	0.99	0.12	0.70	0.12	1.41	0.57	0.67	0.23
	North Tropical Coast and Tablelands	na	na	0.75	0.18	0.06	0.39	0.26	0.16
	Wide Bay and Burnett – coastal	0.89	0.14	0.80	0.17	0.22	0.53	0.27	0.21
Eucalyptus cambageana	Wide Bay and Burnett – inland	0.82	0.17	0.79	0.21	0.00	0.51	0.09	0.20
	Darling Downs and Granite Belt	1.00	0.18	1.00	0.22	0.16	0.57	0.07	0.23
Eucalyptus cloeziana	Wide Bay and Burnett – inland	0.70	0.08	0.72	0.10	0.00	0.37	0.00	0.15

[18] EG × EU = *E. grandis* × *E. urophylla*
[19] ES × ET = *E. saligna* × *E. tereticornis*
[20] ET × EP = *E. tereticornis* × *E. pellita*
[21] EU × EC = *E. urophylla* × *E. camaldulensis*
[22] EU × ET = *E. urophylla* × *E. tereticornis*

Taxon	BOM Region	Pre-thin Survival		Post-thin Survival		Stem Borer Incidence		Old Borer Incidence	
		Estimate	StdE	Est	StdE	Est	StdE	Est	StdE
Eucalyptus cloeziana	Central Coast – Whitsunday	na	na	0.48	0.15	0.07	0.33	0.00	0.14
	Capricornia	0.39	0.20	0.66	0.25	na	na	na	na
	Darling Downs and Granite Belt	0.39	0.12	0.69	0.14	na	na	na	na
	North Tropical Coast and Tablelands	na	na	0.34	0.18	0.01	0.40	0.03	0.16
	Southeast Coast	0.57	0.18	0.91	0.22	0.00	0.52	0.00	0.22
	Wide Bay and Burnett – coastal	0.73	0.10	0.78	0.10	0.03	0.38	0.10	0.15
Eucalyptus crebra	Wide Bay and Burnett – inland	0.98	0.19	0.98	0.24	na	na	na	na
	Capricornia	1.00	0.20	1.00	0.25	na	na	na	na
	Darling Downs and Granite Belt	1.00	0.15	0.58	0.17	na	na	na	na
	Southeast Coast	0.97	0.18	1.00	0.22	0.00	0.52	0.00	0.22
Eucalyptus dunnii	Wide Bay and Burnett – inland	0.72	0.08	0.37	0.09	0.62	0.40	0.37	0.17
	Central Coast – Whitsunday	na	na	0.49	0.16	0.45	0.35	0.19	0.15
	Capricornia	0.56	0.13	0.38	0.15	1.33	0.41	0.48	0.17
	Darling Downs and Granite Belt	0.77	0.11	0.64	0.11	1.34	0.57	0.56	0.23
	Northern Rivers	na	na	0.90	0.26	0.00	0.58	0.00	0.24
	Southeast Coast	0.94	0.12	0.77	0.14	1.21	0.39	0.85	0.22
	Wide Bay and Burnett – coastal	0.72	0.11	0.64	0.10	1.49	0.40	0.76	0.17
Eucalyptus globulus subsp. bicostata	Darling Downs and Granite Belt	na	na	0.39	0.24	na	na	na	na
	Southeast Coast	0.70	0.18	0.15	0.22	na	na	na	na
Eucalyptus globulus subsp. globulus	Darling Downs and Granite Belt	na	na	0.43	0.24	na	na	na	na
Eucalyptus globulus subsp. maidenii	Wide Bay and Burnett – inland	0.74	0.09	0.47	0.11	1.47	0.51	0.58	0.20
	Darling Downs and Granite Belt	0.47	0.14	0.67	0.14	0.75	0.60	0.50	0.26
	Northern Rivers	na	na	0.81	0.26	0.00	0.58	0.00	0.24
	Southeast Coast	0.86	0.12	0.61	0.14	0.69	0.40	0.41	0.22
	Wide Bay and Burnett – coastal	0.87	0.18	0.49	0.13	0.85	0.38	0.53	0.15
Eucalyptus grandis	Wide Bay and Burnett – inland	0.95	0.17	0.37	0.21	1.27	0.51	0.62	0.20
	Central Coast – Whitsunday	na	na	0.46	0.18	0.93	0.44	0.33	0.19
	Capricornia	0.76	0.14	0.37	0.17	2.16	0.38	0.64	0.15
	Darling Downs and Granite Belt	0.74	0.18	0.67	0.16	na	na	na	na
	Northern Rivers	na	na	0.64	0.25	0.11	0.55	0.02	0.22
	Southeast Coast	0.84	0.17	0.29	0.21	na	na	na	na
	Wide Bay and Burnett – coastal	0.66	0.11	0.55	0.09	1.19	0.32	0.70	0.13
Eucalyptus longirostrata	Wide Bay and Burnett – inland	0.82	0.08	0.86	0.10	0.82	0.28	0.21	0.11
	Capricornia	0.90	0.19	0.78	0.24	0.47	0.55	0.20	0.23
	Darling Downs and Granite Belt	1.00	0.18	1.00	0.22	1.03	0.57	0.42	0.23
	Southeast Coast	0.91	0.10	0.95	0.11	0.90	0.39	0.68	0.22
	Wide Bay and Burnett – coastal	0.93	0.18	0.81	0.14	0.28	0.33	0.19	0.14
Eucalyptus macarthurii	Wide Bay – Burnett – inland	0.67	0.18	0.03	0.22	0.16	0.56	0.48	0.24
	Darling Downs and Granite Belt	1.00	0.18	0.14	0.22	na	na	na	na
	Southeast Coast	0.90	0.18	0.00	0.23	0.40	0.64	na	na
Eucalyptus melliodora	Wide Bay and Burnett – inland	0.94	0.19	0.98	0.24	na	na	na	na
	Capricornia	1.00	0.20	0.99	0.25	na	na	na	na
	Darling Downs and Granite Belt	0.83	0.15	0.58	0.17	na	na	na	na

