DWLBC Technical Report

Carbon Sequestration from Revegetation:

Southern Murray-Darling Basin Region

Government of South Australia

Department of Water, Land and Biodiversity Conservation

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Carbon Sequestration from Revegetation: Southern Murray-Darling Basin Region

Trevor J. Hobbs, Craig R. Neumann and Merv Tucker

Agricultural Landscapes Program, Land Management Unit, Department of Water, Land and Biodiversity Conservation

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NRM Research Alliance

FUTURE FARM INDUSTRIES CRC

Government of South Australia

Department of Water, Land and Biodiversity Conservation

Agricultural Landscapes Program, Land Management Unit

Department of Water, Land and Biodiversity Conservation

Waite Road, Urrbrae, SA 5064

GPO Box 2834, Adelaide SA 5001

Telephone	National	(08) 8463 6946
	International	+61 8 8463 6946
Fax	National	(08) 8463 6999
	International	+61 8 8463 6999
Website	www.dwlbc.sa.gov.au	

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FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continues to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

Scott Ashby
CHIEF EXECUTIVE
DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

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SUMMARY

Woody carbon crops and revegetation have the potential to sequester significant amounts of carbon in South Australia. This study was conducted to assist in the evaluation and prediction of carbon sequestration rates from dedicated woody carbon crops, sustainable extractive woody crops and environmental plantings in the low to medium rainfall (300 - 650mm) dryland agriculture zones of the Southern Murray-Darling Basin region.

The natural resources of the Southern Murray-Darling Basin region provide the backbone of a diverse range of ecosystems, agricultural pursuits, industries and communities. Unfortunately the loss of perennial vegetation cover has contributed substantially to a number of natural resource management issues such as dryland salinity, groundwater recharge, soil erosion risk and ecosystem fragmentation and degradation. Dryland plantations of native species can provide many environmental services and economic opportunities for the region. The value of perennial plant systems to reduce salinity, stabilise soils and sequester atmospheric carbon is well recognised. Correctly managed and designed revegetation and agroforestry can also provide positive contributions to ecosystems, habitats and biodiversity.

A number of commercial opportunities, natural resource management drivers and supportive policies exist to encourage greater investments in woody crop industries and revegetation activities in the Southern Murray-Darling Basin region and across the state. The Carbon Pollution Reduction Scheme (CPRS) due to commence in 2011, recent expansion of existing carbon offset/credit programs from energy/liquid fuel sectors (e.g. Mandatory Renewable Energy Targets) and informal “green-friendly” markets are all expected to increase the demand for carbon crops, agroforestry and environmental plantings in Australia. Many woodlots and environmental plantings in South Australia currently fit CPRS and other carbon trading scheme criteria, and the design of many future revegetation plantings will undoubtedly be tailored to comply with these schemes. Carbon is quickly becoming a highly valued product (or co-product) of revegetation and commercial agroforestry.

Previous studies of plantation productivity in the Southern Murray-Darling Basin (and most other low-mid rainfall areas of Australia) have mainly been limited to the evaluation of stemwood production rates of a few forestry and woody crop species. Production rates of species used in woodlots and environmental plantings are largely unquantified. To increase the efficiency of assessing carbon sequestered within revegetation sites this study has developed robust allometric relationships (r^2=0.86) between simple plant measurements and stemwood volumes, total above-ground biomass and carbon contents. Simple classifications of species groups and life forms have improved the predictive capability of these models by a further 4 to 8%. These relationships can now be routinely used to rapidly assess production and carbon sequestration rates for a wide range of species and revegetation sites.

In this study the total above-ground plant biomass and carbon content of 70 revegetation sites of known age were surveyed in the Southern Murray-Darling Basin region. These represent 51 mixed species revegetation sites and 19 monocultures. A total of 76 different species were examined. In examining the factors that influenced productivity this study found stocking rate and rainfall to be most significant, with no significant auto-correlation between rainfall and stocking rates (i.e. stocking rates were not influenced by average rainfall), and soil type/ fertility had little or no influence on site productivity. Most woodlot plantations out-perform environmental plantings when using identical stocking rates on the same site. These surveys found that the average planting density for woodlot plantings was 800 trees per hectare (tph) and 1400 tph for environmental plantings in the region. However, it must be noted that optimum stocking rates vary with species selections and location.

Analysis of the information gathered from these new surveys and existing databases provides a greater insight into the productive potential of a number of species growing in the region, and has facilitated the development of more reliable models to estimate carbon sequestration from revegetation activities. The productivity models developed from this study have been applied to spatial datasets within a geographic information system to estimate likely carbon sequestration rates from revegetation at a 1 hectare resolution. Based on typical stocking rates (i.e. woodlots 800 tph, environmental plantings 1400 tph), and plantation growth relationships to rainfall/soils, average above-ground carbon sequestration rates across the region were 5.8 tonnes of carbon dioxide equivalents per hectare per year (CO_2-e t/ha/yr) in woodlots and 6.0 CO_2-e t/ha/yr in environmental plantings.

The Australian Government Department of Climate Change (DCC) has a strong commitment to the use of the National Carbon Accounting Toolbox (NCAT) for carbon accounting purposes in Australia. Further, the NCAT has been identified as the preferred system to support carbon accounting within the proposed Carbon Pollution Reduction Scheme. At present the FullCAM model (and sub-models) within the NCAT has been predominantly populated by parameters drawn from studies of higher rainfall commercial forestry plantations. However, current NCAT parameter sets for lower rainfall species, plantation designs and mixed environmental plantings are largely absent or poorly validated.

The lack of detailed data from low to medium rainfall agroforestry and environmental plantings has previously hampered the development of suitable NCAT parameter sets for accurate NCAT prediction of carbon balances in the low to medium rainfall regions of Australia. Comparisons between detailed productivity assessments in the Southern Murray-Darling Basin region and FullCAM predictions (using their standard parameter sets) clearly demonstrates that NCAT can severely under-predict carbon sequestration rates in woodlots and environmental planting (27% of observed above-ground carbon) in lower rainfall regions.

A major component of this study was to develop sets of parameters that could be used in conjunction with the FullCAM model to improve the predictive capacity of that system, especially for woodlots and environmental plantings. Although this study provides new information on several plantation parameters (e.g. growth rates, stemwood volumes, plant fractions, wood densities) suited for input to the NCAT system, the underlying NCAT/FullCAM programming and front-end design limits the successful inclusion of these new parameters to create more realistic NCAT predictions of carbon balances in our state. The NCAT system, in its current form, is an unreliable tool for predicting carbon sequestration rates from revegetation in the low to medium rainfall zones of South Australia. There are strong concerns that the NCAT system may seriously mislead carbon accounting analysis across the state, and may pose significant risks to potential investors, landuse planning and government policies relating to carbon sequestration from revegetation.

The information contained within this report can provide guidance to those seeking to evaluate the feasibility of developing new environmental plantations and biomass industries in the Southern Murray-Darling Basin region. However care must be taken to avoid the negative impacts that wholesale landscape planting of carbon crops could have on agricultural production, rural communities and the environment. It is important that these new industries are targeted in areas where they maximise the benefits and profitability of whole farm enterprises and regions.

1. INTRODUCTION

1.1 NATURAL RESOURCE MANAGEMENT AND CARBON SEQUESTRATION FROM REVEGETATION

The integrated management of our natural resources is a high priority for South Australians and is notably reflected in recent developments of policy and legislation in the State. The State Strategic Plan's objectives of "*growing prosperity, improving wellbeing, attaining sustainability, fostering creativity, building communities and expanding opportunity*" (SA Government 2004) are strongly connected to our ability to manage our natural resources and adapt to changing climate for the future benefit of all South Australians. The SA *Natural Resources Management Act 2004* provides the underlying structure for government activities to better manage our natural resources. Overall state goals for NRM are detailed in the *State Natural Resources Management Plan* (SA DWLBC 2006). The *State NRM Plan* identifies a 50 year vision for natural resource management (NRM) in South Australia, and sets out policies, milestones and strategies to achieve that vision (SA DWLBC 2006).

State NRM Plan Vision: South Australia, a capable and prosperous community, managing natural resources for a good quality of life within the capacity of our environment for the long term.

- **Goal 1: Landscape scale management that maintains healthy natural systems and is adaptive to climate change**
- **Goal 2: Prosperous communities and industries using and managing natural resources within ecologically sustainable limits**
- **Goal 3: Communities, governments and industries with the capability, commitment and connections to manage natural resources in an integrated way**
- **Goal 4: Integrated management of biological threats to minimise risks to natural systems, communities and industry.**

This project aims to develop critical information and methodologies to evaluate and predict carbon sequestration rates from sustainable woody crops and environmental revegetation plantings in the lower rainfall (300 to 650mm) dryland agriculture zone of the Southern Murray-Darling Basin region of South Australia. This will support future understanding and adoption of carbon sequestration that will assist in the development of long term natural resource management strategies and policies for maintaining prosperity of the rural communities and natural environment in the dryland agricultural regions of South Australia.

The development of carbon markets will provide an economic driver for the adoption of woody crops and environmental revegetation for diverse multipurpose agricultural systems that are productive, sustainable, resilient and adaptable to climate change (Hobbs *et al.* 2009b). Strategically placed revegetation can provide a wide range of economic benefits to land holders and facilitate ecosystem services that benefit local areas and the broader community. The integration of sustainable woody crop systems (e.g. extractive use, habitat restoration & carbon markets) with other agricultural production (e.g. grazing and cropping) can provide more stable landholder return and the persistence and prosperity of local rural communities and industries while enhancing the natural ecology of these regions. The use of indigenous native species in revegetation activities (commercial or environmental) can minimise the biological threats associated with the introduction of woody crop plant species from other regions of the world. Local biodiversity can typically be enhanced with revegetation through the provision of plant species and structural diversity not found in cleared agricultural lands.

Prior research conducted by DWLBC FloraSearch, Future Farm Industries CRC, Rural Industries Research and Development Corporation and CSIRO has identified the medium rainfall (300-650mm) dryland agricultural zones with the greatest feasibility for developing carbon markets in Australia (Hobbs *et al.* 2009b). By focussing this research project in the Southern Murray-Darling Basin region (Figure 1) we will advance our knowledge and methodologies within a high priority region, prior to application across wider agricultural regions of South Australia. The information and technological outcomes of this study will advance the rapid progression of carbon sequestration assessments, monitoring and evaluations into other NRM regions of South Australia in preparation for the likely introduction of a national Carbon Pollution Reduction Scheme.

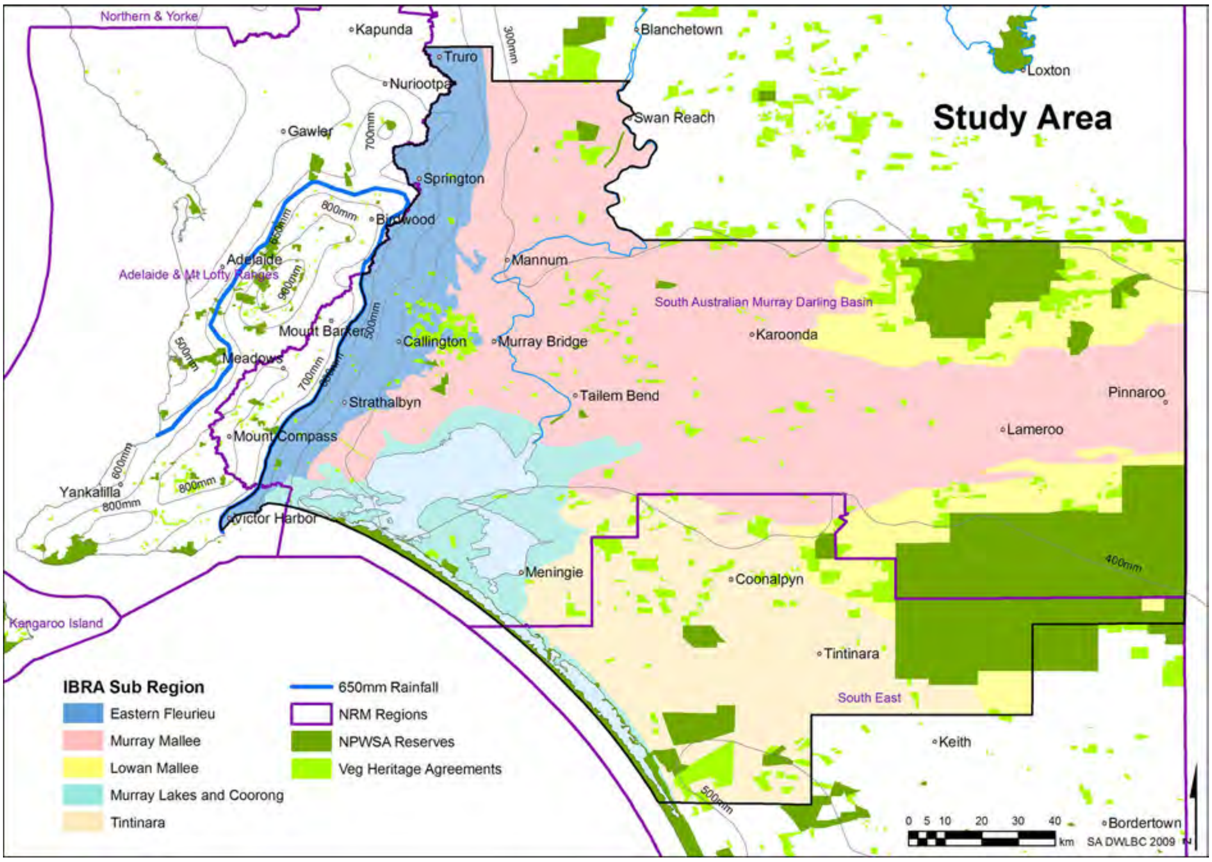


Figure 1. Carbon Sequestration from Revegetation project study area.

1.2 BACKGROUND AND RATIONALE

This study aims to efficiently evaluate and predict carbon sequestration rates from sustainable woody crops and environmental revegetation plantings in the medium rainfall (300 - 650mm) dryland agriculture zones of the Southern Murray-Darling Basin region of South Australia. The objective of this project is to increase the representation, accuracy and reliability of biomass productivity data for revegetation activities in SA and to calibrate carbon accounting models in anticipation of a Carbon Pollution Reduction Scheme coming into effect in 2011. Without this crucial and scientifically rigorous information the state government is at risk of being unable to accurately determine or monitor carbon sequestration rates from revegetation, provide accurate carbon accounting evaluations for the Carbon Pollution Reduction Scheme, or credibly support investments in the development of carbon markets (and other carbon-related sustainability markets) in South Australia.

DWLBC Land Management Unit's team of scientific researchers and technical staff have undertaken this complex research into plant and landscape ecology to develop robust carbon sequestration assessment methodologies, add to databases of species and revegetation community productivity, and create parameter sets for the National Carbon Accounting System and FullCAM carbon modelling program. The work also contributes significantly to the feasibility assessment and development of effective carbon markets in the state. This report outlines current research and is a timely extension of work in a region with a high feasibility for carbon sequestration activities.

This research presented here is consistent with the South Australia's "State NRM Plan 2006 Section 8 - South Australia's monitoring and evaluation framework" and clearly addresses the fundamental requirements that "Natural resource information should be":

- obtained to meet the strategic needs of government, industry and the community
- readily available to government, industry and the community
- captured on an agreed priority basis
- collected using a coordinated approach with uniform measurement standards, data management protocols, storage and retrieval
- consistent with national and international standards and protocols

This research is also consistent with the South Australia's Greenhouse Strategy, "Tackling Climate Change: South Australia's Greenhouse Strategy 2007-2020" (SA DPC 2007). Most notably Section 8 - Natural resources:

- Objective 8.1 - To strengthen the resilience of industries reliant on natural resources in the face of potential impacts of climate change.
- Objective 8.4 - To reduce greenhouse gas emissions from the natural resources sector and increase carbon sinks.

and Section 4 - Industry objectives:

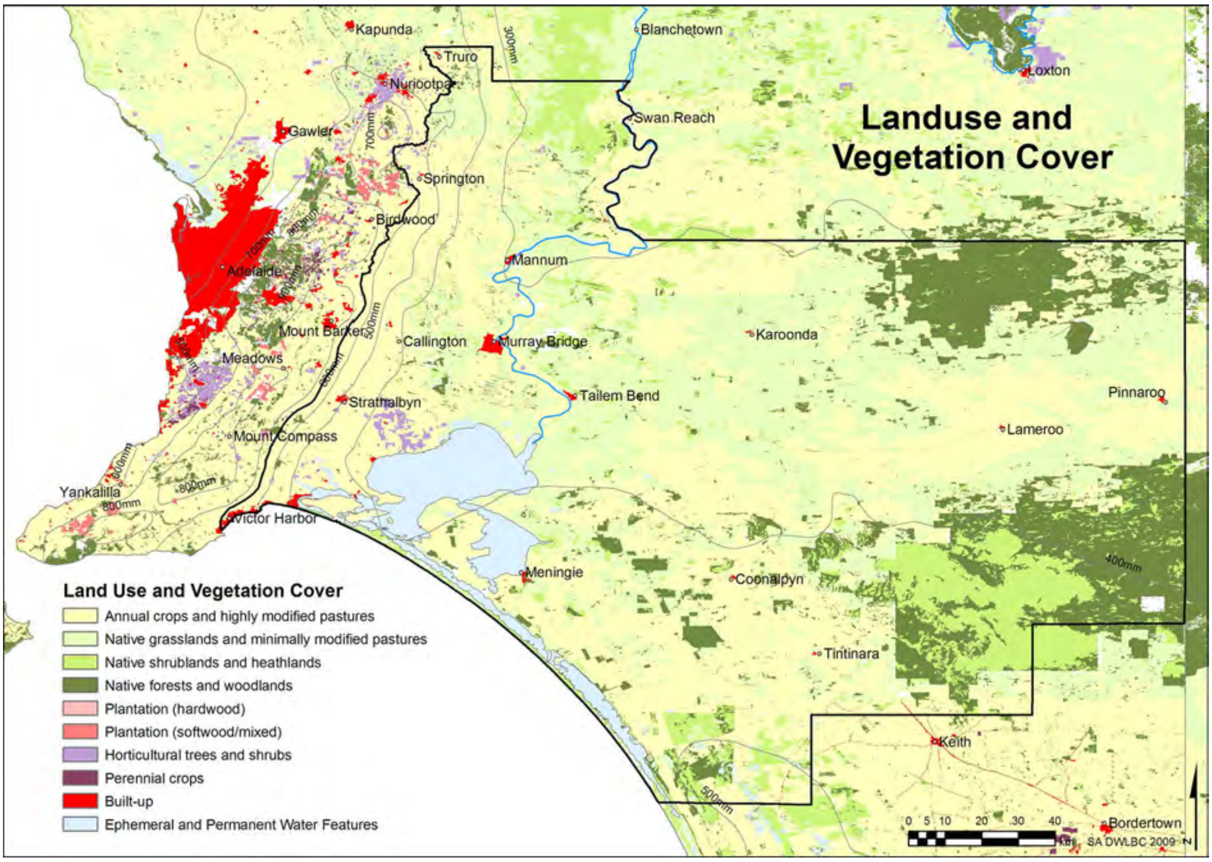
- Objective 4.3 - To target commercial opportunities and develop products and services of the future.

1.2.1 PURPOSE OF REVEGETATION

Many environmental and economic benefits can be achieved from increasing the use of perennial plant species in Australian landscapes (Australian Greenhouse Office & Murray Darling Basin Commission 2001). New plantations of woody perennial species can reduce groundwater recharge, dryland salinity, saline river discharges, wind erosion and drought risk, increase landscape sustainability, biodiversity, livestock production, economic diversification, and the stability of financial returns in the region.

There is increasing interest and awareness of the potential to offset carbon emissions from fossil fuels with environmental and other perennial plantings. Apart form their potential to sequester carbon some of these plantings could be designed as renewable energy sources used to generate electricity (Stucley *et al.* 2004, Zorzetto & Chudleigh 1999, Hague *et al.* 2002, Harper *et al.* 2007). Electricity generation from biomass (bioenergy), especially when combined with co-products like oil, charcoal, tannins or fodder provides a new industry opportunity in many regions of Australia (Zorzetto & Chudleigh 1999; Bartle *et al.* 2007; Bennell *et al.* 2008; Bartle & Shea 2002; Olsen *et al.* 2004, Enecon 2001). Stucley *et al.* (2004) however, states that, *“There is a general lack of information available on the growth of tree plantations in many parts of Australia.”* This lack of information is effectively carried over into the area of carbon sequestration and is particularly acute in the case of environmental plantings where there has been little economic impetus toward acquiring such information in the past.

Large areas across the study area have been highly modified since settlement and opportunities exist across these modified areas to undertake economically viable revegetation in response to climate change issues (Figure 2). One of these options is carbon sequestration in areas planted specifically for biodiversity purposes. This study aims to examine what naturally occuring species are commonly recorded across the study area, and to compare this information with plant sales data from the last 10 years. Plant sales data can also be used to estimate the expected area of revegetation planted in recent years. It is particularly important to examine the species mixes so that this study could adapt previously collected destructive sampling analysis to the current work, and identify problems and areas for future research to cover gaps in the knowledge base.



Source: BRS 2004

Figure 2. Landuse and vegetation cover types in the study region.

1.2.2 CARBON ASSESSMENTS

Unlike most biomass crops where yields of products are readily measured at harvest times, in-situ carbon crops are more difficult to assess. Two main approaches may be used to determine the yields of these carbon crops: 1/ physical measurements supported by destructive subsamples or reliable estimation techniques (i.e. allometrics); or 2/ process or simulation models of predicted carbon yields.

For physical carbon sequestration assessments whole plant biomass is required rather than the simple estimates of stemwood volumes used in classical forestry. To accomplish this, site productivity can be rapidly estimated using reliable relationships (allometrics) between plant measurements and biomass developed from measuring and destructively harvesting representative individual plants and species. By harvesting a small number of individuals of a species and exploring how it's morphological parameters, individual dry biomass and the dry biomass of component fractions (leaves, bark, branches and stemwood) it is possible to develop useful formulas that could be applied to other similar individuals. A set of simple measurements were developed in this way and these can be applied without the need for further destructive sampling. This study aimed to provide a range of these allometric equations for differing life forms and situations. A stemwood volume model was chosen because it was most comparable with the process-based stemwood models used in the FullCAM program, however, many of other models developed in this study are equally as valid and reliable. It is intended that many of the data sets produced from this study could be used as parameter sets within FullCAM and provide improvements to the default parameter sets currently included within that program. Physical and time constraints have limited these assessments to only above ground components of plant biomass. Assessments of growth and carbon sequestration rates for woodlots and windbreaks of both environmental plantings and monocultures will also permit comparisons of sequestration potential of these differing planting regimes. Assessments of productivity at the local level can be also be amalgamated to provide greater accuracy in regional estimates of productivity and carbon sequestration potential.

The National Carbon Accounting Toolbox (NCAT) contains a process-based model (Full Carbon Accounting Model [FullCAM] Version 3.1) to estimate carbon sequestration rates and carbon balances. FullCAM also integrates data on land cover change, land use and management, climate, plant productivity and soil carbon over a thirty year period from 1970 (Dept of Climate Change, 2009) to assist in estimating carbon balances. In this study, the default environmental planting and woodlot forestry models within FullCAM are evaluated for a number of locations across the study area. To test the reliability of NCAT/FullCAM models (and their default parameter sets) this study aims to provide comparisons between NCAT/FullCAM model predictions and physical site assessments of productivity for a range of species and sites.

1.2.3 CARBON ACCOUNTING

Australia's National Carbon Accounting System aims to account for greenhouse gas emissions from land based sectors in Australia, and to ensure credibility under international agreements on greenhouse gas emissions. The Australian Government Department of Climate Change (DCC) has invested strongly over the past decade into the building of a scientifically advanced National Carbon Accounting Toolbox (NCAT) and the FullCAM carbon models.