Taxon	BOM Region	Pre-thin Survival		Post-thin Survival		Stem Borer Incidence		Old Borer Incidence	
		Estimate	StdE	Est	StdE	Est	StdE	Est	StdE
Eucalyptus microcorys	Wide Bay and Burnett – inland	0.70	0.19	0.84	0.24	na	na	na	na
	Capricornia	0.25	0.20	0.44	0.25	na	na	na	na
	Darling Downs and Granite Belt	0.45	0.15	0.25	0.17	na	na	na	na
	Wide Bay and Burnett – coastal	0.74	0.19	0.79	0.24	na	na	na	na
Eucalyptus moluccana	Wide Bay and Burnett – inland	1.00	0.10	0.98	0.12	0.36	0.31	0.13	0.12
	Capricornia	1.00	0.19	0.99	0.23	na	na	na	na
	Darling Downs and Granite Belt	1.00	0.12	0.71	0.12	0.94	0.57	0.36	0.23
	North Tropical Coast and Tablelands	na	na	0.51	0.28	0.06	0.64	0.10	0.29
	Southeast Coast	1.00	0.13	1.00	0.16	2.46	0.52	0.99	0.22
Eucalyptus pellita	Wide Bay and Burnett – inland	0.82	0.19	0.88	0.24	na	na	na	na
	Central Coast – Whitsunday	na	na	0.52	0.17	0.24	0.39	0.12	0.16
	Capricornia	0.73	0.13	0.63	0.15	0.95	0.39	0.43	0.16
	Darling Downs and Granite Belt	0.58	0.15	0.35	0.17	na	na	na	na
	North Tropical Coast and Tablelands	na	na	0.56	0.25	0.03	0.56	0.03	0.23
	Southeast Coast	0.89	0.19	0.42	0.23	na	na	na	na
	Wide Bay and Burnett – coastal	0.80	0.19	0.73	0.16	0.31	0.51	0.26	0.20
Eucalyptus pilularis	Wide Bay and Burnett – inland	0.43	0.12	0.16	0.15	1.23	0.53	0.58	0.22
	Darling Downs and Granite Belt	0.66	0.18	0.83	0.22	na	na	na	na
	Wide Bay and Burnett – coastal	0.54	0.12	0.49	0.12	0.51	0.39	0.42	0.16
Eucalyptus raveretiana	Wide Bay and Burnett – inland	0.95	0.13	0.65	0.16	0.00	0.52	0.09	0.21
	Capricornia	1.00	0.20	0.89	0.25	na	na	na	na
	Darling Downs and Granite Belt	0.84	0.15	0.53	0.17	na	na	na	na
Eucalyptus reducta	Wide Bay and Burnett – coastal	na	na	0.61	0.22	0.30	0.54	0.10	0.22
Eucalyptus resinifera	Wide Bay and Burnett – inland	0.80	0.13	0.75	0.16	0.98	0.51	0.38	0.20
	Capricornia	0.39	0.20	0.18	0.25	na	na	na	na
	Darling Downs and Granite Belt	0.63	0.15	0.33	0.17	na	na	na	na
	Wide Bay and Burnett – coastal	0.71	0.19	0.70	0.14	0.46	0.39	0.22	0.16
Eucalyptus robusta	Wide Bay and Burnett – inland	0.68	0.19	0.28	0.24	na	na	na	na
	Capricornia	0.17	0.20	0.04	0.25	na	na	na	na
	Darling Downs and Granite Belt	0.48	0.15	0.31	0.17	na	na	na	na
	Wide Bay and Burnett – coastal	0.86	0.18	0.31	0.22	0.44	0.57	0.42	0.24
Eucalyptus siderophloia	Wide Bay and Burnett – inland	0.87	0.11	0.96	0.13	0.00	0.53	0.00	0.22
	Southeast Coast	0.93	0.18	0.86	0.23	0.37	0.55	na	na
Eucalyptus sideroxylon	Wide Bay and Burnett – inland	0.92	0.18	0.87	0.22	0.30	0.53	0.07	0.22
	Darling Downs and Granite Belt	1.00	0.18	1.00	0.22	0.00	0.57	0.00	0.23
	Southeast Coast	0.98	0.18	1.00	0.22	0.00	0.52	0.00	0.22
Eucalyptus sphaerocarpa	Wide Bay and Burnett – coastal	na	na	0.67	0.16	0.02	0.39	0.04	0.16
Eucalyptus tereticornis	Wide Bay and Burnett – inland	1.00	0.10	0.95	0.12	0.91	0.38	0.09	0.15
	Central Coast – Whitsunday	na	na	0.64	0.25	0.70	0.57	0.19	0.24
	Capricornia	0.97	0.15	0.90	0.17	0.80	0.52	0.25	0.20