These predictive models attempt to provide estimates for Australia’s greenhouse gas emissions and carbon sinks associated with Australian land systems under a future national Emission Trading Scheme (e.g. Carbon Pollution Reduction Scheme). Carbon accounting methodologies and growth rates for commercial forestry species in higher rainfall regions (>650mm) are now well established within these national carbon accounting schemes and models. However, this information for other native woody crop species, and productivity rates of environmental plantings for medium to lower rainfall regions (<650mm), is currently poorly developed in South Australia and nationally. Consequently, a number of users of the system (DWLBC, SA Water, Greening Australia and Canopy) in conjunction with CSIRO have called for additional sampling studies to produce a more comprehensive dataset for use in carbon accounting models. Previous DWLBC FloraSearch studies have illustrated that currently available national models can misrepresent carbon sequestration rates in lower rainfall regions by over 50% (Hobbs *et al.* 2009a). To permit the use of this national carbon accounting system and associated models, the South Australia government must be able to accurately quantify growth rates and provide carbon calibration data for revegetation activities in the state.

DWLBC has previously invested resources and developed collaborations with the Future Farm Industries CRC and the Rural Industry Research and Development Corporation (RIRDC) to undertake two studies on carbon sequestration rates and evaluation techniques for two areas within SA (Upper South East [Hobbs *et al.* 2006, 2009a] & River Murray Dryland Corridor [Hobbs & Bennell 2005]). The FloraSearch team has collaborated extensively with CSIRO in recent years on other national studies of native plant growth rates and carbon sequestration modelling (Polglase *et al.* 2008). From these investments and collaborations DWLBC has developed a unique capacity to undertake scientifically rigorous evaluations of carbon sequestration rates of native plant species in lower rainfall regions.

While the ultimate objective of the State Government is to develop a comprehensive understanding of carbon sequestration rates from all revegetation plantings in South Australia, the most cost-effective approach will be to develop sound methodologies and information in regions and plant communities with the highest priority for investment. Landscapes currently utilised for dryland agriculture in the lower rainfall regions (300-650mm) have the greatest viability and prospects for investments in revegetation for carbon sequestration, sustainable woody crop production and beneficial environmental outcomes. The development of sustainability markets in South Australia for carbon sequestration in woody crops and environmental plantings requires a scientifically rigorous evaluation process and an understanding of the productivity and carbon sequestration rates of revegetation activities.

2. IDENTIFICATION OF LOCAL REVEGETATION SPECIES AND ACTIVITIES

2.1 LOCAL NATIVE SPECIES

There are many biodiversity and practical site-suitability benefits of utilising common local native species for revegetation. This of course is affected by ease of propagation, targeted diversity of plant species and complexity of plant stratum being created. To determine the most common local native species suited for the study area an analysis regional species frequency was conducted using herbarium and plant surveys records from the SA Department of Environment and Heritage.

To help identify changes in species composition caused by differing environmental conditions the study area was divided into three broad regions using the Interim Biogeographic Regions of Australia (IBRA) mapping as a guide (Figure 1). These regions included the Fleurieu subregion, the Tintinara subregion (including Murray Lakes & Coorong, and southern part Lowan Mallee subregions) and the Murray Mallee subregion (including northern part Lowan Mallee subregion). The Murray Lakes and Coorong subregion and parts of Lowan Mallee subregion were amalgamated into neighbouring broader groups based on climate and species similarities.

For revegetation in Australia to gain accreditation within most existing and proposed carbon trading schemes (e.g. Carbon Pollution Reduction Scheme) they typically must fit the criteria for compliant forests identified by the Kyoto protocol (Department of Climate Change 2008). The Australian definition of a forest for the purpose of Kyoto Protocol accounting specifies a post-1990 planted forest with minimum area of only 0.2 hectares, tree crown cover of 20 per cent and a tree height of two metres.

To make the output from the database more meaningful species lists were divided into three strata; Tall, Medium and Small, to represent overstorey, midstorey and understorey, based on maximum recorded height. Site variations across the study area made it difficult to classify species into an exact stratum position as a midstorey tree at one site may become the main overstorey species at another depending on the species mix and environment. All plants with a maximum recorded height < 2 metres were excluded as they are not currently compliant with the requirements for forest carbon sinks. Table 1 lists those indigenous species recorded ≥ 60 times within each subregion. Frequency of occurrence data for each species in each zone should largely coincide with its importance as a species for environmental revegetation in that area. Clearer evidence of commonly planted species comes from nursery sales / plant distribution data for the region.

Table 1. Common naturally occurring native woody plant species of the study region. Based on the frequency of occurrences from SA DEH herbarium and plant survey records (>60 records) by IBRA sub-regions.

Fleurieu IBRA Sub-region

Height	Species	Count	Height	Species	Count
Tall	*Eucalyptus odorata*	121	Medium	*Dodonaea viscosa*	114
Tall	*Eucalyptus fasciculosa*	108	Medium	*Eucalyptus phenax*	87
Tall	*Allocasuarina verticillata*	97	Medium	*Acacia paradoxa*	76
Tall	*Bursaria spinosa*	84	Small	*Calytrix tetragona*	81
Tall	*Eucalyptus porosa*	73	Small	*Acacia spinescens*	73
Tall	*Eucalyptus leucoxylon*	71	Small	*Olearia pannosa*	72
Medium	*Acacia pycnantha*	123			

Murray Mallee IBRA Sub-region

Height	Species	Count	Height	Species	Count
Tall	*Eucalyptus socialis*	297	Medium	*Acacia calamifolia*	87
Tall	*Melaleuca lanceolata*	289	Medium	*Eucalyptus brachycalyx*	84
Tall	*Eucalyptus dumosa*	235	Medium	*Exocarpos sparteus*	84
Tall	*Myoporum platycarpum*	141	Medium	*Eucalyptus calycogona*	82
Tall	*Eucalyptus oleosa*	116	Medium	*Acacia pycnantha*	82
Tall	*Eucalyptus porosa*	98	Medium	*Dodonaea viscosa*	80
Tall	*Callitris gracilis*	74	Medium	*Eucalyptus yalatensis*	73
Tall	*Pittosporum angustifolium*	69	Medium	*Santalum acuminatum*	72
Medium	*Eucalyptus leptophylla*	355	Medium	*Grevillea pterosperma*	65
Medium	*Eucalyptus incrassata*	310	Medium	*Acacia microcarpa*	65
Medium	*Melaleuca acuminata*	239	Small	*Babingtonia behrii*	196
Medium	*Leptospermum coriaceum*	237	Small	*Phebalium bullatum*	161
Medium	*Eucalyptus gracilis*	209	Small	*Calytrix tetragona*	154
Medium	*Melaleuca uncinata*	193	Small	*Acacia spinescens*	149
Medium	*Callitris verrucosa*	186	Small	*Beyeria lechenaultii*	107
Medium	*Allocasuarina muelleriana*	137	Small	*Senna artemisioides*	100
Medium	*Acacia rigens*	136	Small	*Aotus subspinescens*	93
Medium	*Hakea mitchellii*	125	Small	*Eutaxia microphylla*	91
Medium	*Acacia brachybotrya*	120	Small	*Acacia lineata*	76
Medium	*Callitris canescens*	96	Small	*Muehlenbeckia florulenta*	62
Medium	*Eucalyptus phenax*	93			

Tintinara IBRA Sub-region

Height	Species	Count	Height	Species	Count
Tall	*Eucalyptus diversifolia*	201	Medium	*Melaleuca brevifolia*	87
Tall	*Banksia marginata*	186	Medium	*Leucopogon parviflorus*	85
Tall	*Eucalyptus leucoxylon*	179	Medium	*Melaleuca acuminata*	78
Tall	*Melaleuca lanceolata*	151	Medium	*Hakea rostrata*	65
Tall	*Eucalyptus fasciculosa*	117	Medium	*Exocarpos syrticola*	63
Tall	*Acacia longifolia ssp. sophorae*	114	Small	*Correa reflexa*	279
Tall	*Bursaria spinosa*	110	Small	*Calytrix tetragona*	274
Tall	*Eucalyptus socialis*	80	Small	*Acacia spinescens*	268
Tall	*Myoporum insulare*	79	Small	*Banksia ornata*	263
Tall	*Eucalyptus dumosa*	67	Small	*Allocasuarina pusilla*	225
Medium	*Allocasuarina muelleriana*	292	Small	*Babingtonia behrii*	212
Medium	*Eucalyptus incrassata*	287	Small	*Adenanthos terminalis*	186
Medium	*Hakea mitchellii*	275	Small	*Hakea vittata*	128
Medium	*Eucalyptus leptophylla*	265	Small	*Grevillea ilicifolia*	119
Medium	*Leptospermum myrsinoides*	235	Small	*Calytrix alpestris*	85
Medium	*Leptospermum coriaceum*	229	Small	*Aotus subspinescens*	79
Medium	*Acacia pycnantha*	142	Small	*Eutaxia microphylla*	77
Medium	*Exocarpos sparteus*	140	Small	*Persoonia juniperina*	75
Medium	*Rhagodia candolleana*	113	Small	*Acacia myrtifolia*	70
Medium	*Melaleuca uncinata*	107	Small	*Pomaderris obcordata*	67
Medium	*Callitris verrucosa*	99	Small	*Choretrum glomeratum*	61

2.2 SPECIES USED IN REVEGETATION

In reality what has been planted at any location for revegetation purposes may not reflect the most common native species in the surrounding area. Species selections may be restricted to available nursery stock in any given year. Species that are easy to propagate can dominate the selections available; while ones that are common but are difficult to propagate may be in short supply. Revegetation by direct seeding also favours species that respond well to that treatment skewing species representation in some sites.

Emes *et al.* (2006) determined that Trees For Life (TFL) had provided a significant number of the plants that went into revegetation efforts around the state (29% of total). TFL provides 94% of the plants for revegetation in the Murray Mallee region and 30% of plants in the whole South East region. It must be noted that the smaller percentage of TFL plants in the South East region is due to the dominance of commercial forestry (e.g. Tasmanian Bluegum) plantings in Emes' regional tallies. Due to differences in zone boundaries, it is difficult accurately determine the total number of plants or the proportion of TFL stock used in the study region. However, TFL is clearly the dominant provider of trees and shrubs for environmental plantings (non-commercial) in the Southern Murray-Darling Basin region.

Unlike many organisations that produce native plants for revegetation, Trees For Life (TFL) targets species production for well defined zones (Figure 3). A list of species for each of these zones is available each year and land holders are encouraged to place orders for seedlings based on those lists.

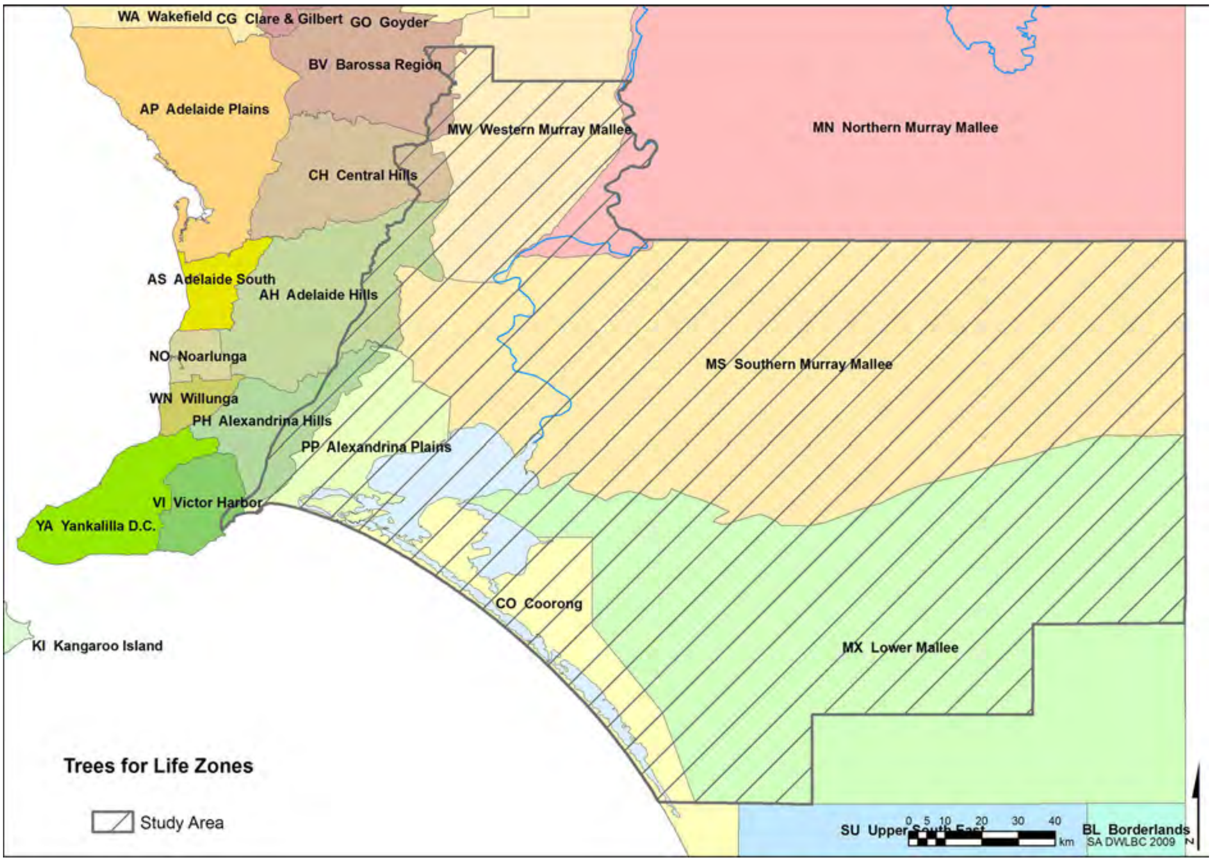


Figure 3. Trees For Life zones in the Southern Murray-Darling Basin region.

Trees For Life kindly permitted access to their plant sales and distribution data for the ten year period from 1999 to 2008 from the TFL zones within the study area (Bernie Odomei, pers. comm.). To estimate the total number of each species planted within the study area:

- it was assumed TFL plants sales were uniformly distributed across each TFL zone;
- higher rainfall species were excluded (not suited to our study area); and
- sales data was proportioned based on the area of overlap between TFL zones and the study region.

Based on these calculations it is estimated that Trees For Life have dispatched 2.4 million trees into the study area over the last ten years (Table 2).

There is a high degree of concurrence between the most common species identified by analysis of DEH plant survey data (Table 1) and the most abundant species distributed by Trees For Life in the region (Table 2). It is also apparent, from comparisons of these lists, that generally few mid and lower story species, or common species difficult to propagate in nurseries (e.g. *Myoporum platycarpum*, *M. insulare*), have been distributed by TFL and planted in the region over the last 10 years. Some species (e.g. *Eucalyptus camaldulensis*, *E. viminalis*, *E. largiflorens*) appear to be planted more frequently than would be expected from analysis of their natural occurrence in the region.

Table 2. Top 50 most commonly planted species in the study area based on 10 years of Trees For Life plant seedling distribution data (1999-2008).

Species	Total Plants Last 10 Years
Eucalyptus fasciculosa	149,197
Allocasuarina verticillata	142,803
Eucalyptus leucoxylon	129,513
Eucalyptus camaldulensis	115,809
Acacia pycnantha	107,173
Melaleuca lanceolata	105,802
Dodonaea viscosa	71,591
Eucalyptus socialis	63,136
Eucalyptus porosa	59,291
Eucalyptus gracilis	51,282
Melaleuca halmaturorum	49,245
Eucalyptus incrassata	43,188
Callistemon rugulosus	39,858
Acacia paradoxa	39,350
Eucalyptus odorata	38,761
Eucalyptus dumosa	38,375
Eucalyptus leptophylla	36,347
Melaleuca uncinata	36,044
Acacia brachybotrya	33,784
Melaleuca acuminata	31,275
Eucalyptus oleosa	31,240
Eucalyptus viminalis	30,478
Eucalyptus largiflorens	30,061
Callitris gracilis	29,537
Eucalyptus calycogona	27,648
Acacia acinacea	26,595

Species	Total Plants Last 10 Years
Acacia ligulata	26,289
Acacia myrtifolia	24,068
Bursaria spinosa	23,577
Allocasuarina muelleriana	22,931
Pittosporum angustifolium	22,140
Eucalyptus brachycalyx	21,828
Acacia microcarpa	21,776
Acacia calamifolia	21,673
Leptospermum lanigerum	18,735
Leptospermum continentale	18,147
Eucalyptus phenax	17,861
Melaleuca decussata	16,868
Eucalyptus baxteri	14,692
Acacia retinodes	14,448
Acacia rigens	14,153
Acacia longifolia ssp. sophorae	12,786
Acacia hakeoides	12,385
Eucalyptus cosmophylla	11,970
Acacia dodonaeifolia	10,650
Banksia marginata	10,460
Xanthorrhoea semiplana	10,234
Acacia cupularis	9,668
Eucalyptus diversifolia	9,428
Allocasuarina striata	8,997
All other species (n=84)	422,554
Total of all species (n=134)	2,375,702

2.3 REVEGETATION ACTIVITIES

The SA Department of Water, Land and Biodiversity have previously commissioned studies to estimate the number of hectares of commercial farm forestry and environmental revegetation planted across the state based on nursery surveys of plant sales and their distribution (Emes *et al.* 2006). Results of these surveys for the period between 1999 and 2005 are collated and presented in Table 3 and Table 4. On average, approximately 6,300 ha of farm forestry and revegetation was planted annually, with indigenous environmental plantings (~4,300 ha/year) and saltbush (~950 ha/year) dominating revegetation activities in lower rainfall regions. However, saltbush plantings for grazing purposes are unlikely to be Kyoto-compliant for carbon accounting.

No precise information exists on the area that has been revegetated in the study region in recent years. Using the planting density estimates provided in Emes *et al.* (2006) of around a 1000 stems per hectare, and Trees For Life plant sales and distribution data, it is estimated that a minimum of ~2,400 hectares of environmental revegetation has been planted in the region over the last ten years, or ~240 hectares per year. This figure excludes areas planted with fodder shrubs (e.g. saltbush) and other extractive farm forestry (e.g. firewood, woodchips, lumber). This estimate largely concurs with an analysis of Emes' regional statistics, when total plant numbers are proportioned according to overlapping areas within the study region.

Table 3. Estimated area of revegetation (hectares) established in SA (1999 - 2005).

Type of revegetation	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Indigenous	3,767	4,052	3,912	4,058	4,539	5,128	4,632
Native (non indigenous)	1,052	381	794	330	95	191	920
Native Grasses	12	16	38	58	21	30	32
Farm Forestry	0	630	254	445	442	507	64
Saltbush	1,492	1,210	1,302	318	1,093	582	635
Tagasaste	572	207	72	10	54	11	6
Product Species (e.g. broombush)	14	47	12	98	33	69	30
Total	6,909	6,543	6,384	5,317	6,277	6,518	6,320

Source: Emes *et al.* (2006) Commercial forestry figures removed.

Table 4. Estimated area of revegetation and commercial forestry (hectares) established in each region of SA (1999 - 2005).

Region	1999	2000	2001	2002	2003	2004	2005
Eyre Peninsula	1,243	1,013	532	456	1,174	658	1,017
Northern Agric. Districts	455	648	497	494	508	347	640
Adelaide Plains	102	269	222	70	113	94	733
Metropolitan Area	511	67	218	296	68	422	407
Murray Darling Basin	403	961	837	629	801	1,259	773
Mount Lofty Ranges/ KI	2,338	6,499	2,286	3,183	2,012	6,089	4,081
South East	6,657	20,926	7,330	6,639	1,742	1,369	2,949
State (region unknown)	1,190	230	1,272	456	1,011	858	1,271
Total	12,899	30,613	13,194	12,223	7,429	13,744	11,871

Source: Emes *et al.* (2006) Commercial forestry figures Included.

2.4 RECOMMENDED SPECIES

2.4.1 PRODUCTIVE SPECIES

Monocultures of woodlot and other commercial extractive-use species are often more productive than environmental plantings at the same plant density (trees per hectare). Prior studies in lower-rainfall regions have identified a number of productive agroforestry species (Table 5) suited for use in commercial revegetation plantations (Hobbs *et al.* 2009a, Bennell *et al.* 2008, Hobbs *et al.* 2006, Hobbs & Bennell 2005, Harwood *et al.* 2001 & 2005, Fairlamb & Bulman 1994). Many of the species listed in Table 5 are widely applicable for this study region. However, some species listed have more specific climate and soil preferences. To guide potential growers within the study area, generalised species preferences for two broad environmental regions based on their dominant climatic conditions and soils are also indicated (Table 5). Local expert advice should be sought from revegetation and farm forestry consultants and groups to ensure optimal species choices for any site. This table also identifies the major product groups to which these species are most suited for commercially-driven revegetation purposes (e.g. solid lumber/timber/posts/poles, pulp/woodfibres, fodder for livestock grazing, Eucalyptus oil, firewood/bioenergy)

The growth rate, lifespan and height of plants chosen for carbon sequestration crops influence their viability as a compliant carbon crop for most carbon trading schemes. Although many *Acacia* species (wattles) are highly productive in their early stages, some do not persist over longer timeframes, and many saltbushes (e.g. *Atriplex nummularia*) may not achieve a Kyoto-compliant height class (e.g. ≥ 2m). Monocultures of these short-lived and lower height species may not be suitable for typical carbon crop contracts.

Table 5. Woody species suitable for production-oriented revegetation in major environmental regions of the Southern Murray-Darling Basin region.

Recommended Species	Common name	E. Fleurieu / Tintinara / Murray Lakes & Coorong	Murray Mallee / Lowan Mallee	Product Group#
Acacia decurrens	black wattle	✓		B,F
Acacia lasiocalyx	silver wattle	✓		B
Acacia mearnsii	black wattle	✓		B,F
Acacia pycnantha	golden wattle	✓	✓	B
Acacia retinodes	wirilda	✓		B
Allocasuarina luehmannii	bull-oak	✓	✓	L,B
Allocasuarina verticillata	drooping she-oak	✓	✓	B
Atriplex nummularia	old man saltbush	✓	✓	F
Casuarina glauca	grey she-oak	✓		L,B
Casuarina obesa	swamp she-oak	✓		L,B
Corymbia citriodora	lemon-scented gum	✓		L,O,B
Corymbia henryi	spotted gum	✓		L,B
Corymbia maculata	spotted gum	✓		L,B
Corymbia variegata	spotted gum	✓		L,B
Eucalyptus angustissima	narrow-leaved mallee	✓	✓	O,B
Eucalyptus aromaphloia	scent bark	✓		O,B
Eucalyptus astringens	brown mallet	✓	✓	B
Eucalyptus baxteri	brown stringybark	✓		B

Recommended Species	Common name	E. Fleurieu / Tintinara / Murray Lakes & Coorong	Murray Mallee / Lowan Mallee	Product Group#
Eucalyptus botryoides	southern mahogany	✓		L,B
Eucalyptus brachycalyx	Chindoo mallee		✓	B
Eucalyptus camaldulensis	river red gum	✓	✓	L,O,B
Eucalyptus cladocalyx	sugargum	✓	✓	P,B
Eucalyptus cneorifolia	KI narrow-leaved mallee	✓	✓	O,B
Eucalyptus cornuta	yate	✓		L,B
Eucalyptus cyanophylla	blue-leaved mallee		✓	B
Eucalyptus cypellocarpa	mountain grey gum	✓		L,B
Eucalyptus diversifolia	coastal white mallee	✓	✓	B
Eucalyptus dumosa	white mallee		✓	B
Eucalyptus gardneri	blue mallet	✓	✓	B
Eucalyptus globulus	Tasmanian bluegum	✓		L,O,B
Eucalyptus gomphocephala	tuart	✓		B
Eucalyptus grandis	flooded gum	✓		L,P,B
Eucalyptus horistes	oil mallee		✓	O,B
Eucalyptus kochii	oil mallee		✓	O,B
Eucalyptus largiflorens	black box	✓	✓	B
Eucalyptus leucoxylon	SA bluegum	✓	✓	B
Eucalyptus loxophleba	Yorke gum	✓	✓	O,B
Eucalyptus macrorhyncha	red stringybark	✓		L,B
Eucalyptus melliodora	yellow box	✓	✓	L,B
Eucalyptus microcarpa	grey box	✓		B
Eucalyptus nortonii	long-leaved box	✓		L,B
Eucalyptus obliqua	messmate stringybark	✓		L,B
Eucalyptus occidentalis	swamp yate	✓	✓	L,P,B
Eucalyptus oleosa	red morell	✓	✓	O,B
Eucalyptus ovata	swamp gum	✓		P,B
Eucalyptus petiolaris	Eyre Peninsula bluegum	✓	✓	B
Eucalyptus polyanthemos	red box	✓		L,B
Eucalyptus polybractea	blue mallee	✓	✓	O,B
Eucalyptus porosa	mallee box	✓	✓	O,P,B
Eucalyptus punctata	grey gum	✓		L,B
Eucalyptus rudis	flooded gum	✓		L,B
Eucalyptus saligna	Sydney bluegum	✓		L,B
Eucalyptus salmonophloia	salmon gum	✓	✓	L,B
Eucalyptus sideroxylon	red ironbark	✓	✓	L,B
Eucalyptus socialis	red mallee		✓	B
Eucalyptus spathulata	swamp mallet	✓	✓	B
Eucalyptus tereticornis	forest red gum	✓		L,B
Eucalyptus tricarpa	red ironbark	✓	✓	L,B
Eucalyptus viminalis	manna gum	✓		L,P,B
Melaleuca armillaris	bracelet honey myrtle	✓		B

#Product category codes: L= Lumber/timber; P= Pulp/fibre; F= Fodder; O= Eucalyptus Oil; B= Bioenergy/firewood

2.4.2 ENVIRONMENTAL PLANTINGS

Non-extractive use revegetation activities in the region are typically focussed on providing natural resource management or other environmental benefits. These environmental plantings can be use for the reduction of groundwater recharge, dryland salinity, saline river discharges, wind erosion, biodiversity loss, livestock protection and amenity purposes. In the past, these permanent environmental plantings of native trees and shrubs did not have a direct financial benefit to the landholder, but provided longer-term benefits to farming systems and the wider community.

Most environmental plantings in the study region have opted to use local indigenous (see Table 1) or other Australian native species in block and windbreak plantings. SA Trees For Life (TFL) has been particularly active within the region and is a dominant provider of tubestock plants to local farmers (see Table 2).

Species lists from SA Department of Environment databases (Table 1), Trees For Life (Table 2, Appendix A) and recent surveys (Table 6, Appendix B) indicate a range of species suitable for environmental plantings within the study area. Local site conditions (e.g. rainfall, soils) and the intended purpose of the environmental planting will dictate the most appropriate species selections. Local site assessments and expert advice should be sought to promote success of any investments in revegetation.

The carbon sequestration potential of environmental plantings may be increased through the use of a greater proportion of fast growing and productive species in the planting mix. This approach may increase the tradeable carbon value of these plantings but may also conflict with other intended values (e.g. biodiversity) of the mixed environmental planting. Ultimately it is the decision of the investors and planning authorities to determine the right blend of species for any environmental revegetation. Monocultures (or limited species blends) of most productive species may provide substantive increases in tradeable carbon stocks and some natural resource management benefits (e.g. recharge reduction) but have lower biodiversity values.

3. DEVELOPMENT OF CARBON ASSESSMENT METHODS

3.1 ASSESSING ABOVE-GROUND PLANT BIOMASS

Evaluations of the carbon sequestration potential of revegetation sites in lower rainfall areas has been hindered by a lack of productivity data for many of the individual species native to those areas and for mixed environmental plantings in general. This study provides refinements in non-destructive methodologies for assessing above-ground plant biomass, and sets of reliable parameters which can be applied to existing models to assess carbon sequestered within lower rainfall plantations.

The accuracy of the carbon accounting models (e.g. National Carbon Accounting Toolbox NCAT FullCAM) rely heavily on the quality of species/site parameters that drive model calculations. Within NCAT FullCAM, species information and model parameters for lower rainfall species and environmental plantings are typically scant, derived from non-applicable situations or are non existent within the package. Default NCAT FullCAM Environmental Plantings models are typically poor predictors of growth and carbon sequestration in lower rainfall regions of SA (Hobbs *et al.* 2009a, see later sections). For most lower-rainfall revegetation options, new species and environmental plantings parameter values for FullCAM models must be manually inserted by the user before the model can function with any greater degree of accuracy than that obtained from the default settings.

To supplement the currently limited data within carbon accounting models this study has undertaken work on plant biometrics and productivity surveys from a range revegetation sites and species within the study area. This work includes measuring and destructive sampling a number of plants so that relationships (allometric models) between simple plant height by stem area measurements and above-ground plant biomass (and carbon content) could be determined. These allometric models have then been used to estimate plant biomass and carbon sequestration rates at many sites across the study area. Additional information was also collected from the destructive samples to determine biomass ratios (or fractions) between *Stemwood : Bark : Branches : Leaves* for a wide range of species common to revegetation sites in the region to match requirement of the NCAT FullCAM models. This study also aims to calibrate spatial empirical models of productivity from soil and climate information (BiosEquil) to estimate likely carbon sequestration rates in the region.

The following sections report on:

- Allometric relationships developed to allow rapid assessment of plant biomass and carbon content in SA revegetation sites;
- Assessments of growth and carbon sequestration rates in woodlots, windbreaks and environmental plantings in the Southern Murray-Darling Basin region (see Figure 4);
- Comparisons of field observations of productivity and carbon sequestration with default NCAT FullCAM model predictions; and
- Regional estimates of productivity and carbon sequestration from revegetation in the Southern Murray-Darling Basin region.

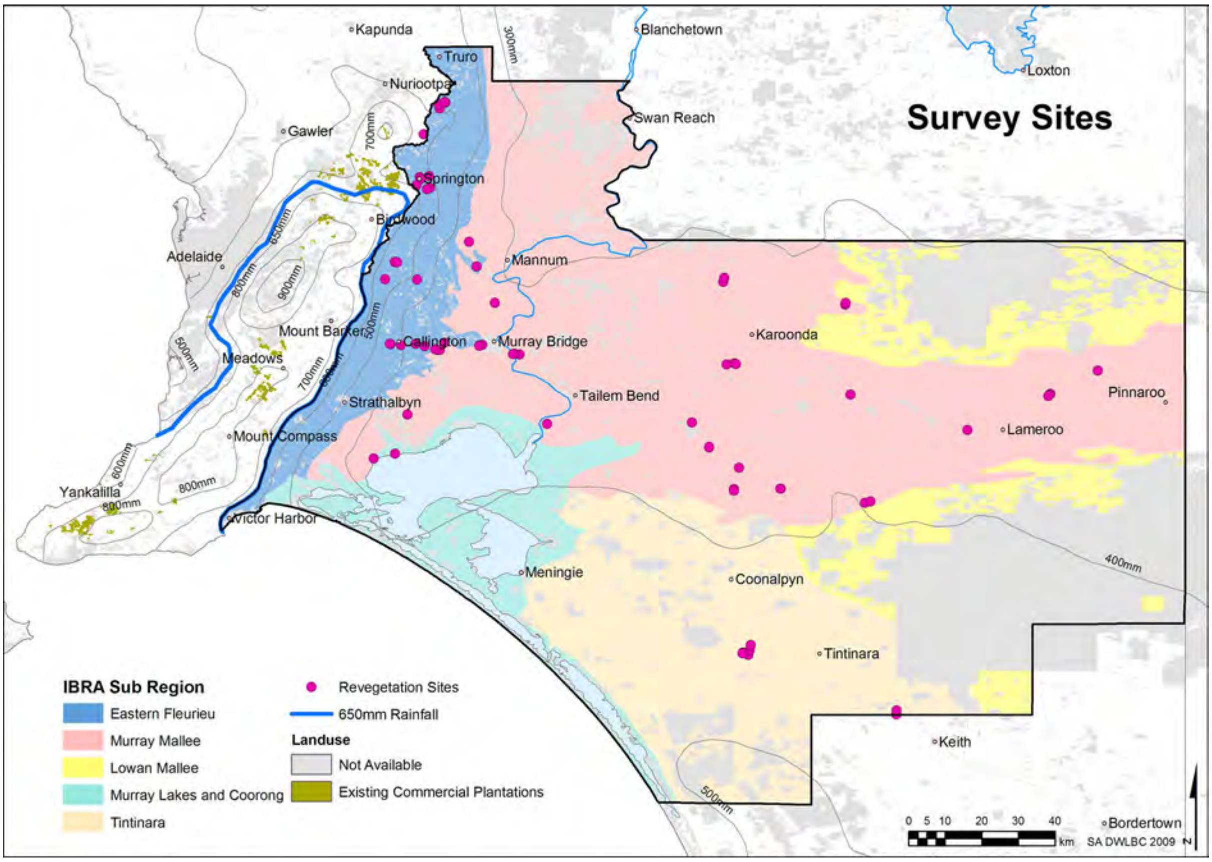


Figure 4. Location of survey sites for destructive sampling and productivity measurements in the Southern Murray-Darling Basin region.

3.2 ALLOMETRIC ASSESSMENT TECHNIQUES

Most existing assessments of plantation productivity are focussed on assessing height and stem diameters. These measures are suitable for estimating stemwood volumes for classical forestry where the focus is on the recoverable solid timber. For carbon sequestration assessments and many biomass industries the focus is on the whole plant biomass and the relative proportions of stemwood, bark, twig and leaf fractions. The dry weights of these fractions can then be used to calculate carbon sequestration rates, and provide accurate estimates of the carbon sequestered by the entire plant. Carbon accounting and other biomass industry productivity assessments require assessment methodologies that can be used to rapidly and reliably assess both total dry biomass and carbon content.

Allometrics is a commonly used technique to non-destructively assay plantation productivity from a limited number of measurements (biometrics). In classical forestry industries, these allometric models are often based on measurements of tree diameter at breast height or basal area calculations (± tree height) to determine stemwood volumes or biomass, with models often being species specific (Snowdon *et al.* 2004, 2002, Grierson 2000, Kiddle *et al.* 1987). However, allometric models based on high rainfall forestry trees are unlikely to be reliable predictors of productivity for the mallee and shrub lifeforms more suited to lower rainfall regions. New allometric models must be developed to non-destructively and efficiently assess plantations of low rainfall agroforestry species. To maintain consistency with NCAT FullCAM modelling parameters current analyses have mainly focussed on relationships between stemwood volume and total plant dry biomass.

3.2.1 SAMPLING

Several new plant species were selected and destructively sampled (39 individual plants) from dryland environments in the Southern Murray-Darling Basin regions from forestry and revegetation sites of known age (Neumann *et al.* 2010) to supplement information from prior work in the River Murray Corridor and Upper South East regions (101 individual plants) (see Table 6; Hobbs & Bennell 2005; Hobbs *et al.* 2006). Plant species were chosen to represent those species most highly ranked for agroforestry development (Hobbs *et al.* 2009a) and environmental plantings for the region. The species selected included forestry tree species, small trees and mallees, and shrubs. A minimum of 3 individuals of each species and location were chosen for detailed biometric measurements of plant morphology and biomass sampling.

Individual plant measurements included height, crown width, distance to neighbouring plants, stem count and circumference at two lower section heights (basal and intermediate: 0.5m and 1.3m for trees and mallees; and 0.2m and 0.8m for shrubs), and visual ranking of leaf density using reference photographs (8 classes). The stemwood volume (outer bark) of each plant was calculated from stem height and circumferences using standard forestry formulas for tree volumes of each stemwood section (1. lower section – cylinder volume; 2. mid section - Smalian's frustrum of a paraboloid volume, and 3. upper section - paraboloid volume).

Samples of wood and bark were taken from each basal and intermediate height for each plant with an additional sample taken half way between the intermediate height and the top of the plant. The diameter of the wood (minus bark) and bark thicknesses were measured across the north-south axis of the sample, and used to determine the bark proportion of the outer bark stemwood volume. The green weight of the wood only and bark only samples were measured immediately. The green volume of the wood only samples was determined by displacement in water, and the separate wood and bark samples were oven dried to a steady dry-weight to determine wood basic density and the moisture content of each sample component.

The whole of each plant was destructively sampled and sorted into three biomass fractions: 1. stemwood and bark (>20mm diameter); 2. twig and bark (2-20mm diameter); and 3. leaf, fine twig and bark (<2mm diameter) and each fraction weighed immediately. Samples (>200g) from each green biomass fraction was weighed immediately, oven dried to a steady dry-weight and reweighed to determine their moisture content. The total dry biomass of each plant was determined from the green weight of each biomass fraction and the observed moisture content of oven-dried subsamples. Whole plant carbon contents were calculated from the sum of dry biomass fractions and the commonly accepted generic conversion factor of 0.5 (Snowdon *et al.* 2002).

Allometric relationships between simple measurements of height, crown area, basal stem area, leaf density, stemwood volumes and observations of total green biomass (including stemwood and bark; twig and bark; and leaf, fine twig and bark) were plotted, explored visually and tested using linear and non-linear regressions. Interactions between these simple measurements and lifeform or plant genera groupings were also evaluated.

Table 6. Plant species measured and destructively sampled for biometric studies, including some key plant characteristics (mean values, n=3).

Species (plantation type)	Rainfall [mm]	Age [years]	Height [m]	Lifeform [Tree/Mallee/Shrub]	Crown Width [m]	Crown Area [m²]	Foliage Density [%]	Basal Area [cm²] at 0.5m height	Stemwood Volume x 1000 [m³]	Basic Density [kg/m³] (n=9)	Total Dry Biomass [kg/plant]	Proportion Dry Biomass by Weight			
												Wood	Bark	Branch	Leaf
Acacia ligulata (block 1)	247	8.5	1.80	S	3.0	6.9	81	62[#2]	7.8	840	15.9	0.06	0.03	0.67	0.23
Acacia ligulata (block 2)	261	13.8	3.23	S	4.4	15.7	62	182	28.9	820	52.9	0.63	0.20	0.12	0.05
Acacia mearnsii (block)	492	12.5	9.90	T	3.3	9.7	57	179	82.4	650	73.5	0.67	0.15	0.11	0.07
Acacia oswaldii (block 1; n=2)	340	12.5	2.03	S	2.9	6.6	95	132[#2]	13.4	859	25.8	0.18	0.04	0.48	0.30
Acacia oswaldii (block 2)	253	8.5	1.40	S	2.1	3.5	57	29[#1]	1.5	878	4.6	0.08	0.03	0.60	0.29
Acacia pycnantha (block 1)	340	13.5	4.10	T	3.8	11.5	43	68	11.1	785	32.4	0.47	0.12	0.26	0.15
Acacia pycnantha (block 2)	387	7.0	3.37	S	3.2	8.3	86	96	14.5	675	35.2	0.34	0.10	0.22	0.34
Acacia rigens (block 1)	340	12.5	2.60	S	2.1	3.7	100	92	10.0	776	24.3	0.22	0.07	0.37	0.33
Acacia rigens (block 2)	357	31.2	2.78	S	7.0	40.0	71	448	44.3	874	168.6	0.49	0.11	0.22	0.18
Allocasuarina verticillata (block 1)	340	12.5	5.67	T	3.3	8.4	43	183	41.4	723	48.3	0.52	0.17	0.18	0.13
Allocasuarina verticillata (block 2)	492	10.9	9.60	T	4.9	19.1	38	484	173.9	724	202.3	0.67	0.16	0.07	0.10
Atriplex nummularia (block 1)	251	7.5	1.90	S	3.2	8.2	81	133[#1]	7.8	793	16.9	0.15	0.01	0.66	0.18
Atriplex nummularia (block 2)	466	3.0	1.77	S	2.5	4.8	86	67[#2]	6.3	626	11.6	0.39	0.02	0.42	0.22
Callitris gracilis (block)	253	8.5	2.13	S	1.4	1.5	76	17[#2]	1.9	619	2.5	0.10	0.03	0.38	0.48
Callitris verrucosa (block)	357	31.3	4.60	S	4.6	16.9	86	642	113.7	642	160.8	0.54	0.09	0.19	0.19
Cor*ymbia maculata* (block)	492	10.8	7.97	T	3.2	7.8	52	114	32.0	601	23.8	0.41	0.30	0.13	0.16
Dodonea viscosa (block)	261	13.8	2.91	S	3.0	7.2	29	141	14.2	830	20.1	0.64	0.14	0.15	0.07
Eucalyptus calycogona (block)	261	8.5	2.70	M	2.5	5.1	57	75[#2]	5.2	775	17.0	0.23	0.07	0.26	0.44
Eucalyptus camaldulensis (windbreak)	460	10.7	11.20	T	4.9	19.1	57	450	172.4	483	92.3	0.59	0.18	0.10	0.12
Eucalyptus cladocalyx (block)	460	6.7	7.07	T	2.7	5.7	71	118	30.2	634	31.0	0.39	0.17	0.21	0.23
Eucalyptus cladocalyx (windbreak)	460	6.7	5.83	T	2.4	4.5	86	142	28.5	600	34.4	0.43	0.15	0.17	0.25
Eucalyptus cyanophylla (block)	261	9.5	2.88	M	2.5	5.2	62	62	5.9	787	22.3	0.20	0.10	0.26	0.44
Eucalyptus diversifolia *(mixed block)*	460	12.7	5.50	M	4.3	15.6	66	208	51.6	581	91.7	0.33	0.06	0.41	0.20

Species (plantation type)	Rainfall [mm]	Age [years]	Height [m]	Lifeform [Tree/Mallee/Shrub]	Crown Width [m]	Crown Area [m²]	Foliage Density [%]	Basal Area [cm²] at 0.5m height	Stemwood Volume x 1000 [m³]	Basic Density [kg/m³] (n=9)	Total Dry Biomass [kg/plant]	Proportion Dry Biomass by Weight			
												Wood	Bark	Branch	Leaf
Eucalyptus dumosa (block)	387	12.0	3.25	M	2.7	6.5	62	63	7.8	767	20.4	0.35	0.12	0.33	0.20
Eucalyptus globulus (block)	460	10.7	13.80	T	3.5	10.1	57	224	126.1	530	90.8	0.63	0.10	0.09	0.17
Eucalyptus gracilis (block 1)	261	6.6	1.77	M	2.0	3.0	91	31[#1]	1.4	830	6.1	0.05	0.02	0.36	0.57
Eucalyptus gracilis (block 2)	357	31.2	10.03	M	7.5	47.6	71	701	318.0	908	422.1	0.75	0.14	0.06	0.05
Eucalyptus incrassata (block)	357	31.2	5.79	M	7.8	47.7	43	423	97.6	824	221.5	0.61	0.12	0.14	0.13
Eucalyptus incrassata (mixed block)	460	12.7	3.55	M	4.3	14.8	71	132	19.0	726	50.9	0.31	0.12	0.29	0.28
Eucalyptus largiflorens (windbreak)	261	10.5	3.77	M	2.6	5.4	52	95	13.0	687	19.2	0.40	0.16	0.22	0.22
Eucalyptus leptophylla (block)	357	31.3	6.57	M	9.2	67.9	71	665	205.7	844	388.8	0.66	0.10	0.13	0.11
Eucalyptus leucoxylon (block)	492	10.7	9.70	T	2.9	6.6	43	172	61.1	657	42.7	0.54	0.27	0.07	0.12
Eucalyptus occidentalis (block)	460	5.7	9.97	T	3.3	8.7	57	238	95.9	538	68.1	0.64	0.10	0.09	0.17
Eucalyptus occidentalis (windbreak)	460	6.7	8.57	T	2.3	4.5	57	133	49.7	604	39.8	0.57	0.10	0.12	0.21
Eucalyptus oleosa (block 1)	261	10.4	2.93	M	3.5	9.9	76	84	8.4	793	25.1	0.24	0.09	0.27	0.39
Eucalyptus oleosa (block 2)	357	31.2	6.43	M	9.2	67.2	57	555	158.8	841	343.2	0.61	0.12	0.12	0.15
Eucalyptus porosa (block 1)	340	12.4	4.50	M	3.6	17.9	71	218	34.3	663	55.4	0.43	0.13	0.18	0.26
Eucalyptus porosa (block 2)	261	9.5	2.37	M	3.1	7.8	76	67	4.4	668	11.6	0.19	0.06	0.39	0.35
Eucalyptus porosa (block 3)	387	6.7	3.90	M	3.8	11.7	71	93	11.6	577	23.3	0.29	0.08	0.26	0.37
Eucalyptus socialis (block)	261	10.5	3.30	M	4.5	16.0	71	136	16.1	757	51.5	0.25	0.09	0.30	0.36
Eucalyptus socialis (windbreak)	357	26.1	5.57	M	7.1	39.5	71	517	107.0	778	185.9	0.64	0.14	0.11	0.12
Eucalyptus viminalis (block)	460	5.7	11.07	T	3.9	12.6	52	312	129.9	487	75.4	0.55	0.15	0.09	0.21
Melaleuca lanceolata (block)	357	31.2	4.00	S	5.0	20.5	71	487	106.6	776	148.8	0.56	0.14	0.16	0.14
Melaleuca uncinata (block)	340	12.4	1.83	S	1.7	2.3	100	73[#1]	7.3	711	10.7	0.10	0.03	0.46	0.41
Melaleuca uncinata (windbreak)	357	16.3	2.27	S	2.2	4.0	71	88[#2]	10.1	769	11.6	0.40	0.09	0.28	0.24
Pittosporum phylliraeoides (block)	357	16.2	2.47	S	2.3	4.3	43	97	13.2	754	18.0	0.51	0.14	0.25	0.11
Senna artemis. ssp. coriacea (block)	261	13.4	1.61	S	2.1	3.5	62	34	2.7	955	5.4	0.00	0.00	0.65	0.35

[#1] basal area at 0.1m height, [2] 0.2m

3.2.2 BIOMETRICS

One hundred and forty individual plants were measured and destructively sampled for the combined biometric studies. These represent 32 species (see Table 6) and include 2 generic species groupings (18 Eucalypts, 14 non-Eucalypts) and 3 lifeform types (10 tree, 11 mallee, 11 shrub forms). Important agroforestry species were sampled more than once (e.g. Sugar gum [*Eucalyptus cladocalyx*], Swamp Yate [*E. occidentalis*], Mallee Box [*E. porosa*], Old Man Saltbush [*Atriplex nummularia*]) from different ages and plantations designs (e.g. blocks and windbreaks). The age of plantations sampled for this study ranged from 3 year old fodder shrubs to a maximum of 31 years for some trees and mallees (overall average 14 years). Table 6 provides a summary of a number of key plant characteristics for species destructively sampled in the biometric studies. Individual plant morphological measurements were converted into a range of biometric parameters commonly used to predict above ground plant biomass. These include plant height, basal stem area (outer bark), crown area (from crown widths), stemwood volume (outer bark; from plant height and 2 stemwood area observations), wood density and foliage density. Foliage density classes were expressed as a percent of maximum density (i.e. very dense 100%, dense 86%, moderately dense 71%, moderate 57%, moderately sparse 43%, sparse 29%, very sparse 14%, no leaves 0%).

3.2.3 ALLOMETRIC RELATIONSHIPS

Allometric relationships between these morphological parameters and individual plant dry biomass were explored. Separate analyses were conducted for total dry biomass and dry biomass fractions: 1/ wood (>20mm diameter) 2/ stemwood bark; 3/ branch and twig (2-20mm diameter) and bark; and 4/ leaf, fine twig (<2mm diameter) and bark. The interaction of species groups and lifeform classes on biomass predictions from morphological measurements are often significant (Hobbs *et al.* 2006).