Taxon	BOM Region	Pre-thin Survival		Post-thin Survival		Stem Borer Incidence		Old Borer Incidence	
		Estimate	StdE	Est	StdE	Est	StdE	Est	StdE
Eucalyptus tereticornis	Darling Downs and Granite Belt	0.90	0.11	0.65	0.12	1.84	0.57	0.89	0.23
	North Tropical Coast and Tablelands	na	na	0.69	0.18	0.05	0.40	0.30	0.16
	Southeast Coast	0.89	0.10	0.86	0.11	1.30	0.39	0.77	0.22
	Wide Bay and Burnett – coastal	0.88	0.14	0.72	0.13	0.23	0.53	0.28	0.21
Eucalyptus tetrodonta	Wide Bay and Burnett – inland	0.00	0.17	0.21	0.21	na	na	na	na
	North Tropical Coast and Tablelands	na	na	0.22	0.19	0.34	0.43	0.42	0.18
Eucalyptus urophylla	Wide Bay and Burnett – coastal	0.78	0.19	0.07	0.14	1.50	0.38	0.74	0.15
Flindersia australis	Wide Bay and Burnett – inland	0.80	0.19	0.85	0.24	na	na	na	na
	Capricornia	0.97	0.20	0.91	0.25	na	na	na	na
	Darling Downs and Granite Belt	0.36	0.15	0.10	0.17	na	na	na	na
Grevillea robusta	Wide Bay and Burnett – inland	0.92	0.19	0.13	0.24	na	na	na	na
	Capricornia	1.00	0.20	1.00	0.25	na	na	na	na
	Darling Downs and Granite Belt	0.48	0.15	0.30	0.17	na	na	na	na
Khaya senegalensis	North Tropical Coast and Tablelands	na	na	0.67	0.15	0.00	0.33	0.01	0.14
Melaleuca armillaris	Wide Bay and Burnett – inland	0.86	0.19	0.62	0.24	na	na	na	na
	Capricornia	0.55	0.20	0.04	0.25	na	na	na	na
	Darling Downs and Granite Belt	0.53	0.15	0.15	0.17	na	na	na	na
Melaleuca bracteata	Wide Bay and Burnett – inland	0.88	0.19	0.71	0.24	na	na	na	na
	Capricornia	0.77	0.20	0.63	0.25	na	na	na	na
	Darling Downs and Granite Belt	0.45	0.15	0.58	0.17	na	na	na	na
Melaleuca linarifolia	Wide Bay and Burnett – inland	0.72	0.19	1.00	0.24	na	na	na	na
	Capricornia	0.59	0.20	0.74	0.25	na	na	na	na
	Darling Downs and Granite Belt	0.55	0.15	0.58	0.17	na	na	na	na
Pinus caribaea var. hondurensis	Wide Bay and Burnett – coastal	na	na	0.88	0.22	0.29	0.54	0.09	0.22
Pine hybrid[23]	Wide Bay and Burnett – coastal	na	na	0.85	0.22	0.29	0.54	0.09	0.22
Tipuana tipu	Wide Bay and Burnett – inland	1.00	0.17	0.56	0.22	na	na	na	na
	Capricornia	1.00	0.19	0.89	0.23	na	na	na	na
	Darling Downs and Granite Belt	0.79	0.14	0.58	0.16	na	na	na	na

[23] Pine hybrid = the F2 hybrid from *Pinus elliottii* × *Pinus caribeaea* var. *hondurensis*

Appendix 3 - Predicted wood density, volume, carbon sequestered and pulp productivity at age 10 years for selected taxa

Taxon	BOM region[24]	Wood density (kg/m^3)		Volume MAI (m^3/ha)		CO_2 equiv sequestered (tonnes/ha)		Pulp productivity (tonnes/ha)	
		Est	StdE	Est	StdEr	Est	StdEr	Est	StdEr
Corymbia citriodora subsp. *citriodora*	Wide Bay and Burnett – coastal	726	26.2	5.05	1.30	152.0	33.23	43.6	9.06
	Wide Bay and Burnett – inland	750	17.5	2.64	1.13	42.3	23.38	11.1	6.26
	Darling Downs and Granite Belt	775	19.2	2.26	1.83	18.9	24.38	4.9	6.62
	Central Coast – Whitsunday	715	16.0	9.88	1.85	128.6	20.08	37.3	5.47
	Capricornia	746	26.3	4.85	2.60	55.8	34.14	15.6	9.19
	Southeast Coast	747	22.9	1.72	1.74	51.0	31.33	12.6	8.43
Corymbia citriodora subsp. *variegata*	Wide Bay and Burnett – coastal	729	27.9	7.91	1.08	184.5	34.67	54.5	9.45
	Wide Bay and Burnett – inland	742	10.3	3.50	1.05	48.0	13.22	13.3	3.61
	Darling Downs and Granite Belt	777	19.2	2.14	1.32	24.5	24.38	6.4	6.62
	Northern Rivers	717	24.7	10.28	3.05	135.1	31.91	37.6	8.71
	Southeast Coast	768	17.6	3.41	1.35	56.2	22.93	14.9	6.23
	Central Coast – Whitsunday	701	19.5	9.34	2.09	159.1	24.87	45.9	6.72
	Capricornia	740	15.4	8.49	1.82	115.3	19.45	32.2	5.30
Corymbia henryi	Wide Bay and Burnett – inland	728	16.2	3.08	1.26	48.6	22.35	13.2	5.97
CT × CCV	Wide Bay and Burnett – inland	816	29.4	3.05	2.17	62.6	37.37	15.3	9.97
EG × ER	Wide Bay and Burnett – inland	699	25.1	3.27	1.30	68.4	33.64	16.0	8.97
Eucalyptus argophloia	Southeast Coast	710	22.8	4.94	1.54	43.3	31.31	11.7	8.42
	Wide Bay and Burnett – inland	699	11.2	4.49	1.09	55.0	14.51	14.2	3.94
	Darling Downs and Granite Belt	723	15.4	3.54	1.33	59.1	19.56	14.4	5.32
	Capricornia	664	20.7	8.82	2.14	100.6	25.70	26.0	6.98
Eucalyptus camaldulensis	Wide Bay and Burnett – inland	659	16.5	2.45	1.37	39.9	22.59	9.6	6.04
	Capricornia	663	24.8	3.91	2.08	49.5	32.76	12.0	8.83
Eucalyptus cambageana	Wide Bay and Burnett – inland	744	24.9	2.64	2.10	46.0	33.52	11.9	8.93
	Darling Downs and Granite Belt	736	23.7	3.99	2.23	44.2	32.12	11.9	8.64
Eucalyptus cloeziana	Wide Bay and Burnett – inland	706	12.3	2.73	1.13	40.4	16.25	10.3	4.39
	Central Coast – Whitsunday	681	15.1	10.31	1.80	130.1	19.20	34.3	5.24
Eucalyptus crebra	Wide Bay and Burnett – inland	625	24.7	2.25	2.31	26.2	33.38	6.6	8.88
	Capricornia	609	26.3	2.66	2.60	21.4	34.14	5.8	9.19
	Darling Downs and Granite Belt	635	19.2	1.24	1.83	3.6	24.38	1.0	6.62
Eucalyptus dunnii	Central Coast – Whitsunday	572	16.1	9.97	1.85	109.2	20.01	30.3	5.46
	Capricornia	587	24.5	2.04	1.82	38.8	32.70	10.1	8.80
	Wide Bay and Burnett – inland	649	16.9	2.20	1.09	62.4	22.88	15.9	6.12

[24] Samples from the North Tropical Coast and Tablelands Region were collected, but data was not available at the time of writing this report.