Plots and results illustrate simple relationships between many parameters (and their interactions) and dry biomass values (Figure 5 to Figure 9). Regression relationships between stemwood volume and above-ground dry biomass for different lifeform by species group and plant components are represented by the simple formulas presented in Table 7. The resulting generalised model (r^2=0.86) of total dry biomass (kg/plant) from stemwood volume (outer bark) measurements (with no species group or lifeform interactions) is presented in Figure 5. However, by including 4 lifeforms by species group classes (1/ Tree Eucalypt, 2/ Tree Non-Eucalypt, 3/ Mallee Eucalypt, 4/ Shrub Non-Eucalypt) as model interactions stronger predictions can be made (r^2=0.90) of total dry biomass (kg/plant) from stemwood volume (outer bark) calculations.

Table 7. Simple regression relationships between stemwood volume and total above-ground dry biomass for different lifeform by species group.

Species and Lifeform Group	Obs. [n]	Model Fit [r^2]	Dry Biomass [kg/plant]
Total Above-ground Plant Biomass			
All Species (Unsorted)	140	0.86	= 2.0828 x (Stemwood Volume x 1000 [m³])$^{0.8720}$
Tree (Eucalypt)	27	0.90	= 2.1908 x (Stemwood Volume x 1000 [m³])$^{0.7431}$
Tree (Non-Eucalypt)	12	0.87	= 2.3894 x (Stemwood Volume x 1000 [m³])$^{0.8165}$
Mallee (Eucalypt)	51	0.94	= 2.3733 x (Stemwood Volume x 1000 [m³])$^{0.9208}$
Shrub (Non-Eucalypt)	50	0.88	= 1.3824 x (Stemwood Volume x 1000 [m³])$^{1.0195}$
Stemwood Biomass (excluding bark)			
All Species (Unsorted)	140	0.80	= 0.8649 x (Stemwood Volume x 1000 [m³])
Tree (Eucalypt)	27	0.93	= 0.5591 x (Stemwood Volume x 1000 [m³])$^{0.9242}$
Tree (Non-Eucalypt)	12	0.91	= 0.7324 x (Stemwood Volume x 1000 [m³])
Mallee (Eucalypt)	51	0.91	= 1.0507 x (Stemwood Volume x 1000 [m³])
Shrub (Non-Eucalypt)	50	0.74	= 0.8320 x (Stemwood Volume x 1000 [m³])
Bark Biomass			
All Species (Unsorted)	140	0.85	= 0.1450 x (Stemwood Volume x 1000 [m³])
Tree (Eucalypt)	27	0.66	= 0.5301 x (Stemwood Volume x 1000 [m³])$^{0.6065}$
Tree (Non-Eucalypt)	12	0.92	= 0.1605 x (Stemwood Volume x 1000 [m³])
Mallee (Eucalypt)	51	0.94	= 0.1611 x (Stemwood Volume x 1000 [m³])
Shrub (Non-Eucalypt)	50	0.70	= 0.1633 x (Stemwood Volume x 1000 [m³])
Branch and Twig Biomass			
All Species (Unsorted)	140	0.46	= 1.4947 x (Stemwood Volume x 1000 [m³])$^{0.4919}$
Tree (Eucalypt)	27	0.36	= 0.9568 x (Stemwood Volume x 1000 [m³])$^{0.4142}$
Tree (Non-Eucalypt)	12	0.35	= 2.8946 x (Stemwood Volume x 1000 [m³])$^{0.2770}$
Mallee (Eucalypt)	51	0.72	= 1.3691 x (Stemwood Volume x 1000 [m³])$^{0.6140}$
Shrub (Non-Eucalypt)	50	0.68	= 0.8914 x (Stemwood Volume x 1000 [m³])$^{0.7388}$
Leaf and Fine Twig Biomass			
All Species (Unsorted)	140	0.55	= 1.0738 x (Stemwood Volume x 1000 [m³])$^{0.5773}$
Tree (Eucalypt)	27	0.54	= 0.8647 x (Stemwood Volume x 1000 [m³])$^{0.5504}$
Tree (Non-Eucalypt)	12	0.58	= 0.8602 x (Stemwood Volume x 1000 [m³])$^{0.5272}$
Mallee (Eucalypt)	51	0.65	= 1.9850 x (Stemwood Volume x 1000 [m³])$^{0.5247}$
Shrub (Non-Eucalypt)	50	0.61	= 0.5252 x (Stemwood Volume x 1000 [m³])$^{0.7803}$

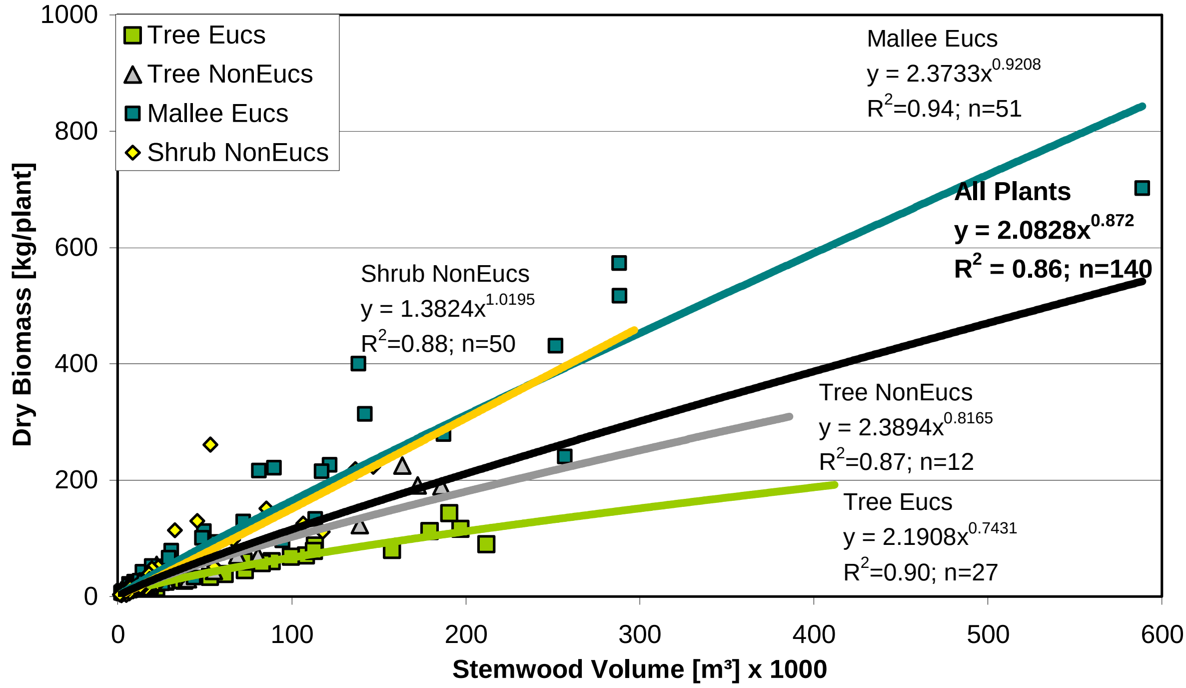


Figure 5. Allometric relationships between plant stemwood volume measurements and above ground dry biomass for trees, mallees and shrubs.

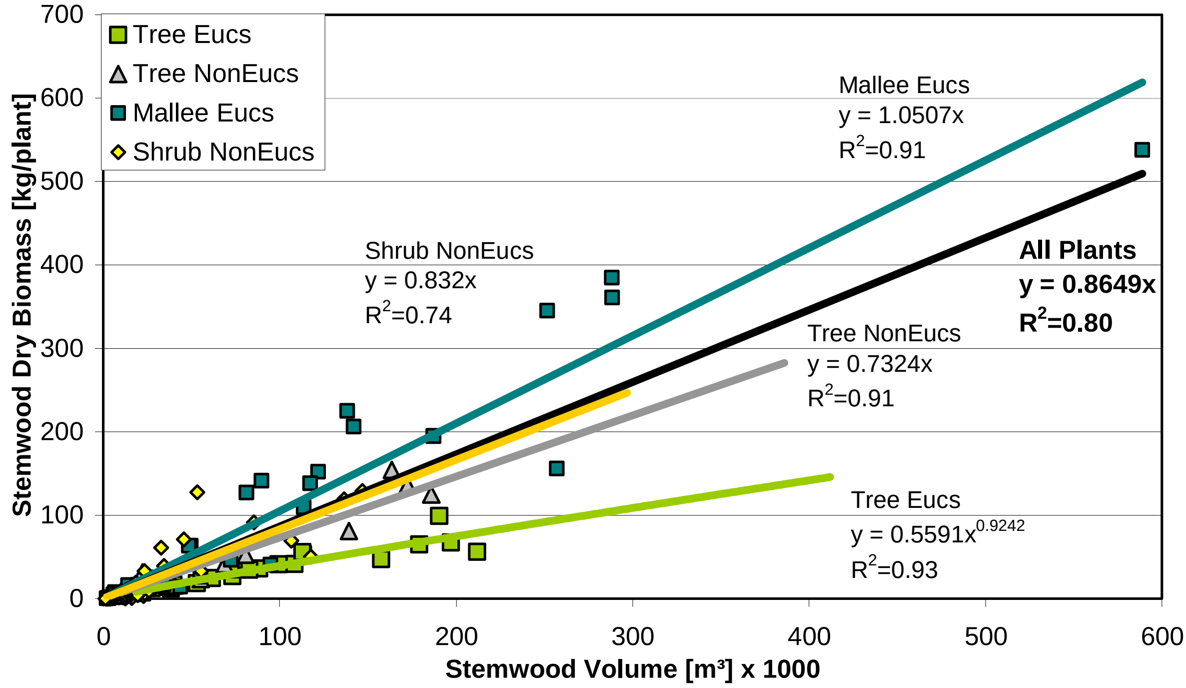


Figure 6. Allometric relationships between plant stemwood volume measurements and dry stemwood biomass for trees, mallees and shrubs.

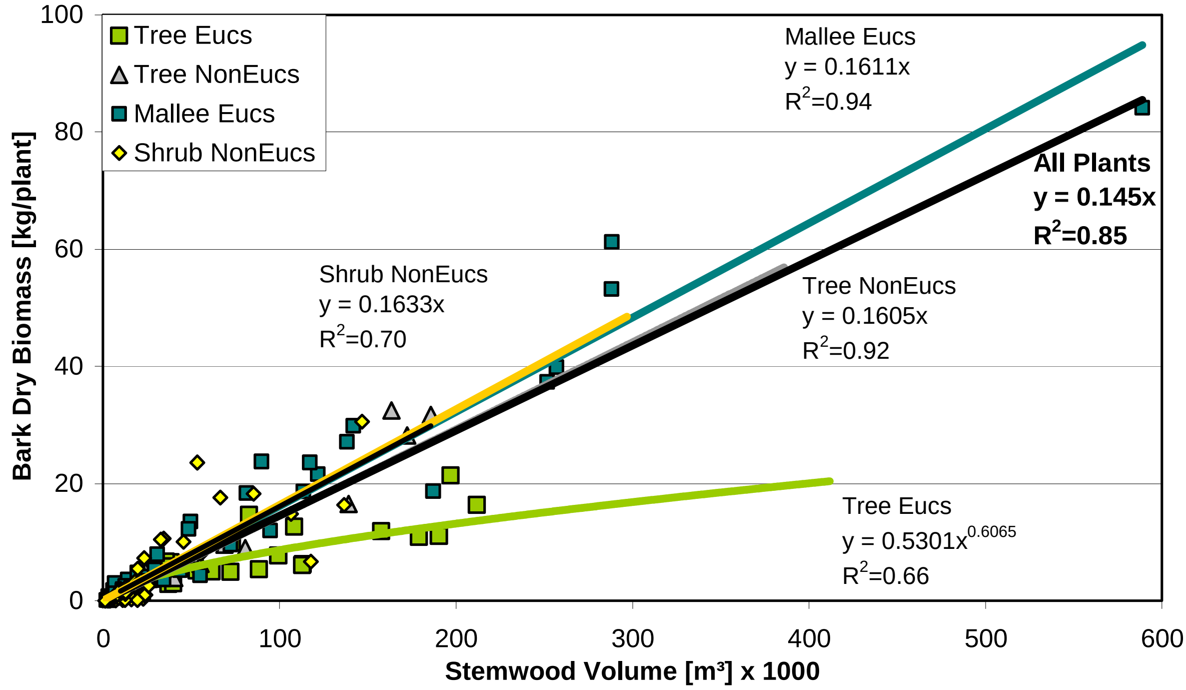


Figure 7. Allometric relationships between plant stemwood volume measurements and dry bark biomass for trees, mallees and shrubs.

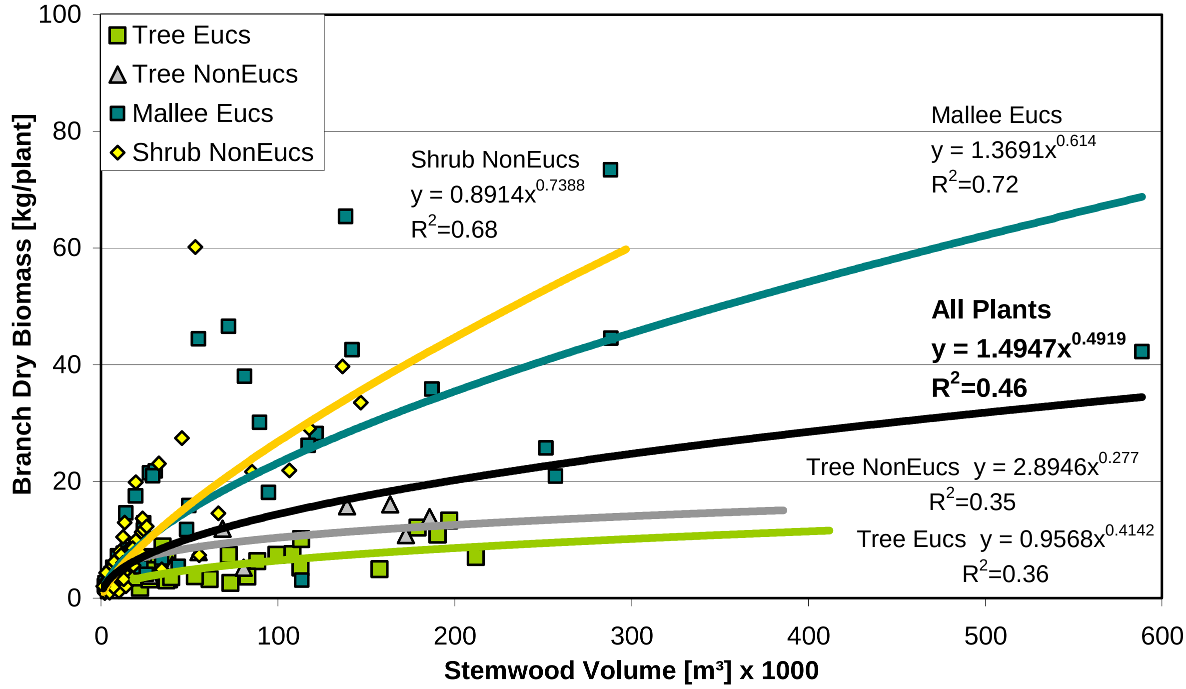


Figure 8. Allometric relationships between plant stemwood volume measurements and dry branch biomass for trees, mallees and shrubs.

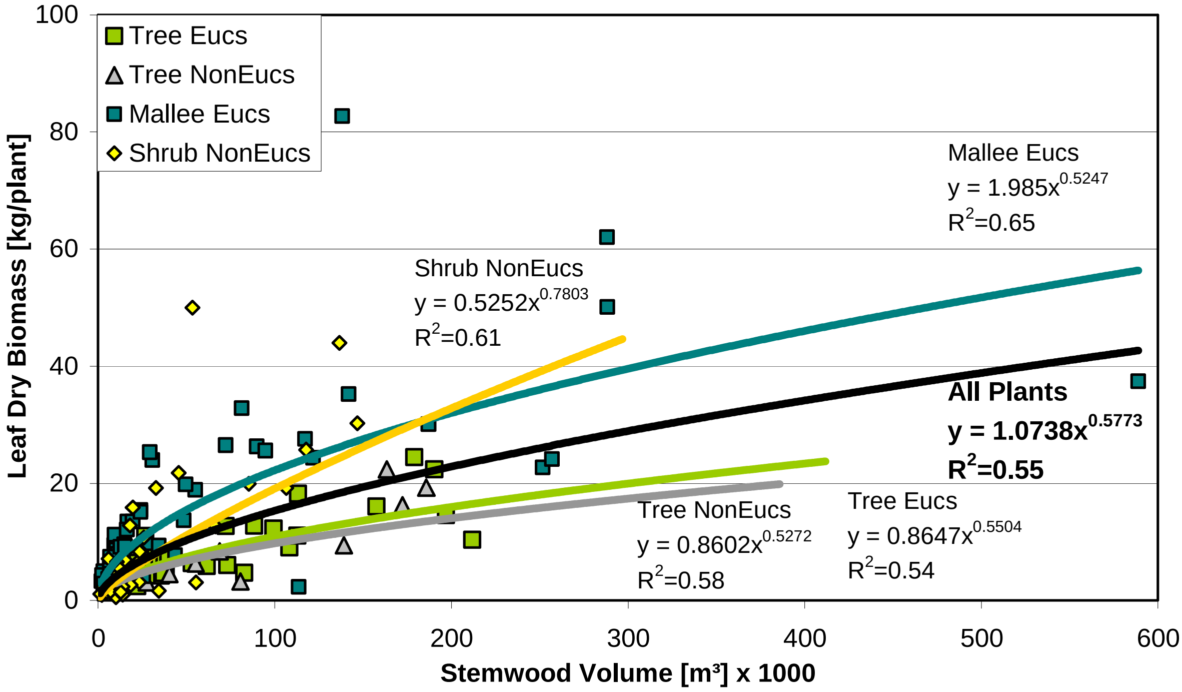


Figure 9. Allometric relationships between plant stemwood volume measurements and dry leaf biomass for trees, mallees and shrubs.

For the Field Trials of Woody Germplasm project (Hobbs *et al.* 2009a), where stemwood volume has not yet been measured, allometric models have been developed from available biometric data on plant volume to estimate plant dry biomass (Figure 10, Table 8). This model allows us to estimate above ground plant dry biomass by using height and crown diameter data only, and is only ~2% less capable than models based on stemwood volume measurements. Plant basal area (from stem diameter measurements) is a commonly used plant biometric used in many individual species allometric models. The generalised relationship with plant dry biomass from destructive measurements (Figure 11, Table 8) is strong for plants with small stem areas, but increasing variable (and less reliable) with increasing stem area.

To generate the allometric models for the commonly utilised fodder shrub Old Man Saltbush (*Atriplex nummularia*), a set of destructive biomass measurements for 3 year old plants located at the Field Trials of Woody Germplasm trial site at Murray Bridge has been reanalysed. Within this site, there was a combination of *Atriplex nummularia* ssp. *nummularia* germplasm collected from near Yando in Victoria, and the commercial clone, Eyres Green. At Murray Bridge, each of these provenances was planted in 2004 as 4 replicated plots of 8 rows of 8 plants at 3m by 1.5m spacing. In late Autumn 2007, the height and width (along and across the row) was measured for 16 plants in the northwest quadrant of each plot. Plants were then cut plants back to a height and width of approximately 50-60cm and the harvested green biomass (leaf and stems combined) of each plant weighed. For two of the 16 plants from each plot of Yando, and for all plants from each plot of Eyres Green, harvested materials were subdivided and weighed for the edible (leaf and fine stem < 3mm) and woody (all material > 3mm) green biomass fractions. The biomass of the remaining standing in-ground stems was visually estimated using the modified Adelaide technique of Andrew *et al.* (1979). This approach requires taking a branch unit of known weight that is representative of the branches within the plant to be measured. A count is then made of the number of representative branch equivalents on the plant, which is then multiplied by the weight of the branch unit to get the standing biomass. Unharvested branch weight estimates were then added to the weight of harvested material in order to calculate whole-plant biomass. Subsamples from these plants were oven-dried to determine the moisture content of each biomass fraction and field observed green biomass values converted to dry matter equivalents. Several biometrics were explored to determine the best predictor of plant dry biomass. The relationship between plant volume (height x elliptical crown area) is presented in Figure 12 and Table 8.

Table 8. Additional dry biomass allometric relationships.

Species	Obs. [n]	Model Fit [r^2]	Total Above-ground Plant Biomass [kg/plant]
All Species	140	0.88	= 0.8056 x Plant Volume [m^3]
All Species	140	0.89	= 0.0875 x Basal Area [cm^2]$^{1.2248}$
Old Man Saltbush	125	0.82	= 2.6531 x Plant Volume [m^3]$^{0.8158}$

Plant Volume = Height [m] x Elliptical Crown Area [m^2].

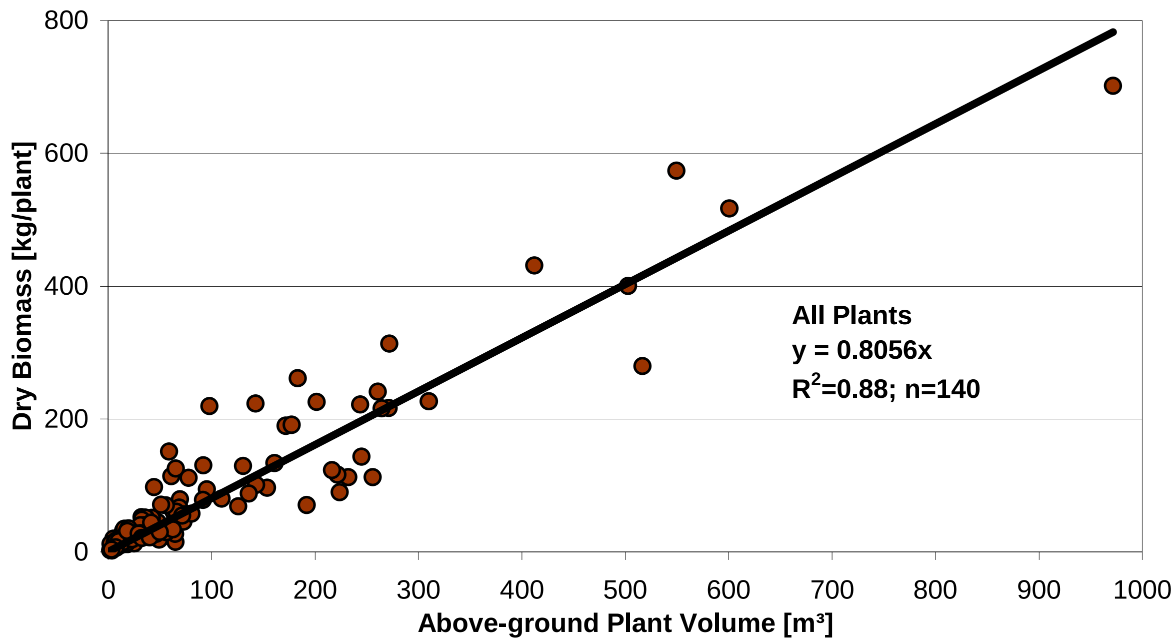


Figure 10. The relationship between above-ground plant volume (height [m] x crown area [m²]) and dry biomass from trees, mallees and shrubs destructively sampled in SA biometric studies.

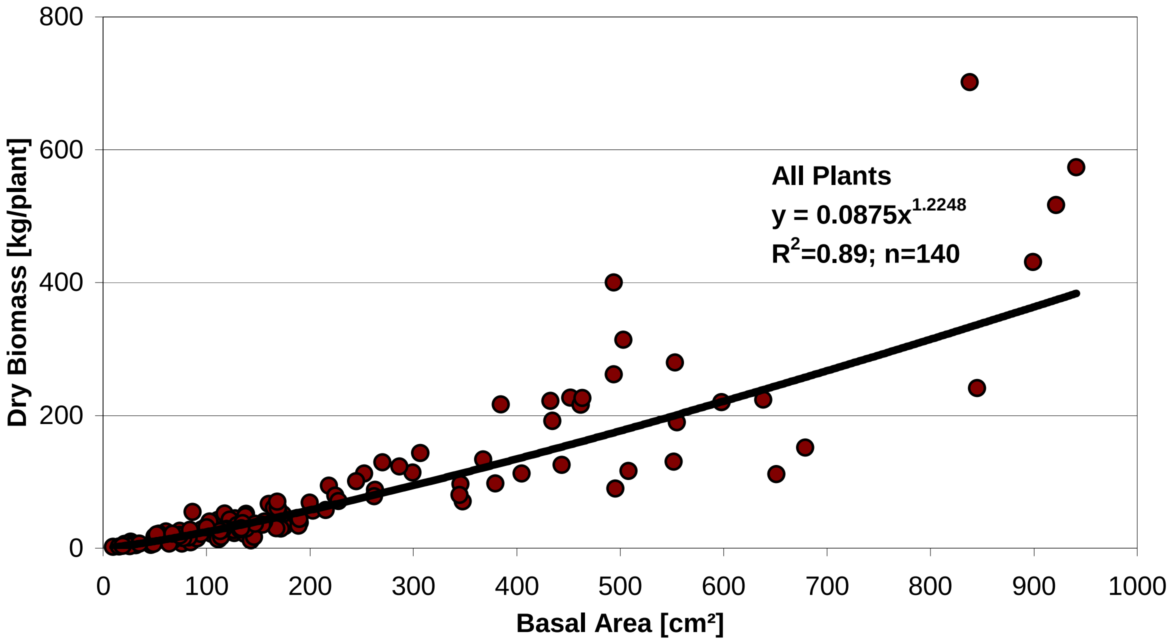


Figure 11. The relationship between basal area [cm²] and dry biomass from trees, mallees and shrubs destructively sampled in SA biometric studies.

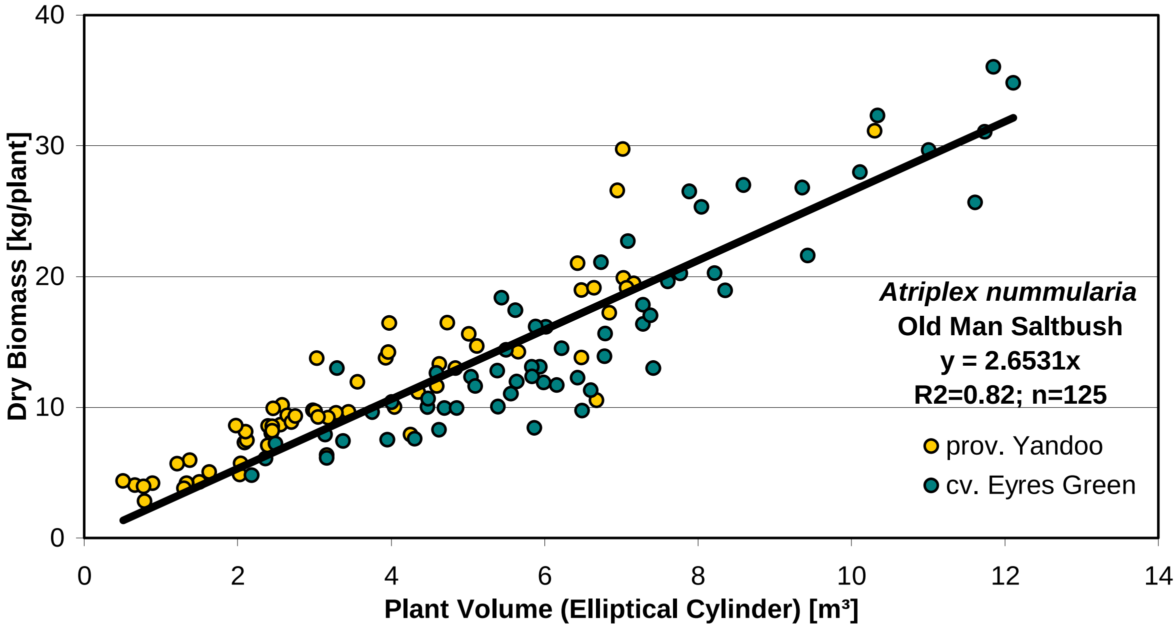


Figure 12. *Atriplex nummularia* relationships between plant elliptical cylinder volume and above ground dry biomass.

4. PRODUCTIVITY AND CARBON SEQUESTRATION FROM REVEGETATION

4.1 ASSESSMENT OF PLANTATION PRODUCTIVITY

Seventy sites of known age were chosen across the study area to assess plant growth and carbon sequestration rates from forestry and environmental revegetation plantings in the low to medium rainfall (300 - 650mm) dryland agriculture zones of the Southern Murray-Darling Basin region of South Australia. The information gathered from these sites were designed to bolster existing plantation information (53 plantations) collected from various sources during the FloraSearch projects within Murray-Darling Basin region (Hobbs *et al.* 2009a); and to provide information on species grown in mixed species environmental plantings. Recent surveys (70 sites) comprise of 51 mixed species plantings, 19 monocultures plantings and a total of 76 different species. Data from a total of a 123 plantations (26 woodlots, 37 windbreaks & 60 environmental plantings) was available for evaluations of productivity and carbon sequestration in the region.

Productivity assessment protocols varied according to planting designs and species mixes (see Table 9). These were based on 2 planting designs (block and windbreak) and 2 species group types (monocultures and mixed species). Sites were sub-sampled using 6 randomly placed segments of continuous plants along rows (and avoiding ends of rows). Segments typically comprised of 10 individuals in mixed species plantings and 6 individuals in monocultures. The larger number of observations in mixed species planting was utilised to determine proportion of biomass contribution by each species within the plantation. At each segment, individual species (>2m high) were recorded and plant measurements included height, crown width, form (tree/mallee/shrub), distance to neighbouring plants, stem count and circumference at two lower section heights (basal and intermediate: 0.5m and 1.3m) for trees and mallees; and at 0.2m for shrubs), and visual ranking of foliage density using reference photographs (8 classes). Foliage density classes were expressed as a percent of maximum density (i.e. very dense 100%, dense 86%, moderately dense 71%, moderate 57%, moderately sparse 43%, sparse 29%, very sparse 14%, no leaves 0%).

The stemwood volume (outer bark) of each plant was calculated from stem height and circumferences using standard forestry formulas for tree volumes of each stemwood section (1. lower section – cylinder volume; 2. mid section - Smalian's frustrum of a paraboloid volume, and 3. upper section - paraboloid volume). Robust and reliable allometric models (see preceding sections) were applied to the results gathered at the field sites to estimate stemwood volume, above-ground dry biomass productivity and carbon sequestration rates of these plantations of low rainfall species.

Pre-existing survey data of predominantly monocultures (53 plantations; Hobbs *et al.* 2009a) followed an identical methodology to that outlined above. However, within these plantations the number of observations was typically fewer (30 individuals for woodlots; and 3 to 6 for some environmental plantings and biometric studies). The combined dataset and species encountered during these surveys is summarised in Table 10 and Appendix A.

Table 9. Generalised summary of measurement protocols used in 70 surveys of plantation productivity in the Southern Murray-Darling Basin study.

Plantation	Size	Total Observations (Subsites & Layout)	Subsite Location
Block - Single species	>4 rows; >110m long	36 (6x6 plant segments)	6 segments randomly located within inside rows
Block - Mixed species	>4 rows; >110m long	60 (6x10 plant segments)	6 segments randomly located within inside rows
Windbreak - Single species	3 or 4 rows; >110m long	36 (6x6 plant segments)	3 segments inside row; 3 segments edge rows
Windbreak - Mixed species	3 or 4 rows; >110m long	60 (6x10 plant segments)	3 segments inside row; 3 segments edge rows

The average observed planting densities of revegetation sites in our study was 803 trees per hectare (tph, n=37) for Woodlots and 1385 tph for Environmental Plantings (n=57). The overall average of 1156 tph is slightly higher than that 1000 tph assumed by Emes *et al.* (2006) in their state estimates for hectares of revegetation from nursery plant sales surveys data.

Productivity values for each revegetation site have been were standardised to an annual biomass accumulation rate to account for the different ages of the plant studied. The average annual rainfall (CSIRO Land & Water 2001), BiosEquil (BE) model values (Raupach *et al.* 2001, Hobbs *et al.* 2006) and NCAT Forest Productivity Index (DCC 2009) for each sampled locality was extracted from spatial coverages of annual rainfall using ArcGIS (ESRI 2009). NCAT Model Maximum Dry Matter values were extracted from the NCAT data server (DCC 2009) for each site. A summary of site data and observed productivity rates for woodlots, windbreaks and environmental plantings is presented in Table 10. Detailed species breakdowns for mixed species sites are available in Appendix A.

Table 10. Plantation growth and carbon sequestration rates from woodlots, windbreaks and environmental plantings observed in the Southern Murray-Darling Basin region.

See Appendix A for detailed breakdowns of Mixed Species plantings

	Site Detail				Field Survey										Proportion of Above-ground Dry Biomass			
Species	**Rain [mm]**	**NCAT Model – Max. Dry matter [t/ha]**	**NCAT Forest Productivity Index**	**BiosEquil Model [t C/ha/yr]**	**Age**	**TPH**	**Stand Type [Block, WindBreak,,Random/Natural**	**Observations#**	**Height [m]**	**Stem Volume MAI [m³/ha/yr]**	**Dry Biomass [t/ha/yr]**	**Carbon [t/ha/yr]**	**CO_2e [t/ha/yr]**	**Stemwood**	**Bark**	**Branches**	**Leaf**
Woodlots																	
Eucalyptus camaldulensis	362	49.1	4.1	1.7	7.6	142	BL	30	5.7	0.58	0.495	0.25	0.90	0.50	0.15	0.14	0.21
Eucalyptus camaldulensis	376	48.5	4.1	1.6	15.0	995	BL	36	15.5	16.45	8.382	4.16	15.26	0.70	0.11	0.07	0.13
E. camaldulensis/leucoxylon	370	47.2	4.1	1.6	15.0	600	BL	60	6.6	1.68	1.215	0.60	2.21	0.55	0.14	0.12	0.18
E. camald./tricarpa/cladocalyx, +4sp	478	108.2	6.7	2.9	20.9	1376	BL	60	13.0	10.39	6.001	2.98	10.92	0.66	0.12	0.08	0.14
Eucalyptus cladocalyx	339	39.5	3.7	1.2	98.0	281	BL	36	10.7	0.49	0.275	0.14	0.50	0.66	0.12	0.08	0.14
Eucalyptus cladocalyx	460	64.8	4.8	1.7	10.7	440	BL	30	14.9	13.44	6.757	3.35	12.30	0.71	0.10	0.06	0.12
Eucalyptus cladocalyx	460	64.2	4.8	1.7	14.0	778	BL	36	10.2	5.98	3.708	1.84	6.75	0.62	0.13	0.09	0.16
Eucalyptus cladocalyx	460	65.1	4.8	1.7	6.7	793	BL	33	5.6	2.82	2.539	1.26	4.62	0.48	0.16	0.15	0.21
Eucalyptus cladocalyx	465	120.2	7.3	3.0	14.9	502	BL	36	12.1	3.45	2.195	1.09	3.99	0.61	0.13	0.10	0.16
Eucalyptus cladocalyx	557	131.6	7.8	2.6	17.9	2277	BL	36	13.0	15.43	9.126	4.53	16.61	0.64	0.12	0.09	0.15
E. cladocalyx/camaldulensis	478	101.7	6.4	2.9	21.9	1210	BL	36	16.3	9.42	5.316	2.64	9.68	0.66	0.12	0.08	0.14
E. cladocalyx/camaldulensis, +1sp	478	102.2	6.5	2.9	21.9	1257	BL	60	14.6	9.63	5.373	2.67	9.78	0.66	0.12	0.08	0.14
Eucalyptus globulus	460	65.4	4.9	1.7	10.7	898	BL	33	12.5	11.01	6.448	3.20	11.74	0.64	0.12	0.09	0.15
E. grandis/camaldulensis	478	102.2	6.5	2.9	21.9	1600	BL	36	18.9	14.83	8.152	4.04	14.84	0.67	0.11	0.07	0.14
E. largiflorens/cladocalyx	330	39.0	3.7	1.2	98.0	390	BL	60	7.0	0.28	0.189	0.09	0.34	0.58	0.14	0.11	0.17
Eucalyptus leucoxylon	379	54.9	4.4	2.2	32.9	568	BL	36	6.3	1.01	0.717	0.36	1.31	0.56	0.14	0.11	0.18
Eucalyptus leucoxylon	361	43.5	3.9	1.3	99.0	235	BL	36	8.3	0.32	0.188	0.09	0.34	0.64	0.12	0.09	0.15
E. leucoxylon, +3sp	403	117.9	7.2	2.9	33.0	527	BL	60	5.3	0.77	0.727	0.36	1.32	0.56	0.13	0.14	0.18
E. leucoxylon/camaldulensis	315	40.0	3.7	1.3	9.0	384	BL	60	5.7	1.65	1.330	0.66	2.42	0.52	0.15	0.13	0.20
Eucalyptus loxophleba ssp. lissophloia	318	40.1	3.7	1.2	8.0	2094	BL	36	4.8	3.06	5.489	2.72	9.99	0.44	0.10	0.21	0.25
Eucalyptus occidentalis	460	64.2	4.8	1.7	5.7	708	BL	34	9.8	13.54	8.607	4.27	15.67	0.61	0.13	0.09	0.16
E. occidentalis/leucoxylon, +3sp	364	43.1	3.9	1.5	19.0	351	BL	60	9.7	1.74	1.216	0.60	2.21	0.61	0.13	0.10	0.16

Species	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
	Rain [mm]	NCAT Model – Max. Dry matter [t/ha]	NCAT Forest Productivity Index	BiosEquil Model [t C/ha/yr]	Age	TPH	Stand Type [Block, WindBreak,,Random/Natural	Observations#	Height [m]	Stem Volume MAI [m³/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]	Stemwood	Bark	Branches	Leaf
Eucalyptus polybractea	318	39.3	3.7	1.2	8.0	1872	BL	36	4.2	4.28	9.096	4.51	16.56	0.49	0.08	0.20	0.23
Eucalyptus salmonophoia	330	39.4	3.7	1.2	95.0	942	BL	36	18.7	2.37	1.259	0.62	2.29	0.69	0.11	0.07	0.13
Eucalyptus viminalis	460	64.8	4.8	1.7	5.7	526	BL	33	10.0	10.83	6.600	3.27	12.01	0.63	0.13	0.09	0.16
Eucalyptus viminalis ssp. cygnetensis	460	64.8	4.8	1.7	9.0	561	BL	36	12.9	13.04	7.103	3.52	12.93	0.68	0.11	0.07	0.14
Windbreaks																	
Acacia myrtifolia	585	129.2	7.7	3.0	8.0	114	WB	6	1.5	0.03	0.135	0.07	0.25	0.43	0.09	0.29	0.19
Allo. verticillata, E. socialis, +7sp	399	49.9	4.2	1.3	15.0	1492	WB	36	4.8	1.99	3.447	1.71	6.28	0.56	0.09	0.18	0.16
Callitris gracilis, E. platypus/dund., +7sp	362	48.7	4.1	1.7	18.9	227	WB	60	7.2	2.92	2.647	1.31	4.82	0.72	0.11	0.09	0.09
Casuarina cunninghamiana, +5sp	465	116.6	7.1	3.0	14.9	675	WB	39	5.4	1.61	2.176	1.08	3.96	0.64	0.11	0.14	0.11
Eucalyptus baxteri	585	130.9	7.7	3.0	8.0	226	WB	6	3.6	0.69	0.835	0.41	1.52	0.52	0.15	0.13	0.20
Eucalyptus camaldulensis	460	65.4	4.9	1.7	10.0	580	WB	36	13.8	31.37	14.142	7.01	25.74	0.75	0.09	0.05	0.10
Eucalyptus camaldulensis	376	50.8	4.2	1.6	7.7	1027	WB	30	9.6	9.78	6.549	3.25	11.92	0.59	0.13	0.10	0.17
Eucalyptus camaldulensis	460	65.4	4.9	1.7	10.7	513	WB	33	11.4	10.62	5.717	2.84	10.41	0.68	0.11	0.07	0.14
E. camald., Cas. cunninghamiana, +1sp	585	115.3	7.0	3.0	14.9	754	WB	60	6.1	1.68	1.529	0.76	2.78	0.58	0.12	0.15	0.15
Eucalyptus cladocalyx	460	71.9	5.1	1.7	6.7	419	WB	30	5.0	1.79	1.558	0.77	2.84	0.49	0.15	0.15	0.21
Eucalyptus cladocalyx	460	68.6	5.0	1.7	6.7	789	WB	30	6.4	4.02	3.378	1.68	6.15	0.50	0.15	0.14	0.20
E. fasciculosa, A. pycnantha/ret., +5sp	465	113.4	7.0	3.0	16.9	636	WB	72	5.7	1.25	1.458	0.72	2.65	0.62	0.11	0.14	0.13
E. fasciculosa, A. retinodes/pycn., +4sp	585	128.7	7.6	3.0	14.9	1372	WB	70	6.1	7.23	5.128	2.54	9.34	0.66	0.11	0.11	0.13
E. fasciculosa, M. lanceolata, +3sp	554	120.4	7.3	2.9	16.9	2959	WB	36	5.7	8.99	6.608	3.28	12.03	0.60	0.12	0.11	0.16
Eucalyptus gomphocephala	460	68.4	5.0	1.7	12.0	334	WB	6	12.4	20.32	8.744	4.34	15.92	0.77	0.09	0.04	0.10
E. gracilis/socialis/incrassata, +7sp	317	46.0	4.0	1.4	16.0	531	WB	60	3.7	1.44	4.228	2.10	7.70	0.66	0.10	0.12	0.12
E. incrassata/leptophylla, +7sp	357	49.9	4.2	1.9	28.9	2801	WB	60	3.9	1.16	2.214	1.10	4.03	0.48	0.08	0.21	0.23
Eucalyptus leucoxylon	339	45.1	4.0	1.6	14.0	405	WB	36	4.6	1.77	2.501	1.24	4.55	0.60	0.10	0.14	0.16
E. leucoxylon, +2sp	557	127.2	7.6	2.6	16.0	620	WB	36	5.4	2.37	1.903	0.94	3.46	0.61	0.13	0.11	0.15
E. leucoxylon/camaldulensis, +1sp	376	48.6	4.1	1.6	24.0	300	WB	36	11.8	7.68	3.463	1.72	6.30	0.77	0.09	0.05	0.09
E. leucoxylon/cladocalyx/tricarpa, +2sp	478	106.5	6.7	2.9	20.9	1134	WB	36	12.4	9.35	6.075	3.01	11.06	0.67	0.11	0.09	0.13
E. leucoxylon/gracilis/incrassata, +10sp	357	46.2	4.0	1.9	28.9	279	WB	60	6.4	1.19	1.457	0.72	2.65	0.67	0.11	0.11	0.12
Eucalyptus occidentalis	460	68.5	5.0	1.7	6.7	603	WB	30	10.2	8.04	5.279	2.62	9.61	0.60	0.13	0.10	0.17

Species	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
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Eucalyptus occidentalis	460	68.6	5.0	1.7	6.7	762	WB	32	8.2	5.57	4.273	2.12	7.78	0.54	0.15	0.12	0.19
Eucalyptus occidentalis	460	68.5	5.0	1.7	6.5	645	WB	6	12.1	12.20	7.557	3.75	13.76	0.62	0.13	0.09	0.16
E. occidentalis/megacornuta, +1sp	460	60.5	4.6	1.7	15.0	756	WB	60	8.4	6.69	3.994	1.98	7.27	0.64	0.12	0.09	0.15
Eucalyptus oleosa	357	49.9	4.2	1.9	28.9	3325	WB	36	5.0	1.41	2.996	1.49	5.45	0.47	0.08	0.21	0.24
E. porosa, Bursaria spinosa, +10sp	317	44.4	3.9	1.4	17.0	1590	WB	60	4.4	6.24	6.739	3.34	12.27	0.63	0.10	0.14	0.13
E. porosa/fasciculosa, Allo. verticill., +8sp	332	84.2	5.7	2.0	17.0	580	WB	61	4.7	0.97	1.118	0.55	2.04	0.56	0.12	0.16	0.17
E. porosa/gracilis/socialis, +3sp	321	43.8	3.9	1.7	14.0	1836	WB	60	4.3	2.58	5.730	2.84	10.43	0.53	0.08	0.19	0.20
E. porosa/leucoxylon, +5sp	339	45.1	4.0	1.6	12.0	447	WB	63	3.5	1.82	2.852	1.41	5.19	0.59	0.09	0.16	0.16
Eucalyptus socialis	357	46.2	4.0	1.9	26.1	444	WB	3	5.6	1.82	3.795	1.88	6.91	0.66	0.10	0.12	0.11
Eucalyptus viminalis ssp. cygnetensis	585	130.9	7.7	3.0	9.0	597	WB	6	7.6	5.80	4.599	2.28	8.37	0.62	0.13	0.09	0.16
Melaleuca armillaris ssp. armillaris	362	51.3	4.2	2.0	11.0	122	WB	6	2.7	0.44	1.063	0.53	1.93	0.71	0.11	0.10	0.08
M. lanceolata, +7sp	375	116.1	7.1	2.2	16.9	807	WB	36	4.8	3.15	4.165	2.07	7.58	0.59	0.11	0.16	0.14
Melaleuca uncinata	357	50.6	4.2	1.9	16.3	585	WB	3	2.3	0.36	0.651	0.32	1.18	0.46	0.09	0.27	0.18
Pittosporum phylliraeoides	357	47.6	4.1	1.9	16.2	460	WB	3	2.5	0.38	0.657	0.33	1.20	0.48	0.09	0.26	0.17
Environmental Plantings																	
Acacia calamifolia	371	50.6	4.2	2.1	6.0	756	RN	6	2.0	1.62	2.810	1.39	5.11	0.48	0.09	0.26	0.17
Acacia hakeoides	371	51.9	4.3	2.1	3.7	752	RN	6	1.3	0.90	2.570	1.27	4.68	0.50	0.10	0.24	0.16
Acacia hakeoides	371	51.6	4.2	2.1	2.0	2226	RN	6	1.2	2.46	5.291	2.62	9.63	0.39	0.08	0.33	0.20
Acacia ligulata	261	22.9	3.0	1.1	13.8	1111	BL	30	2.7	1.71	2.916	1.45	5.31	0.52	0.10	0.23	0.15
Acacia ligulata	261	22.9	3.0	1.1	13.8	484	BL	3	3.2	1.01	2.073	1.03	3.77	0.53	0.10	0.22	0.15
Acacia montana	371	51.3	4.2	2.1	6.0	738	RN	6	2.1	1.82	3.117	1.55	5.67	0.49	0.10	0.25	0.17
Acacia pycnantha	340	44.9	4.0	1.9	13.8	2778	BL	60	3.7	2.70	5.053	2.51	9.20	0.56	0.09	0.23	0.13
A. pycnantha/microcarpa, +6sp	364	68.8	5.0	2.4	18.0	6736	BL	86	4.0	1.56	3.647	1.81	6.64	0.39	0.07	0.37	0.17
Acacia rigens	357	48.9	4.1	1.9	31.2	197	BL	3	2.8	0.28	0.430	0.21	0.78	0.54	0.11	0.21	0.15
Allo. verticillata, E. leucoxylon, +1sp	403	95.9	6.2	2.9	33.0	310	BL	60	6.0	1.00	1.069	0.53	1.95	0.72	0.11	0.08	0.09
Callitris gracilis, E. camaldulensis, +12sp	335	92.3	6.0	1.7	18.0	1981	BL	60[w]	8.9	24.43	13.939	6.91	25.37	0.73	0.10	0.07	0.10
Callitris gracilis, E. leucoxylon/por., +6sp	376	109.4	6.8	2.2	31.9	280	BL	60	7.0	1.27	1.385	0.69	2.52	0.70	0.11	0.10	0.10
Callitris verrucosa	357	46.7	4.0	1.9	31.3	140	BL	3	4.6	0.51	0.729	0.36	1.33	0.58	0.11	0.18	0.13