Taxon	BOM region[24]	Wood density (kg/m^3)		Volume MAI (m^3/ha)		CO_2 equiv sequestered (tonnes/ha)		Pulp productivity (tonnes/ha)	
		Est	StdE	Est	StdEr	Est	StdEr	Est	StdEr
	Darling Downs and Granite Belt	697	18.0	4.02	1.33	65.1	23.26	16.5	6.32
Eucalyptus dunnii	Northern Rivers	614	26.2	24.39	3.12	273.6	33.24	73.9	9.06
	Southeast Coast	617	23.0	5.28	1.56	126.0	31.44	33.1	8.46
Eucalyptus globulus subsp. *maidenii*	Wide Bay and Burnett – inland	663	23.3	1.83	1.18	46.1	32.21	11.7	8.58
	Northern Rivers	621	26.2	12.30	3.12	138.9	33.24	37.5	9.06
	Darling Downs and Granite Belt	687	23.6	4.41	1.52	72.0	31.61	18.5	8.56
Eucalyptus grandis	Central Coast Whitsunday	633	20.3	10.53	2.07	159.0	25.45	40.0	6.88
	Northern Rivers	616	26.2	6.08	3.02	98.6	33.24	26.8	9.06
	Darling Downs and Granite Belt	689	25.2	4.09	1.72	65.8	32.97	16.3	8.92
Eucalyptus longirostrata	Wide Bay and Burnett – inland	675	12.3	3.56	1.13	43.3	16.19	11.0	4.37
	Darling Downs and Granite Belt	690	23.7	4.62	2.23	49.4	32.12	12.2	8.64
	Wide Bay and Burnett – coastal	649	26.2	10.59	1.45	235.2	33.23	60.7	9.06
	Southeast Coast	675	15.0	5.35	1.37	79.6	19.08	20.0	5.21
	Capricornia	614	24.5	8.83	2.49	108.2	32.70	27.0	8.80
Eucalyptus melliodora	Wide Bay and Burnett – inland	709	24.7	2.36	2.31	30.3	33.38	7.7	8.88
	Capricornia	716	26.3	4.49	2.60	48.8	34.14	12.0	9.19
	Darling Downs and Granite Belt	731	25.6	2.28	1.83	33.5	33.74	7.9	9.04
Eucalyptus moluccana	Southeast Coast	759	23.9	3.67	1.73	45.5	32.16	12.8	8.66
	Darling Downs and Granite Belt	759	17.5	1.79	1.40	14.4	22.84	3.9	6.19
	Wide Bay and Burnett – inland	753	13.2	3.53	1.25	55.2	18.01	15.2	4.84
	Capricornia	723	23.8	7.58	2.46	90.4	32.00	25.3	8.62
Eucalyptus pellita	Central Coast Whitsunday	637	17.1	8.83	1.98	113.2	22.68	27.1	6.13
	Capricornia	678	18.1	2.98	1.78	63.0	23.34	13.6	6.33
Eucalyptus sideroxylon	Southeast Coast	698	23.9	4.20	2.21	50.5	32.16	13.0	8.66
	Darling Downs and Granite Belt	713	23.7	4.14	2.23	44.7	32.12	11.3	8.64
Eucalyptus tereticornis	Darling Downs and Granite Belt	651	19.2	1.00	1.35	4.8	24.38	1.2	6.62
	Wide Bay and Burnett – inland	668	24.7	2.33	1.27	48.9	33.38	10.7	8.88
	Capricornia	670	26.3	3.96	1.97	59.4	34.14	13.6	9.19

Appendix 4 - Testing for Significant differences between taxa

Determining the significance of differences can be accomplished using the LSMeans (LSM) and standard errors (SE) presented in Appendices 1-3. As well, an approximation of confidence intervals may be made using the LSM and SE, with the probability of making an error when assuming another LSM is different from a selected LSM being 32, 4.5 and less than 1 percent if the other estimate is less than or greater than the LSM of interest plus or minus 1, 2 or 3 times the standard error.

A generalised test for the significance of differences between any two samples may be determined as follows:
$Z = (LSMean_2 – LSMean_2) / ((SE_1+SE_2)/2)$
If Z is greater than or less than 1.65, 1.96 or 2.58, the probability of falsely declaring two samples to be significantly different is 0.1, 0.05 or 0.01, respectively.

Appendix 5 - Graphical presentation of volume equations and actual data for selected taxon

(Calculated volume versus BA*Height)