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Casuarina cunninghamiana	585	121.8	7.3	3.0	14.9	828	BL	36	6.3	1.59	2.682	1.33	4.88	0.65	0.10	0.15	0.10
Dodonaea viscosa	261	22.9	3.0	1.1	13.8	2251	BL	30	2.6	0.85	1.596	0.79	2.91	0.44	0.09	0.29	0.18
Dodonaea viscosa	261	22.9	3.0	1.1	13.8	633	BL	3	2.9	0.65	1.122	0.56	2.04	0.48	0.09	0.26	0.17
E. camald./largiflorens, A. ligulata, +6sp	387	47.2	4.1	1.4	11.9	1309	BL	60	4.6	3.69	4.579	2.27	8.34	0.55	0.11	0.18	0.15
E. camaldulensis/oleosa, +6sp	387	47.2	4.1	1.4	9.9	1104	BL	60	4.5	2.76	3.591	1.78	6.54	0.54	0.10	0.18	0.19
Eucalyptus cyanophylla	261	22.9	3.0	1.1	13.4	555	BL	30	3.6	1.02	2.042	1.01	3.72	0.52	0.08	0.19	0.21
Eucalyptus diversifolia	460	64.8	4.8	1.7	12.7	1279	RN	3	5.5	5.17	9.333	4.63	16.99	0.58	0.09	0.16	0.17
E. diversifolia/incrassata, +4sp	460	64.8	4.8	1.7	17.0	1119	BL	60	5.5	6.32	9.775	4.85	17.79	0.65	0.10	0.13	0.12
Eucalyptus dumosa	323	46.4	4.0	1.6	30.0	1091	RN	6	4.9	1.36	2.468	1.22	4.49	0.56	0.09	0.17	0.18
Eucalyptus dumosa	387	46.3	4.0	1.4	12.0	836	BL	31	3.8	0.90	1.988	0.99	3.62	0.47	0.07	0.21	0.24
E. fasciculosa, A. retinodes/pycn., +3sp	585	128.7	7.6	3.0	14.9	2010	BL	70	5.8	4.18	3.787	1.88	6.89	0.57	0.12	0.16	0.15
E. fasciculosa/leuco., Allo. vertic., +3sp	546	129.5	7.7	2.8	18.0	1119	BL	60	9.5	10.38	7.350	3.65	13.38	0.71	0.10	0.08	0.11
Eucalyptus gracilis	357	51.9	4.3	1.9	31.2	329	BL	3	10.0	3.35	4.939	2.45	8.99	0.71	0.11	0.10	0.08
Eucalyptus gracilis	261	22.9	3.0	1.1	14.3	554	BL	30	3.4	0.59	1.334	0.66	2.43	0.48	0.07	0.21	0.24
E. gracilis/porosa/incrassata, +7sp	340	46.3	4.0	1.6	15.0	473	BL	60	4.4	1.91	2.549	1.26	4.64	0.59	0.10	0.15	0.16
Eucalyptus incrassata	357	51.9	4.3	1.9	31.2	208	BL	3	5.8	0.65	1.086	0.54	1.98	0.63	0.10	0.14	0.13
Eucalyptus incrassata	374	47.3	4.1	1.5	8.0	1120	BL	30	3.7	1.89	4.273	2.12	7.78	0.46	0.07	0.22	0.25
E. incrassata, Allo. verticillata, +12sp	369	51.3	4.2	1.8	16.0	908	BL	61	3.9	1.52	2.741	1.36	4.99	0.54	0.09	0.19	0.18
E. incrassata/A. ligulata, +8sp	399	49.1	4.1	1.3	15.0	1383	BL	60	3.2	0.97	1.896	0.94	3.45	0.47	0.08	0.24	0.20
Eucalyptus largiflorens	261	22.9	3.0	1.1	14.4	392	BL	30	4.5	0.98	0.797	0.40	1.45	0.52	0.15	0.14	0.20
E. largiflorens, Allo. verticillata, +3sp	322	77.7	5.4	1.8	17.0	1150	BL	60	4.7	1.25	1.271	0.63	2.31	0.48	0.13	0.19	0.19
Eucalyptus leptophylla	261	22.9	3.0	1.1	13.4	1133	BL	30	2.0	0.41	1.213	0.60	2.21	0.37	0.06	0.25	0.32
Eucalyptus leptophylla	357	46.7	4.0	1.9	31.3	153	BL	3	6.6	1.00	1.549	0.77	2.82	0.68	0.10	0.11	0.10
E. leucoxylon, A. ligulata/brachy., +3sp	350	49.6	4.2	1.7	15.9	1471	BL	60	3.9	2.00	2.481	1.23	4.52	0.53	0.12	0.19	0.17
E. leucoxylon, Cal. gracilis, +2sp	379	52.9	4.3	2.2	32.9	230	BL	60	7.8	1.51	1.310	0.65	2.38	0.75	0.12	0.05	0.08
E. leucoxylon, Cal. gracilis, +8sp	379	54.4	4.4	2.2	32.9	242	BL	60	6.0	0.64	0.542	0.27	0.99	0.65	0.11	0.10	0.14
E. leucoxylon, Cal. gracilis, A. ret., +5sp	335	90.2	5.9	1.7	18.0	683	BL	60	9.9	7.01	5.233	2.60	9.53	0.73	0.11	0.07	0.10
E. leucoxylon/largiflorens, +12sp	382	58.4	4.5	2.1	17.0	3441	BL	60	5.9	7.65	6.144	3.05	11.18	0.56	0.13	0.14	0.18

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E. leucoxylon/porosa/calycogona, +7sp	376		6.9	2.2	32.9	235	BL	60	7.2	1.04	0.962	0.48	1.75	0.69	0.11	0.09	0.11
E. microcarpa/brockwayii/calycog., +8sp	379	54.9	4.4	2.2	32.9	295	BL	60	7.9	2.10	1.379	0.68	2.51	0.70	0.10	0.08	0.12
E. odorata/camaldulensis, +5sp	474	68.6	5.0	2.6	12.0	2211	BL	60	6.7	6.31	5.687	2.82	10.35	0.53	0.13	0.16	0.19
E. odorata/incrassata, A. pycnantha, +8sp	443	61.1	4.7	1.8	19.0	2778	BL	68	5.4	5.77	7.664	3.80	13.95	0.63	0.11	0.13	0.14
Eucalyptus oleosa	261	22.9	3.0	1.1	10.4	403	BL	30	3.2	0.35	0.836	0.41	1.52	0.44	0.07	0.23	0.27
Eucalyptus oleosa	357	49.9	4.2	1.9	28.9	1736	BL	36	5.0	1.21	2.431	1.21	4.43	0.52	0.08	0.19	0.21
Eucalyptus oleosa	387	47.2	4.1	1.4	6.8	1585	BL	30	3.0	2.15	5.222	2.59	9.51	0.43	0.07	0.23	0.27
Eucalyptus oleosa	357	47.6	4.1	1.9	31.2	224	BL	3	6.4	1.14	1.781	0.88	3.24	0.67	0.10	0.12	0.11
E. oleosa/brachycalyx, +2sp	335	57.2	4.5	1.7	17.9	385	BL	60	5.1	1.31	1.533	0.76	2.79	0.59	0.09	0.15	0.17
Eucalyptus porosa	387	47.2	4.1	1.4	6.7	1522	BL	33	3.9	5.23	10.590	5.25	19.28	0.52	0.08	0.19	0.21
E. porosa, +2sp	403	117.5	7.1	2.9	33.0	4202	BL	60	3.3	1.08	2.191	1.09	3.99	0.44	0.10	0.22	0.25
Eucalyptus socialis	261	22.9	3.0	1.1	14.4	1936	BL	30	3.8	3.11	6.306	3.13	11.48	0.52	0.08	0.19	0.21
E. viminalis ssp. cygnetensis, +9sp	443	62.5	4.7	1.8	19.0	1990	BL	67	7.9	15.80	12.352	6.13	22.48	0.68	0.11	0.09	0.12
Leptospermum continentale	546	141.2	8.2	2.8	7.0	339	RN	6	1.6	0.06	0.213	0.11	0.39	0.38	0.08	0.34	0.21
Melaleuca lanceolata	357	47.4	4.1	1.9	31.2	458	BL	3	4.0	1.56	2.257	1.12	4.11	0.58	0.11	0.18	0.13
Melaleuca lanceolata	261	22.9	3.0	1.1	12.5	319	BL	30	2.2	0.38	0.641	0.32	1.17	0.49	0.10	0.25	0.17
Senna artemisioides ssp. coriacea	261	22.9	3.0	1.1	13.4	2254	BL	30	1.7	0.44	0.917	0.45	1.67	0.40	0.08	0.32	0.20
Senna artemisioides ssp. coriacea	261	22.9	3.0	1.1	13.4	3518	BL	3	1.6	0.70	1.481	0.73	2.70	0.40	0.08	0.32	0.20
Viminaria juncea	639	88.8	5.9	2.8	7.0	1057	RN	6	4.7	2.61	4.663	2.31	8.49	0.59	0.09	0.20	0.12

Note: Shaded cells indicate sites with limited number of observations or [W] access to additional water (river edge) that have been excluded from analysis for woodlots and environmental plantings.
For additional information on mixed species revegetation site see Appendix B

4.2 PREDICTING PLANTATION PRODUCTIVITY

For the purpose of creating generalised productivity models the revegetation sites were divided into 2 broad classes based on species selections and designs (see Table 10):

1. **Woodlots -** Blocks and windbreaks containing monocultures (or a few species) of typical woodlot species, including Sugar gum (*Eucalyptus cladocalyx*), River red gum (*E. camaldulensis*), SA Blue gum (*E. leucoxylon*) and productive mallees (*E. loxophleba* & *E. polybractea*).
2. **Environmental Plantings -** Blocks and windbreaks containing predominately mixtures of native species for biodiverse/habitat plantings or non-woodlot species intended for other environmental services.

The significant differences in production rates from these 2 classes are clearly illustrated in Figure 13 and Figure 14.

Although the contrary was expected due to general planting recommendations for the region, statistical tests between average annual rainfall and planting density revealed no significant auto-correlation. This permitted valid evaluations of planting density interactions with rainfall, NCAT Forest Productivity Index and BiosEquil models. Planting density (trees per hectare, tph) and average annual rainfall have the greatest influence on the productivity in woodlots and environmental plants in our study area (see Table 11, Figure 13, Figure 14). In higher rainfall regions outside of our study area, where water is a less limiting factor, soil fertility is reported to have a significant influence on plantation growth. This soil fertility principle is evident in NCAT Forest Productivity Index (FPI) model coverages across Australia which shows significant variations in productivity based on soil types (Landsberg & Kesteven 2001, see Figure 20b).

Analysis of plantation/revegetation growth rates in the study region revealed no statistically significant soil type or fertility influences on productivity. NCAT Forest Productivity Index (which underpins the NCAT FullCAM model) was found to be the weakest predictor of plantation/revegetation productivity, and after factoring different stocking rates only accounted for 0 – 2 % of model variation. After stocking rates, average annual rainfall was found to account for the greatest variations in site productivity, especially for woodlots (+7%). BiosEquil model values (also strongly influenced by climate parameters) provide a similar level of predictive capacity as rainfall based models, especially for environmental plantings (+6%). In this study, woodlots appear to be less influenced by soil conditions than environmental plantings.

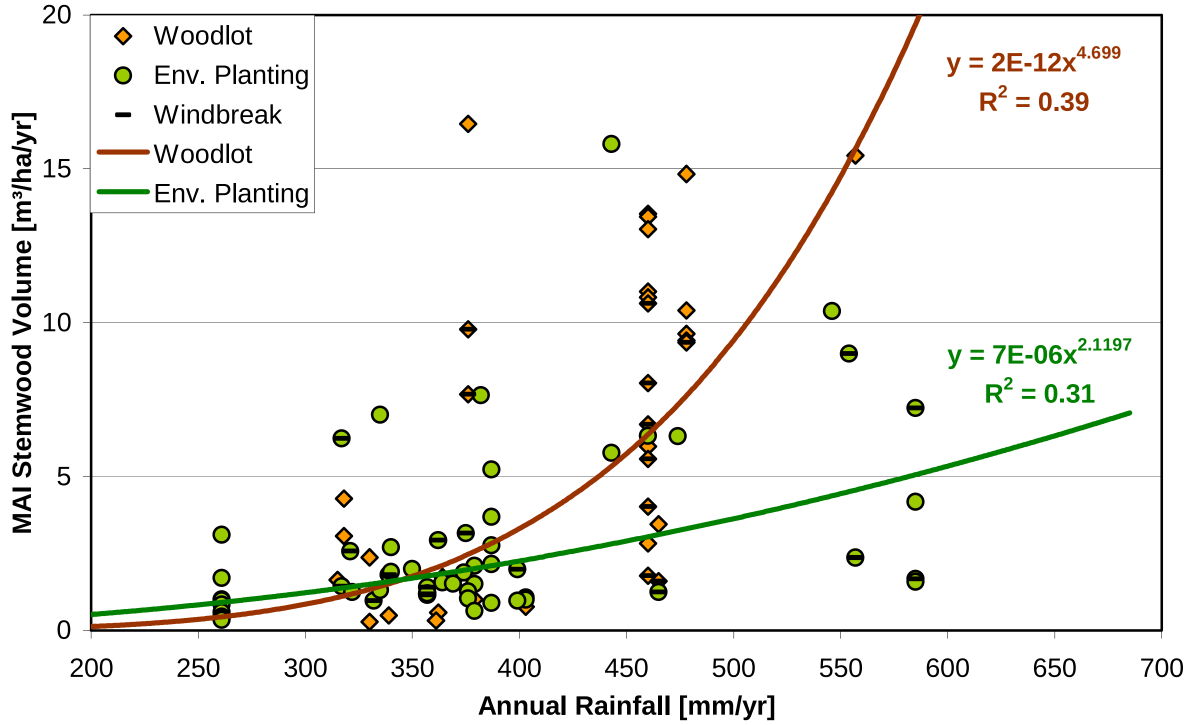
Table 11. Relationships between mean annual rainfall, NCAT Forest Productivity Index, BiosEquil model predictions and observed productivity in the Murray-Darling Basin region.

Productivity by Plantation Type (y)	Predictor Variable (x)	Model Fit [r^2]	Formula
Mean Annual Increment (MAI) Stemwood Volume [m³/ha/yr]			
Woodlot	Mean Annual Rainfall (R) [mm/yr]	0.39	$y = 1.96E\text{-}12 \times R^{4.6990}$
(n = 37)	NCAT Forest Productivity Index (FPI)	0.15	$y = 0.1615 \times FPI^{2.0155}$
	BiosEquil (BE) [t C/ha/yr]	0.20	$y = 0.4723 \times BE^{3.4878}$
	Trees Per Hectare [TPH]	0.36	$y = 0.00234 \times TPH^{1.1406}$
	R x TPH	0.47	$y = 1.64E\text{-}06 \times (Rx\ TPH)^{1.1718}$
	FPI x TPH	0.39	$y = 0.00127 \times (FPI \times TPH)^{0.9928}$
	BE x TPH	0.41	$y = 0.00164 \times (BE \times TPH)^{1.0929}$
Env. Planting	Mean Annual Rainfall (R) [mm/yr]	0.31	$y = 6.90E\text{-}06 \times R^{2.1197}$
(n =57)	NCAT Forest Productivity Index (FPI)	0.17	$y = 0.3017 \times FPI^{1.2161}$
	BiosEquil (BE) [t C/ha/yr]	0.28	$y = 0.7661 \times BE^{1.8559}$
	Trees Per Hectare [TPH]	0.13	$y = 0.1374 \times TPH^{0.3824}$
	R x TPH	0.24	$y = 0.00492 \times (Rx\ TPH)^{0.4660}$
	FPI x TPH	0.24	$y = 0.0381 \times (FPI \times TPH)^{0.4662}$
	BE x TPH	0.24	$y = 0.0607 \times (BE \times TPH)^{0.4677}$
Carbon Sequestration Rate [t CO_2-e/ha/yr]			
Woodlot	Mean Annual Rainfall (R) [mm/yr]	0.29	$y = 5.19E\text{-}10 \times R^{3.8174}$
(n = 37)	NCAT Forest Productivity Index (FPI)	0.13	$y = 0.3116 \times FPI^{1.7672}$
	BiosEquil (BE) [t C/ha/yr]	0.15	$y = 0.9206 \times BE^{2.8227}$
	Trees Per Hectare [TPH]	0.48	$y = 0.00169 \times TPH^{1.2308}$
	Rainfall x TPH	0.55	$y = 1.49E\text{-}06 \times (Rx\ TPH)^{1.2003}$
	FPI x TPH	0.48	$y = 0.00120 \times (FPI \times TPH)^{1.0328}$
	BE x TPH	0.50	$y = 0.00159 \times (BE \times TPH)^{1.1347}$
Env. Planting	Mean Annual Rainfall (R) [mm/yr]	0.14	$y = 0.00382 \times R^{1.2082}$
(n =57)	NCAT Forest Productivity Index (FPI)	0.03^{ns}	$y = 2.4893 \times FPI^{0.4366}$
	BiosEquil (BE) [t C/ha/yr]	0.11	$y = 2.9435 \times BE^{1.0054}$
	Trees Per Hectare [TPH]	0.35	$y = 0.1316 \times TPH^{0.5235}$
	Rainfall x TPH	0.41	$y = 0.00548 \times (Rx\ TPH)^{0.5300}$
	FPI x TPH	0.37	$y = 0.0689 \times (FPI \times TPH)^{0.5059}$
	BE x TPH	0.41	$y = 0.0991 \times (BE \times TPH)^{0.5271}$

^{ns} not statistically significant, trend formula only.

Stemwood Productivity

a) Stemwood Production Rates versus Annual Rainfall



b) Stemwood Production Rates versus NCAT Forest Productivity Index

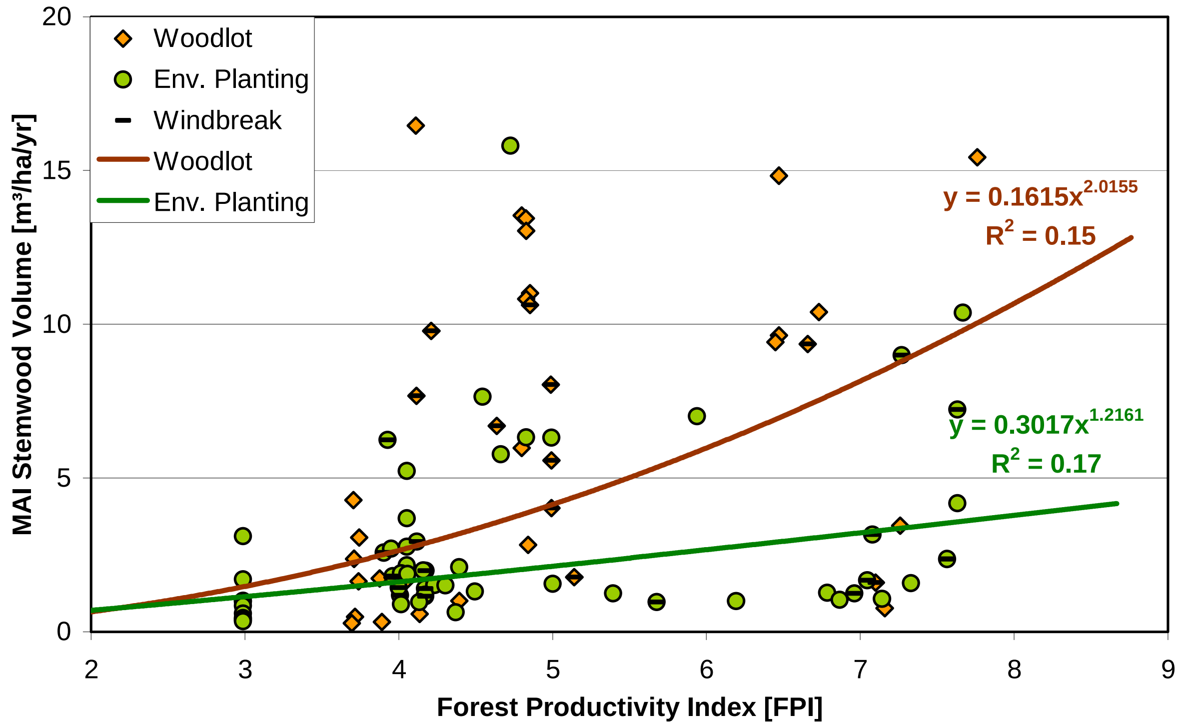
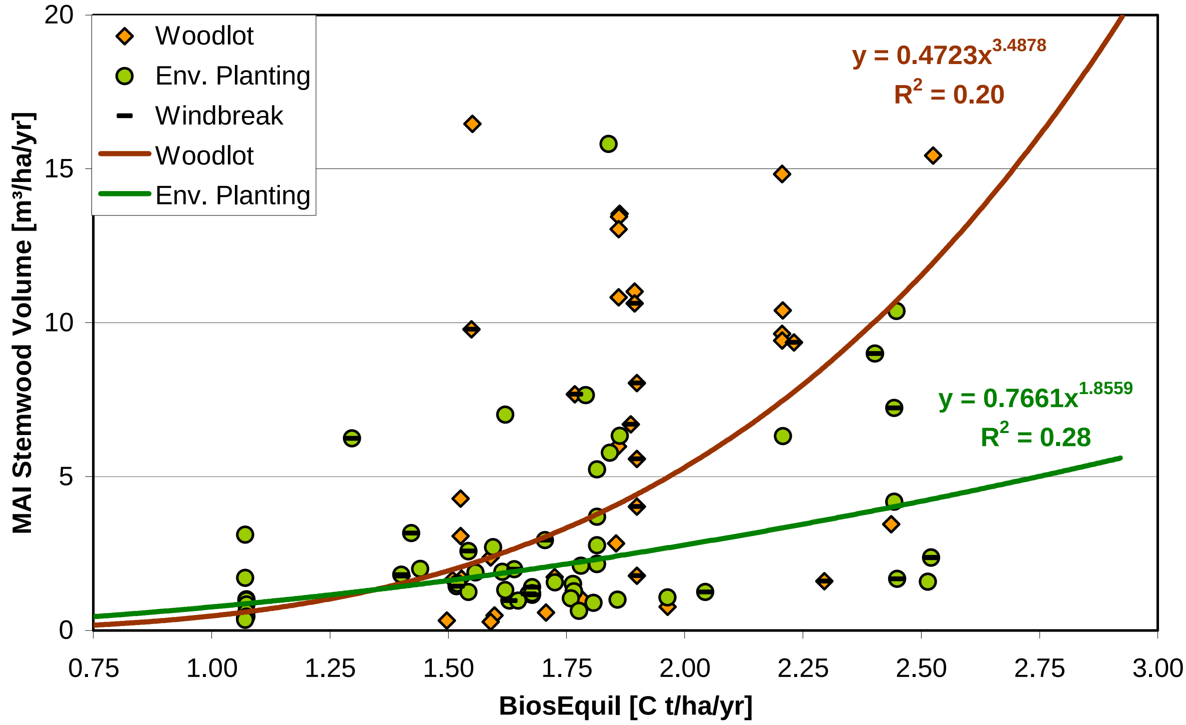


Figure 13. Relationships between primary productivity drivers and stemwood production rates from woodlot, windbreak and environmental plantings.