Figure A5.1 - CCV

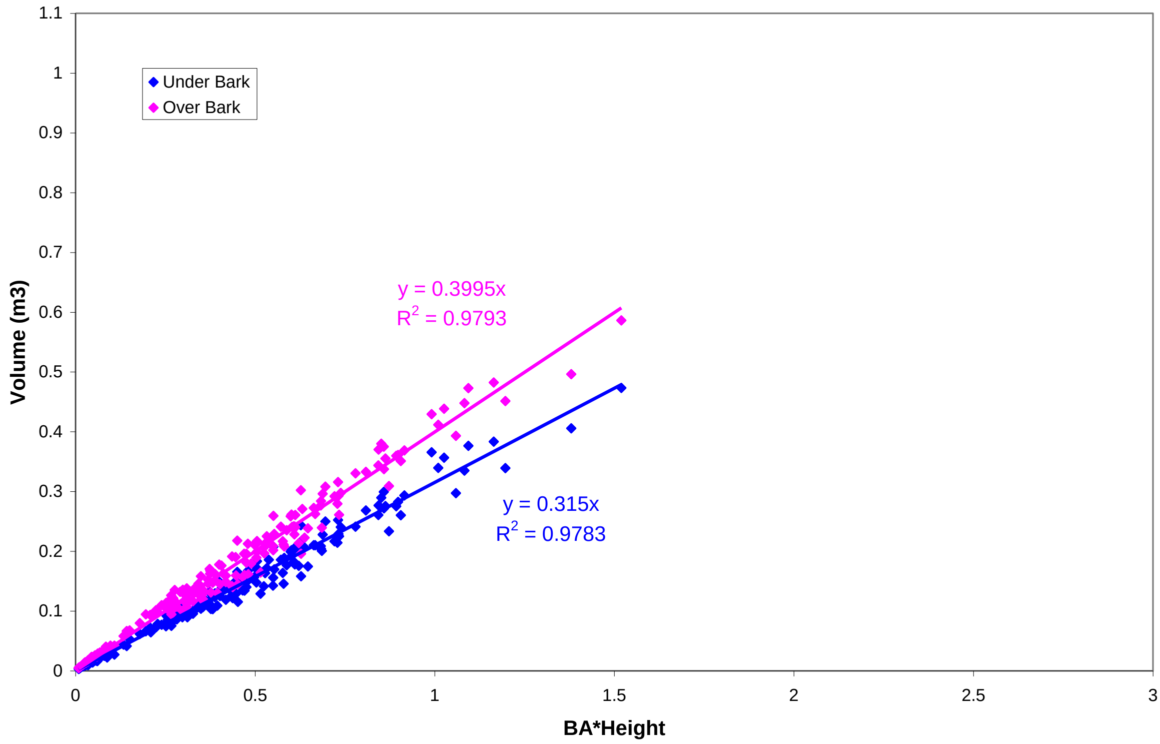
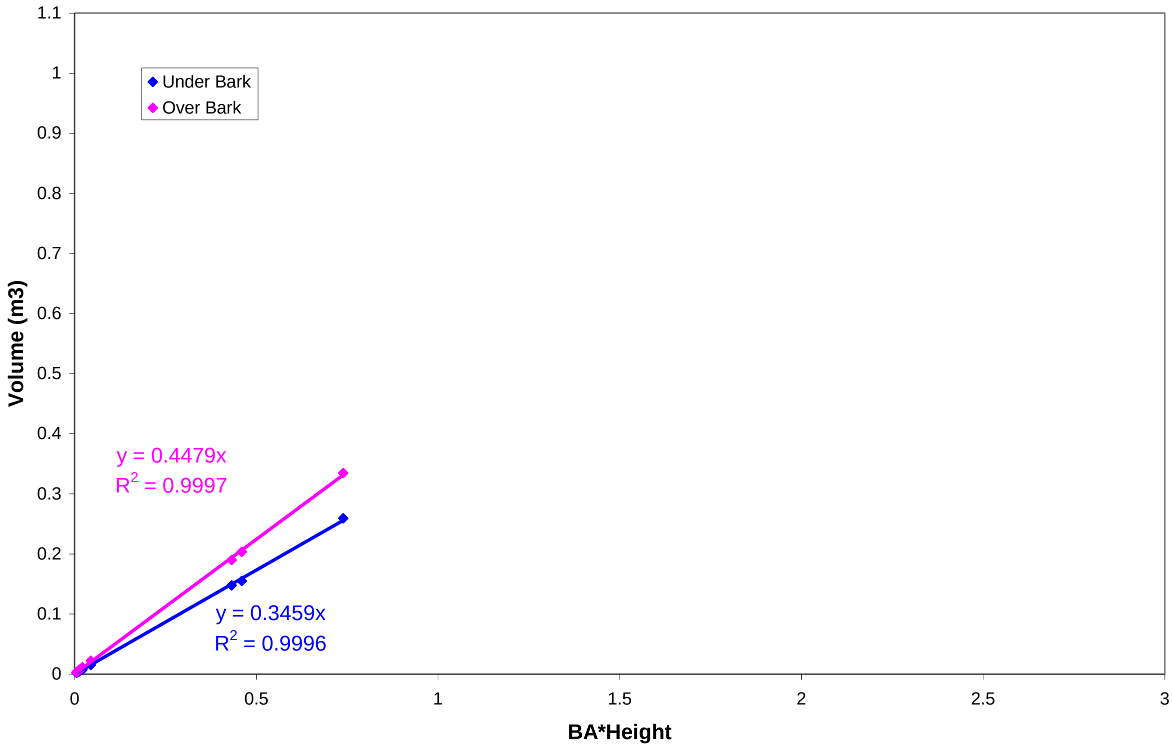
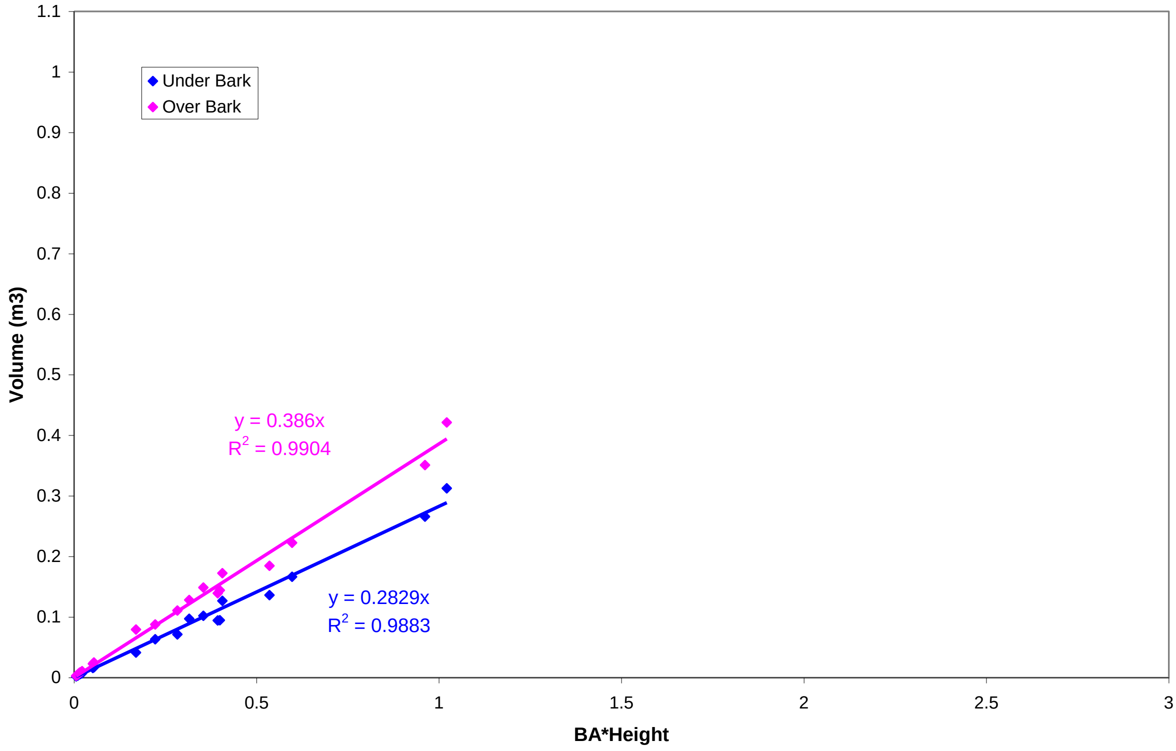