Stemwood Productivity

c) Stemwood Production Rates versus BiosEquil Model Predictions



d) Stemwood Production Rates versus Plant Stocking Density

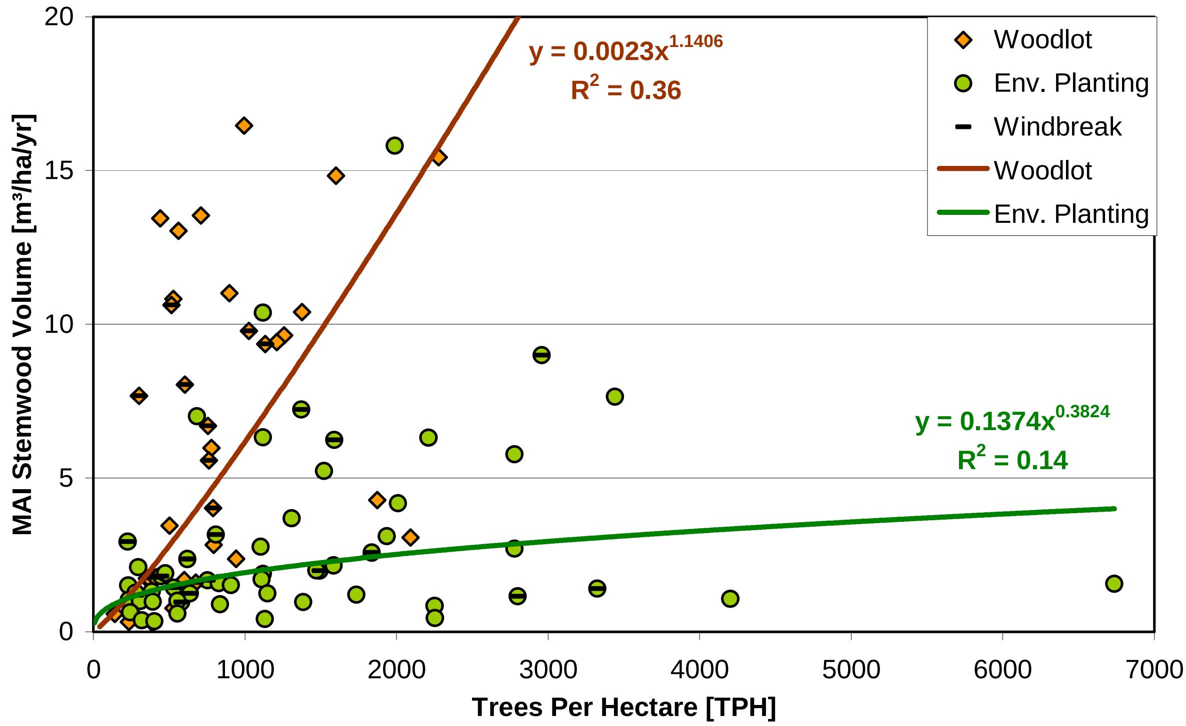
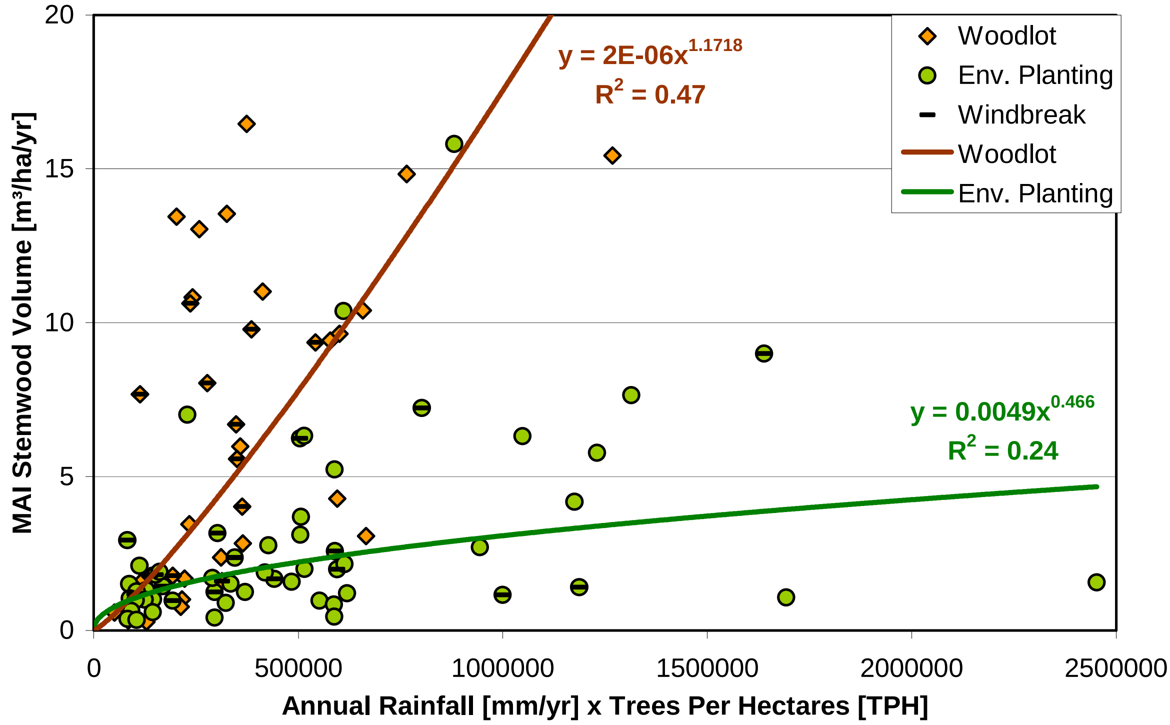


Figure 13. Relationships between primary productivity drivers and stemwood production rates from woodlot, windbreak and environmental plantings. (continued)

Stemwood Productivity

e) Stemwood Production Rates versus Annual Rainfall x Plant Stocking Density



f) Stemwood Production Rates versus Forest Productivity Index x Plant Stocking Density

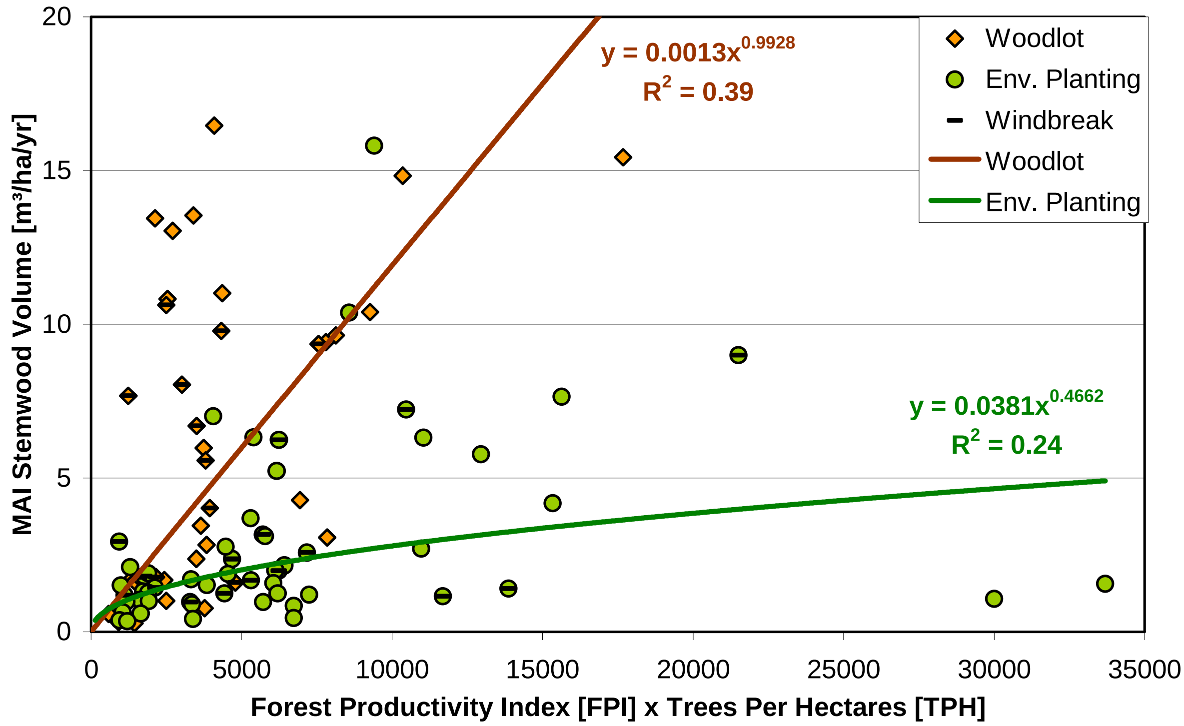


Figure 13. Relationships between primary productivity drivers and stemwood production rates from woodlot, windbreak and environmental plantings. (continued)

Stemwood Productivity

g) Stemwood Production Rates versus BiosEquil Model Predictions x Plant Stocking Density

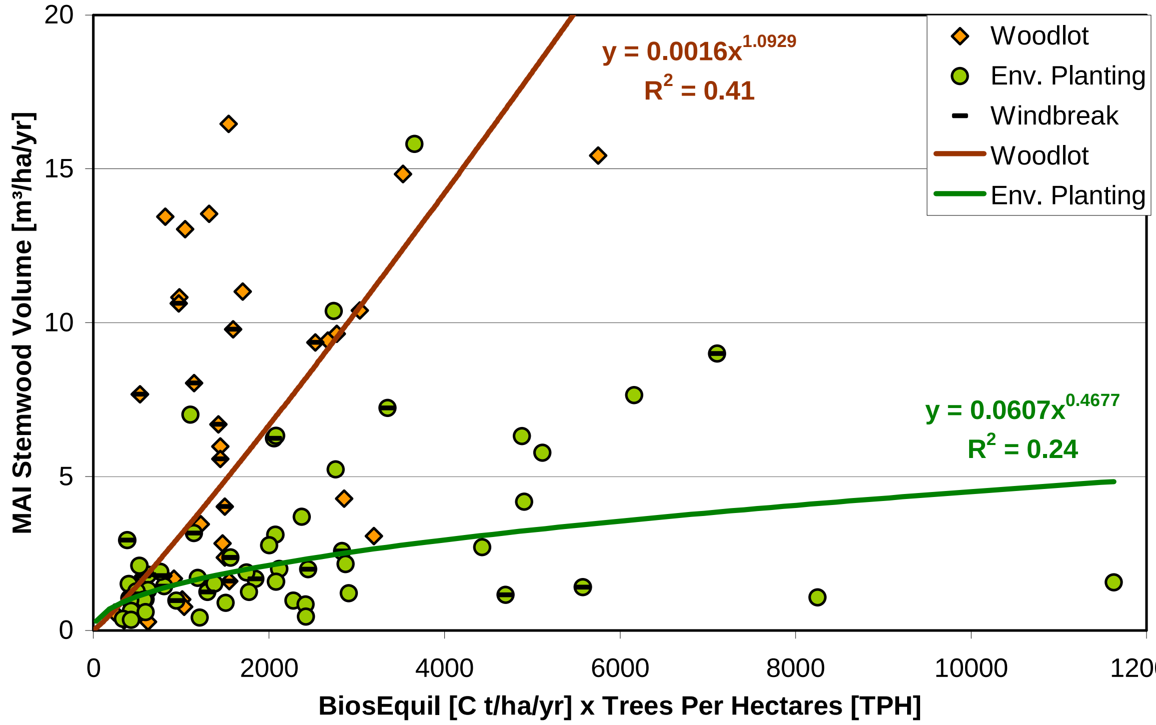
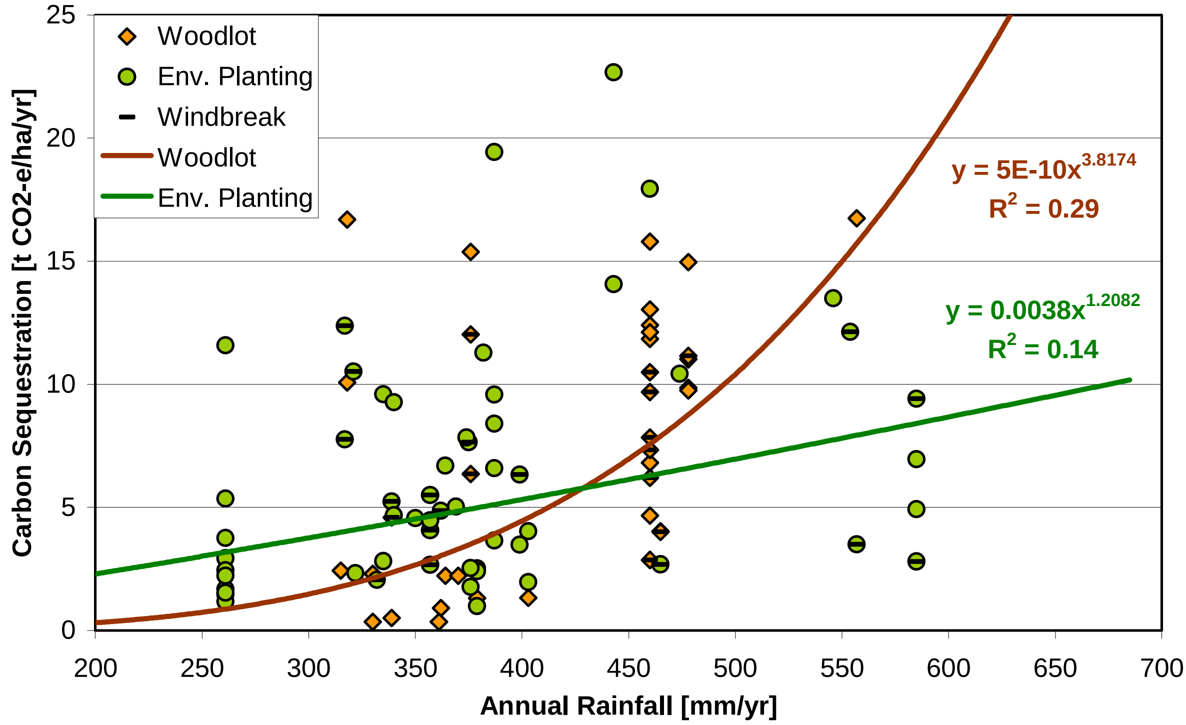


Figure 13. Relationships between primary productivity drivers and stemwood production rates from woodlot, windbreak and environmental plantings. (continued)

Carbon Sequestration

a) Carbon Sequestration Rates versus Annual Rainfall



b) Carbon Sequestration Rates versus NCAT Forest Productivity Index

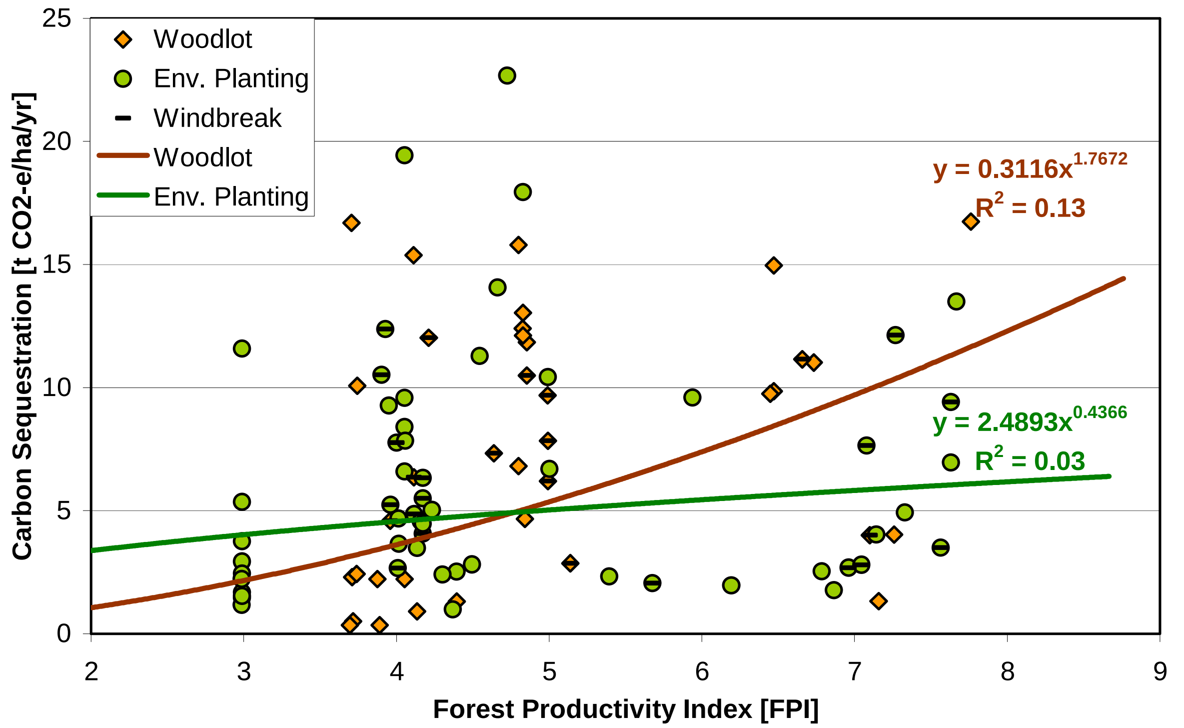
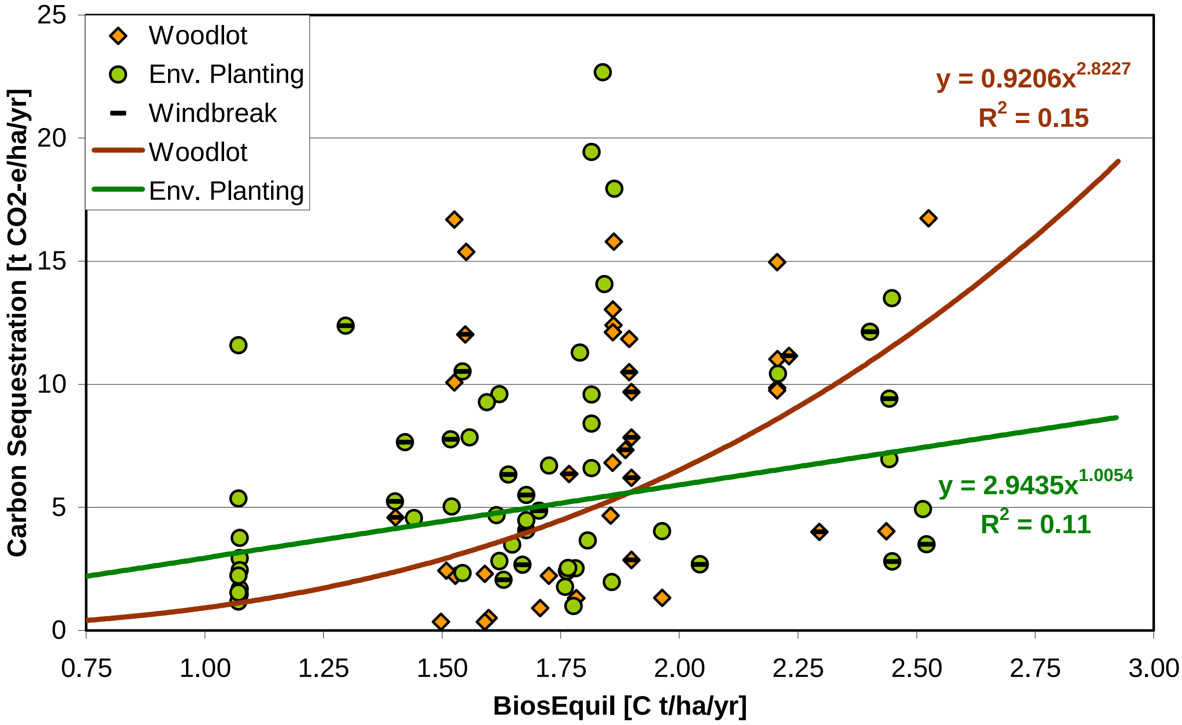


Figure 14. Relationships between primary productivity drivers and carbon sequestration rates from woodlot, windbreak and environmental plantings.

Carbon Sequestration

c) Carbon Sequestration Rates versus BiosEquil Model Predictions



d) Carbon Sequestration Rates versus Plant Stocking Density

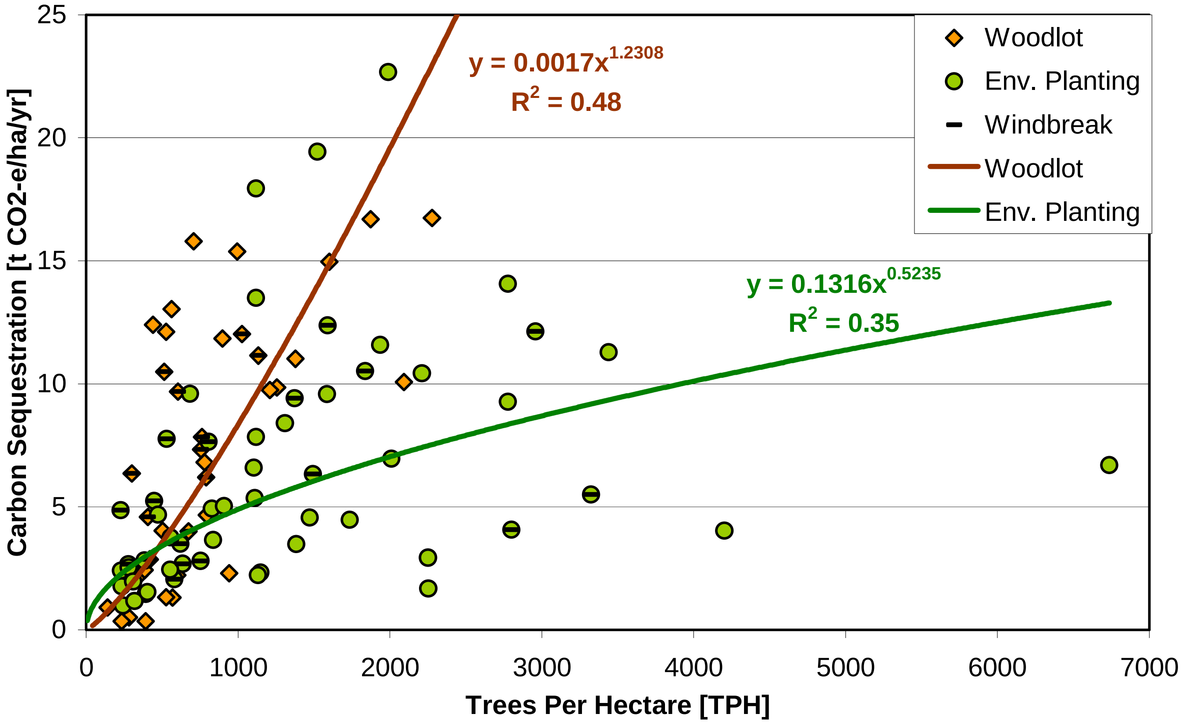
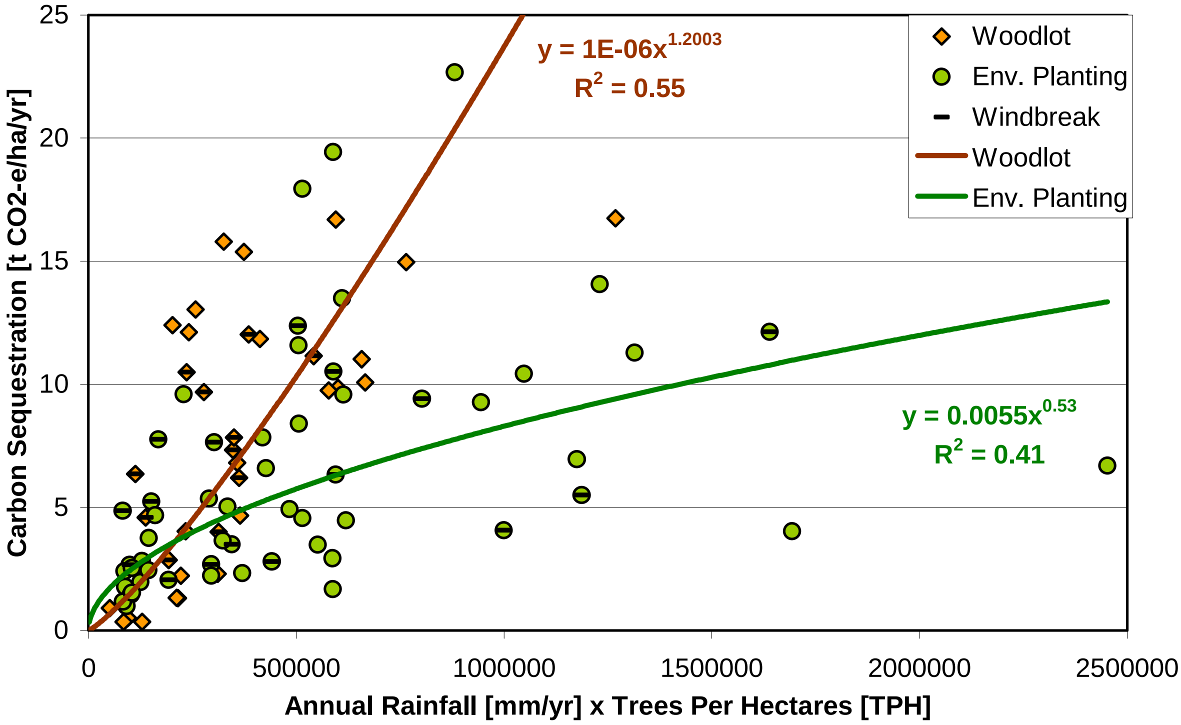