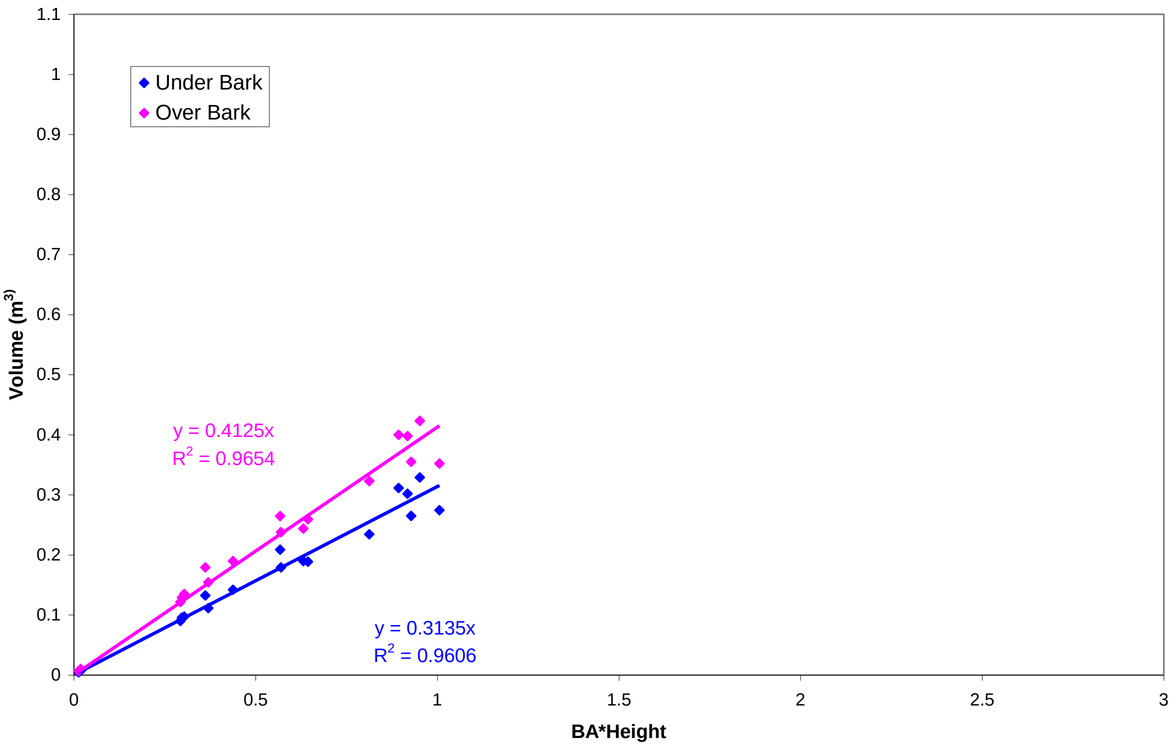
Figure A5.2 - CCC



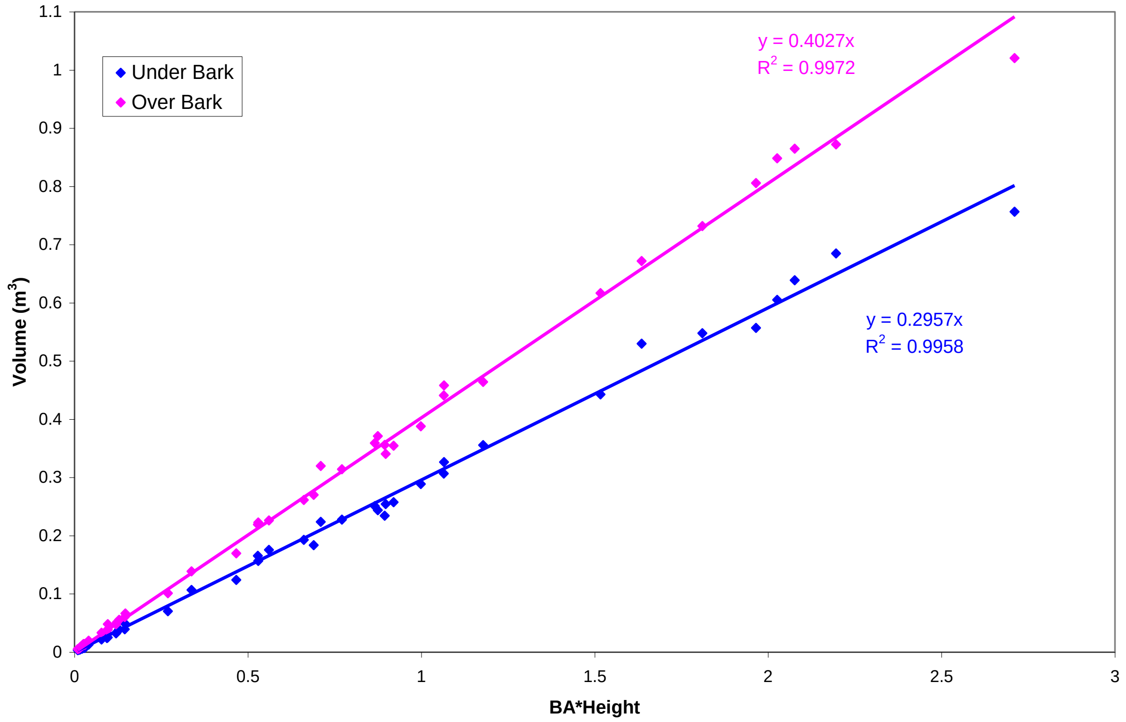
A5.3 - C. henryi



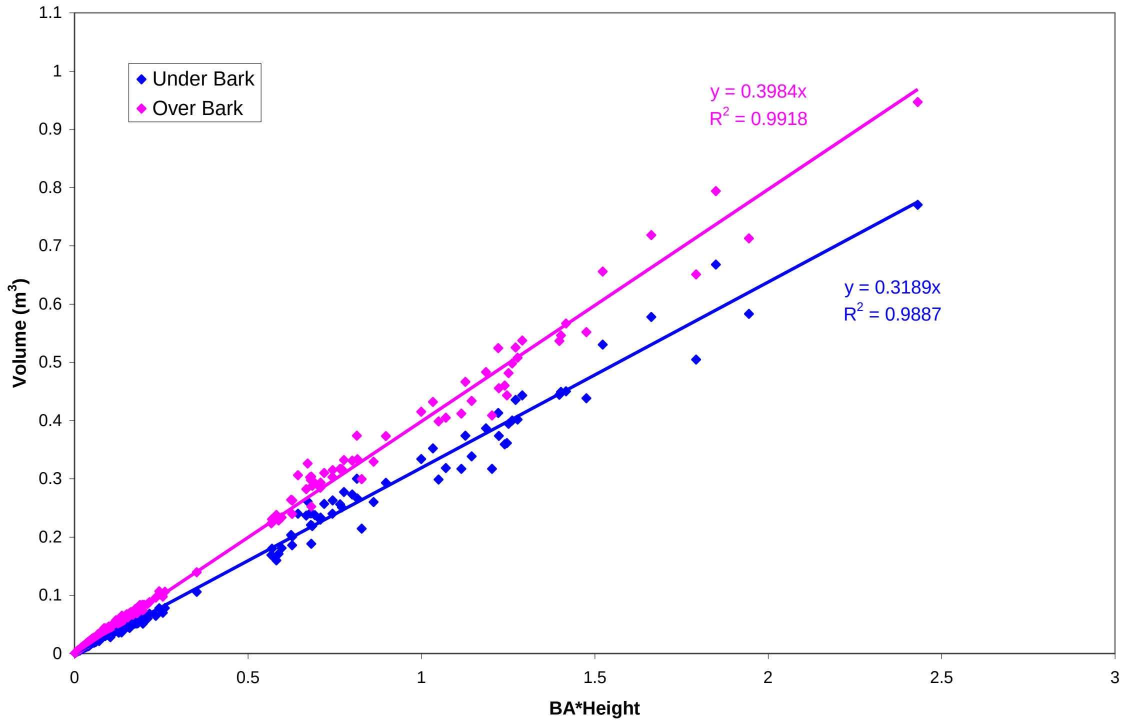
A5.4 - *E. argophloia*



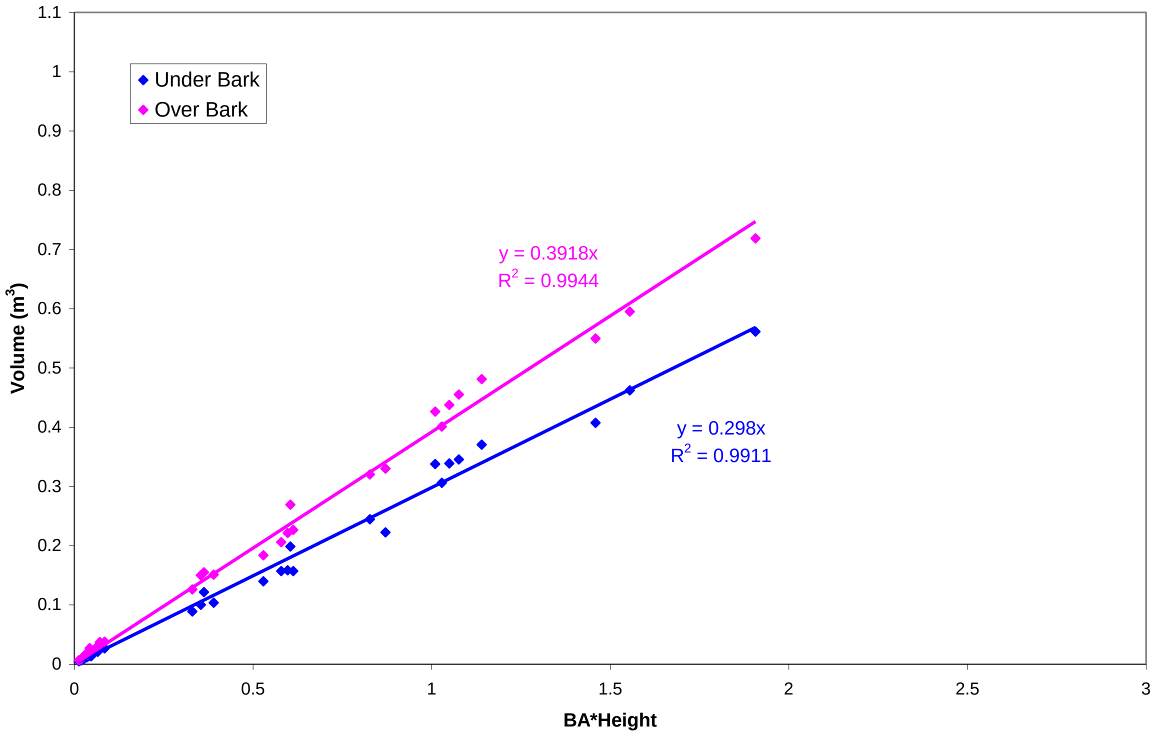
A5.5 - *E. cloeziana*



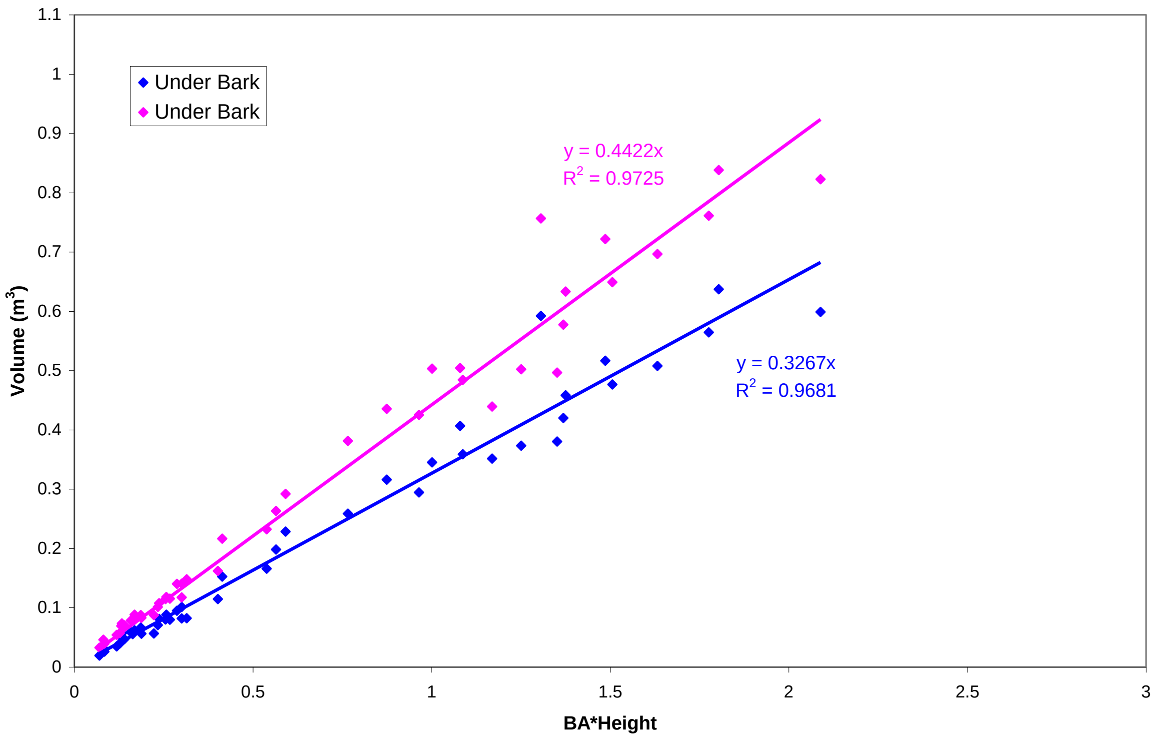
A5.6 - *E. dunnii*



A5.7 - *E. longirostrata*



A5.8 - *E. pellita*



Appendix 6 - Summary of the regression model used to predict mean annual increment based on climatic and soil parameters of taxa trials

Simple linear regression was used to develop an empirical model that relates environmental variables to mean annual increment. Table A6.2 details the variables that were found to significantly influence volume production and the associated parameter estimates can be used to develop a linear model that provides mean annual increment estimates.

Table A6.1 Summary of model relating model developed to relate yield to environmental parameters

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**p > F**
Model	18	3152.21	175.12	33.32	<.0001
Error	518	2722.17	5.26		
Corrected Total	536	5874.38			

Table A6.2 Summary of MAI prediction model based on environmental drivers

	Variable [a]	**Parameter Estimate**	**Standard Error**	**Type II SS**	**F Value**	**p > F**
	Intercept	-78.80465	11.27219	256.85	48.88	<.0001
*	Wetindex	-236.68375	32.62545	276.57	52.63	<.0001
*	MinT	0.69935	6.09131	0.07	0.01	0.9086
*	Rain	0.15019	0.01902	327.80	62.38	<.0001
*	Raindays	1.18560	0.15679	300.50	57.18	<.0001
*	MaxT	1.47457	0.20169	280.90	53.45	<.0001
*	Water	1.68739	0.17573	484.56	92.21	<.0001
	TAWA	-0.02243	0.00232	489.49	93.14	<.0001
	QQIT	-1.14486	0.36276	52.34	9.96	0.0017
	QQWA	-0.04958	0.00730	242.65	46.17	<.0001
	EVRD	-0.00059594	0.00007512	330.76	62.94	<.0001
	EVIT	-0.00277	0.00069421	83.41	15.87	<.0001
	EVBW	-0.00018873	0.00006861	39.77	7.57	0.0062
	EVFR	0.00016826	0.00003777	104.29	19.85	<.0001
	WIRD	-0.24947	0.08212	48.50	9.23	0.0025
	WIFR	-0.89691	0.18139	128.48	24.45	<.0001
	RDBW	0.00205	0.00103	20.84	3.97	0.0469
	ATIT	0.59471	0.06292	469.42	89.33	<.0001
	ITWA	0.03164	0.00289	629.95	119.87	<.0001
Forced into the model by the INCLUDE= option in SAS						

[a] Environmental variables included in the overall model generated from this data set.

Evaporation	Annual evaporation average over trial plus 3 months
Frost	Number of days with frost < -1° C for more than 2 hours
Prof Water	Profile water (estimate based on texture and structure and truncated at 80 cm)
Prof BW	Estimate of colour for the profile (Buntley & Westin 1965) - Brighter soils have larger number (red soil = large number, grey soil = low number)
Prof %Clay	Profile clay percentage
Q	Net mean daily surface radiation in MJ / m^2

Raindays	Annual average number of rain day over trial period plus 3 months.
Rainfall	Annual rainfall average over trial plus 3 months
MaxT	Extreme high temp for trial period
MinT	Extreme low temp for trial period
Tmax	Mean daily max temperature
Tmin	Mean daily min temperature
Wetness index	(Annual rainfall average over trial plus 3 months)/(Annual evaporation average over trial plus 3 months)

Translation of two-way interactions included in model including all taxa -
TAWA - Tmax X Prof Water
TIBW – Tmin X Prof BW
QQIT – Q x MinT
QQWA – Q x Prof Water
RABW – Rainfall x Prof BW
EVRD – Evaporation x Raindays
EVIT – Evaporation x MinT
EVBW – Evaporation x Prof BW
EVFR – Evaporation x Frost
WIRD - Wetness index x Raindays
WIFR - Wetness index x Frost
RDBW – Raindays x Prof BW
ATIT – MaxT x MinT
ITWA – MinT x Prof Water

Figure A6-1 - Summary of model fit for all species across all taxa trials included in the project