Figure 14. Relationships between primary productivity drivers and carbon sequestration rates from woodlot, windbreak and environmental plantings. (continued)

Carbon Sequestration

e) Carbon Sequestration Rates versus Annual Rainfall x Plant Stocking Density



f) Carbon Sequestration Rates versus Forest Productivity Index x Plant Stocking Density

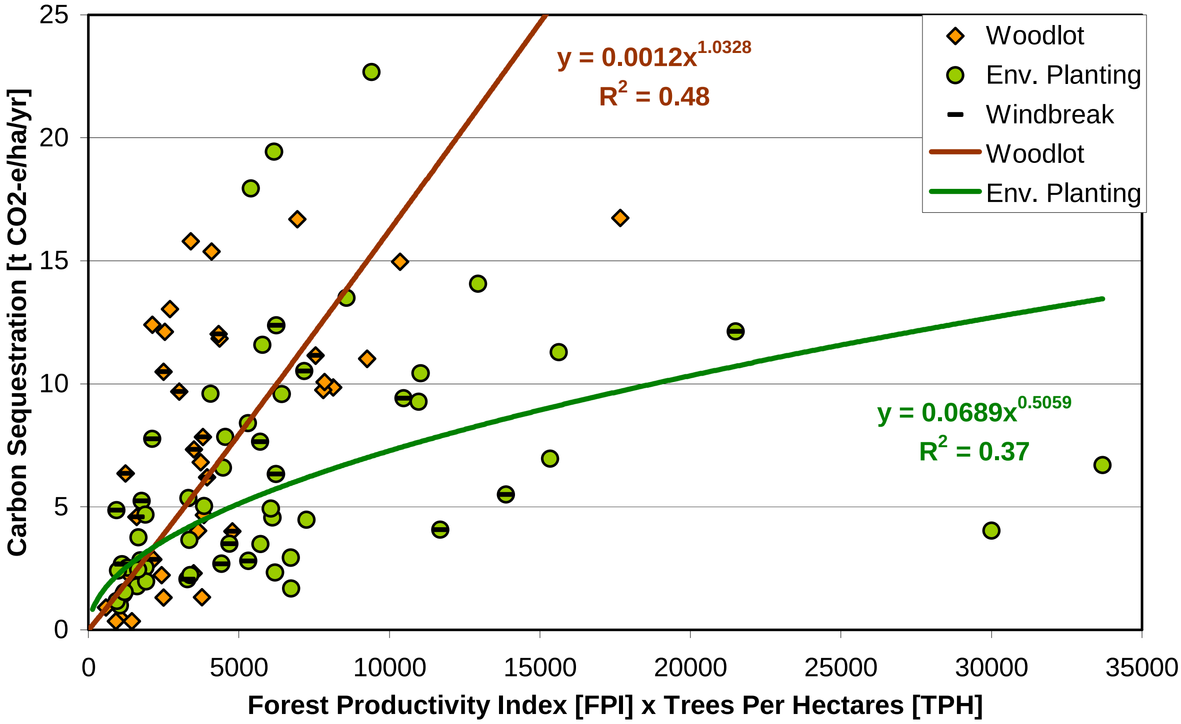


Figure 14. Relationships between primary productivity drivers and carbon sequestration rates from woodlot, windbreak and environmental plantings. (continued)

g) Carbon Sequestration Rates versus BiosEquil Model Predictions x Plant Stocking Density

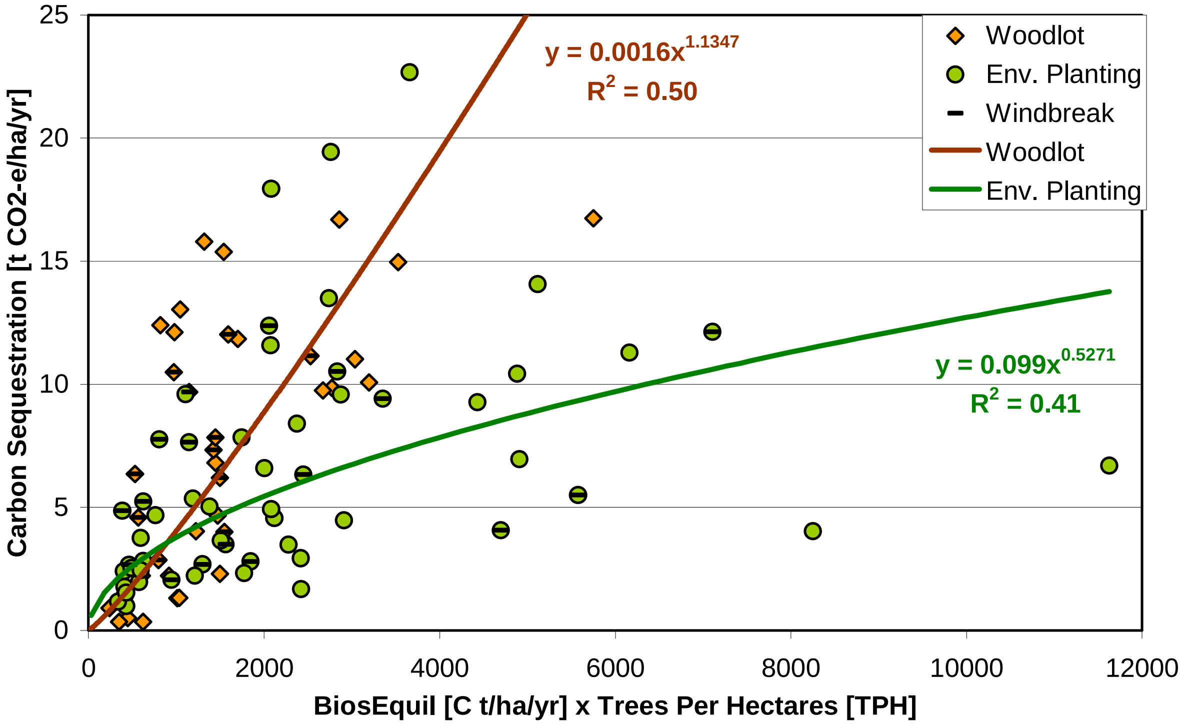


Figure 14. Relationships between primary productivity drivers and carbon sequestration rates from woodlot, windbreak and environmental plantings. (continued)

4.3 REVIEW OF NCAT FULLCAM MODEL PREDICTIONS

To take advantage of any emissions trading scheme, industry needs to be confident of the amount of carbon stored in any plantations it uses to offset emissions. Although several carbon accounting and growth models exist (e.g. FullCAM, CABALA, 3-PG, BiosEquil) the National Carbon Accounting Toolbox (NCAT) is currently the preferred package for the anticipated Carbon Pollution Reduction Scheme and the federal Department of Climate Change. NCAT uses the Full Carbon Accounting Model (FullCAM) and modified 3-PG models (Landsberg & Waring 1997) to predict time series data on plantation growth and carbon balances and sequestration rates. NCAT FullCAM Version 3.1 software allows users to calculate estimates of carbon balances under a range of landuse scenarios. The toolbox also contains a range of technical reports relevant to carbon accounting in Australia.

Public users can readily attain this NCAT software from the federal Department of Climate Change (http://www.climatechange.gov.au) and use default parameter settings to create site specific predictions of growth and carbon sequestration rates from limited range of standard planting types by entering only location and planting date parameters. Within the NCAT many site and plantation model parameter can be user-modified to refine predictions. The complex NCAT FullCAM model contains many parameters that are unfamiliar to most users and many more parameters that require detailed site and plantation specific measurements to populate model parameter sets.

Most users will rely on default settings within the NCAT models due to the lack of alternative information available or their comprehension level of NCAT model complexity. The following analyses provide an evaluation of the level of concurrence between default NCAT model predictions and observed plantation productivity data for the Southern Murray-Darling Basin region.

4.3.1 NCAT FULLCAM MODEL

The FullCAM Version 3.1 software has a number of default model parameter sets for a range of predominantly forestry species and systems suited to medium to higher rainfall zone. Users may select one of the forestry systems and apply predictive models to their specific location of interest. Alternatively, users may enter their own species and site parameter sets and run FullCAM simulations of carbon balances (see Appendix C for details). Many of the site variables are able to be changed by entering the user's own data into spreadsheets located via buttons on the various windows and sub windows. Rainfall, temperature and pan evaporation are able to be changed in this way if better quality data is available for a specific site. However, soil is restricted to a small range of types listed for each location, and while minor soil adjustments are possible, the basic characteristics remain.

While site data may be broadly applicable over larger areas, vegetation data is more variable, being dependant on the species selected. The range of background default values for species other than *Pinus radiata* and *Eucalyptus globulus* are very generalised, and in the case of mixed environmental plantings, appear very similar to *E. globulus*. But, where as *E. globulus* has a range of wood densities that vary with age, mixed environmental plantings are allocated a single wood density of 750 kilograms of dry matter per square metre regardless of age or species mix. Wood densities can vary from location to location, plant to plant and with age. Density data from a range of species destructively sampled during this study and earlier FloraSearch surveys can be used to replace default values within the FulCAM system where appropriate. Unless the FullCAM user has established wood density data for their species, it might be useful to use a source like 'Wood Densities Phase 1' (Ilic *et al.* 2000) to obtain a more realistic figure for the species on the site. A link to Ilic *et al.* (2000) exists within the NCAT Toolbox.

The forest productivity index, maximum dry matter rate and growth multipliers are also able to be adjusted if (very rarely) the user has better data for an individual site. All these site variables need to be individually adjusted for each new plot and will revert to the default values with each new site unless the user adjusts an existing saved plot and proceeds to save it separately.

Several key issues make comparisons between FullCAM predictions and field observations difficult: FullCAM does not specify trees per hectare (tph) planting rates; site-specific maximum dry matter production data used in FullCAM is irrespective of the species used; and our survey data on productivity is limited to a single measurement and cannot provide information on variation in growth rates over time. In this study the standing plant biomass for mature revegetation plantings was assessed at a range of sites (Appendix B). However, most of these sites are unlikely to have reached peak dry matter production and these surveys only provide an indication of potential site maximum biomass.

FullCAM default estimates of site maximum dry biomass for mature forestry plantations in lower rainfall areas appears to be unreliable. For example, an assessment of a very mature Salmon Gum (*Eucalyptus salmonophoia*) plantation (95 years old) nearing its expected peak standing biomass and determined an above ground dry biomass of 119.6 t/ha (942 tph). The FullCAM default parameter for the same site was only 39.4 t/ha (at unknown planting density) which is only 33% of the observed production and a significant underestimation of site productivity. Unspecified planting density (tph) within the FullCAM model parameter sets is a serious limitation of the model.

Another parameter set within the FullCAM is the allocated carbon percentages of each plant fraction. These are all set within a few percent of each other and could be set at 50% of dry biomass for each fraction without altering the modelled output significantly. A significant factor at this point is the actual proportion of total dry biomass in each plant fraction (i.e. stem, bark, branches & leaves). These proportions can be adjusted using either percentages of maximum tree dry biomass, fractional mass, or a combination of fractional mass and stem volume.

This current study has produced a set of these plant fractional parameters for the above ground portion of a range species (Table 6). For mature plantations approaching peak standing biomass these proportions may be applied within FullCAM with little modification. Gifford (2000a,b) also provides plant proportion data that maybe be manually entered into the FullCAM model to represent other poorly documented species. Users must be cautious when using plant proportions data from young plant observations as they may not represent the architecture of mature plants.

Another way the program can be tailored to individual site needs is to run it in the increment mode, rather than the default tree yield formula mode. Running the program in this mode requires the user to insert stem volume data into the model. Annual stem volume production rates from our plantation surveys and these may be inserted into the FullCAM model to approximate the production rates in the first 20-30 years of growth. Where data exists the user may enter more detailed growth data (i.e. time series) within the FullCAM model to better represent the changes in growth rates with plantation age.

The FullCAM model is complex and contains many parameters which are difficult to accurately quantify. This makes it difficult for users to readily utilise the FullCAM model for carbon accounting purposes. The most commonly used manipulation of default FullCAM parameters so that FullCAM predictions match observational data is the simplistic adjustment of site ‘Maximum Aboveground Biomass’ and ‘Forest Productivity Index - Multiplier’ parameters. Although these manipulations are readily applied to apparently improve FullCAM model fit at a particular site, the user must exercise great caution before applying those parameter corrections to other sites.

4.3.2 ACCURACY OF NCAT FULLCAM PREDICTIONS

For comparative purposes, this analysis involved FullCAM models runs for 70 ground survey sites of environmental planting and woodlot revegetation using default parameter sets for “Mixed species environmental planting #2097” and “Eucalyptus globulus #1008” from the planting date of each site until the year 2100 (see Appendix C for a step-by-step guide). Predictions of growth and carbon balances for each revegetation site were extracted from FullCAM model outputs on dates matching physical site surveys. FullCAM predictions and site survey data of above ground dry matter production were then compared to determine the reliability of the FullCAM predictions in our study region. Although this current study has assimilated some new FullCAM parameter datasets from recent surveys of species and revegetation types (see earlier sections of this report), these parameters have not been used in this current analysis. For a further model comparison, BiosEquil model (Raupach *et al.* 2001) predictions of dry matter production were generated for each site.

Weak relationships exist between observed aboveground dry matter production for woodlots or environmental plantings and the default outputs from NCAT FullCAM model (Figure 15). On average, NCAT significantly under-predicts dry matter production in the region. (~27% of observed production). In the absence of better parameter sets the default ‘Site Productivity - Multiplier’ within NCAT may be manually adjusted to account for these differences. Our data suggests that the default ‘Site Productivity - Multiplier’ parameter within NCAT would need to be corrected to a value of 4 x to reasonably represent dry matter production and carbon sequestration in the Southern Murray-Darling Basin region. Relationships between observed dry matter production and BiosEquil model predictions were also weak, but on average closer to parity (92% for Woodlots and 75% for Environmental plantings) with of observed production. For both NCAT FullCAM and BiosEquil models there is a high degree of scatter between predicted biomass production and observed values.

A current key component of the default NCAT FullCAM model is time series predictions of biomass using a logistic growth response curve (see Figure 16a). For this function to behave correctly the user must either rely on default site values of ‘Maximum Aboveground Biomass’ from a generalised spatial prediction located on a NCAT computer server or define these values manually. Unfortunately this parameter is the dominating driver for time series predictions of growth and carbon sequestration within the default FullCAM model and the most difficult to estimate. Detailed studies of biomass stores in old-age revegetation sites are required to determine this value for each site. For the majority of users and locations across Australia this makes the NCAT unusable as a reliable predictor of carbon sequestration. Our data clearly shows the current default NCAT parameters and predictions cannot provide statistically valid predictions of carbon sequestration in lower rainfall regions of South Australia.

Alternatively, users may define the initial shape of growth curves and yield information by entering their own data within the 'Stem Volume Increments' sub-module within NCAT. This module requires time series data to be entered by the user (Figure 17) but resulting predictions are still constrained to logistic curve functions for 'Maximum Aboveground Biomass' parameter and logistic curve functions (Figure 16b).

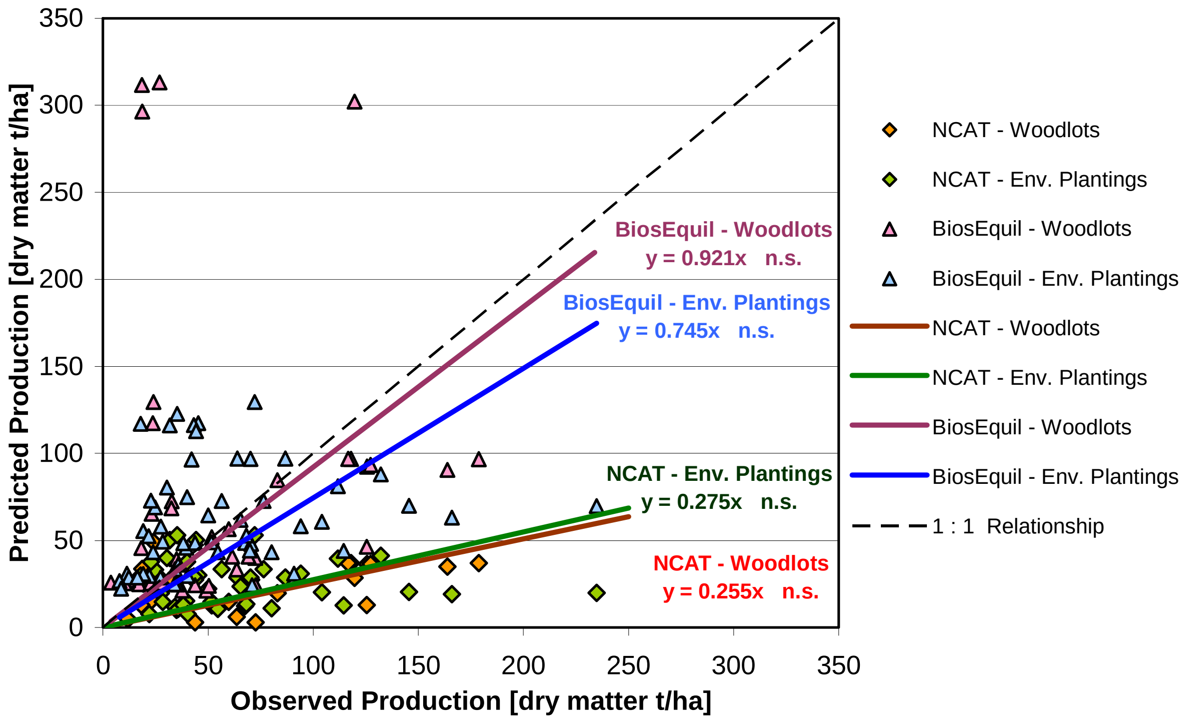
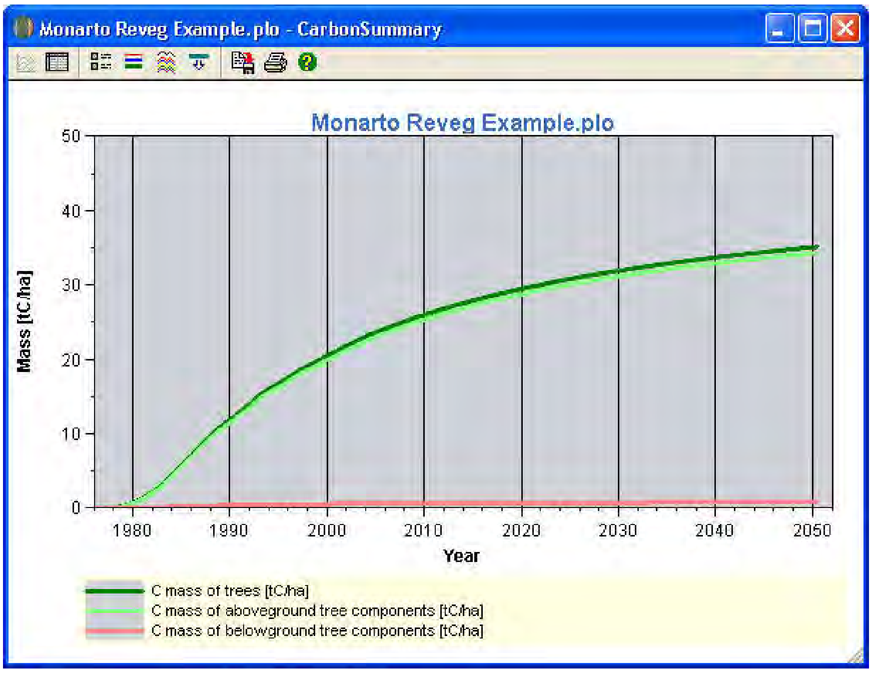


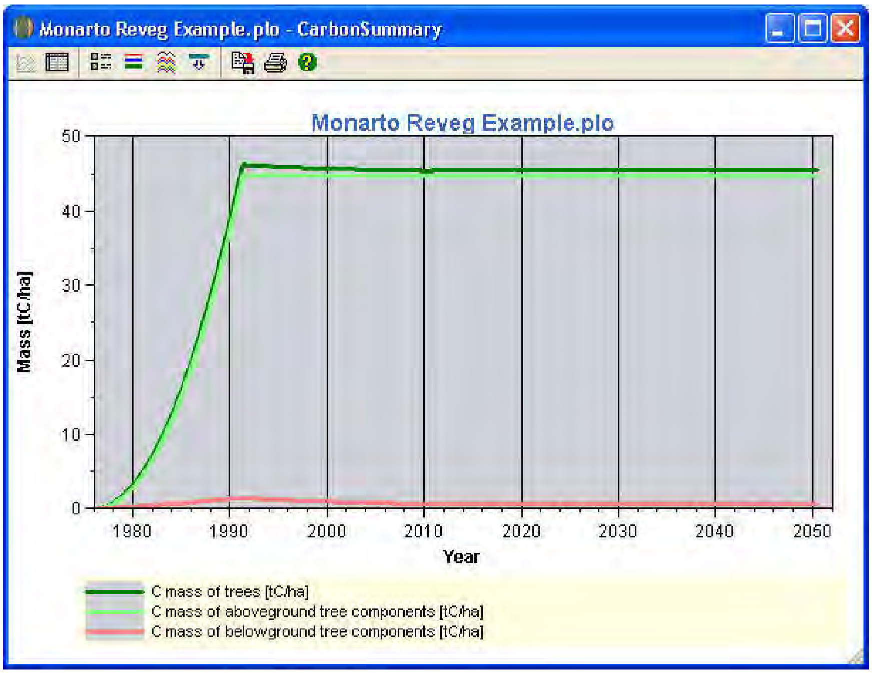
Figure 15. Predicted dry matter production from NCAT FullCAM software and raw BiosEquil model versus observed dry matter production at revegetation sites in the Southern Murray-Darling Basin region.

A major component of this study was to develop sets of parameters that could be used in conjunction with the NCAT FullCAM model to improve the predictive capacity of that system, in particular when dealing with mixed species environmental plantings. While this study has assimilated data for a number of species and plantation types, the predictive capacity of FullCAM is still restricted by limited data, especially measurements from a single point in time. For the FullCAM model to have more powerful predictive capability it requires sets of measurements over longer time periods to account for variations in plant growth with age. The spatial resolution and accuracy of site-specific information (e.g. soils, climate, Forest Productivity Index & predicted maximum aboveground biomass) downloaded from the federal Department of Climate Change NCAT data server is limited due to coarse resolution of the underlying mapping used in the national system. While the climate data from this server is expected to be of a suitable standard, the national soil mapping is of a much lesser quality than those available from SA soil mapping (SA DWLBC Soil and Land Program 2006).

a) Default "Tree Production – Tree yield formula" model



b) Default "Tree Production – Increments" model with user-defined "Stemwood volume increments"



Mixed Environmental Planting - *Eucalyptus microcarpa/brockwayii/calycogona* +8sp

Figure 16. NCAT FullCAM predicted carbon sequestration for the Monarto revegetation site using: a) default tree yield formulas; and b) user-defined tree stemwood increments.

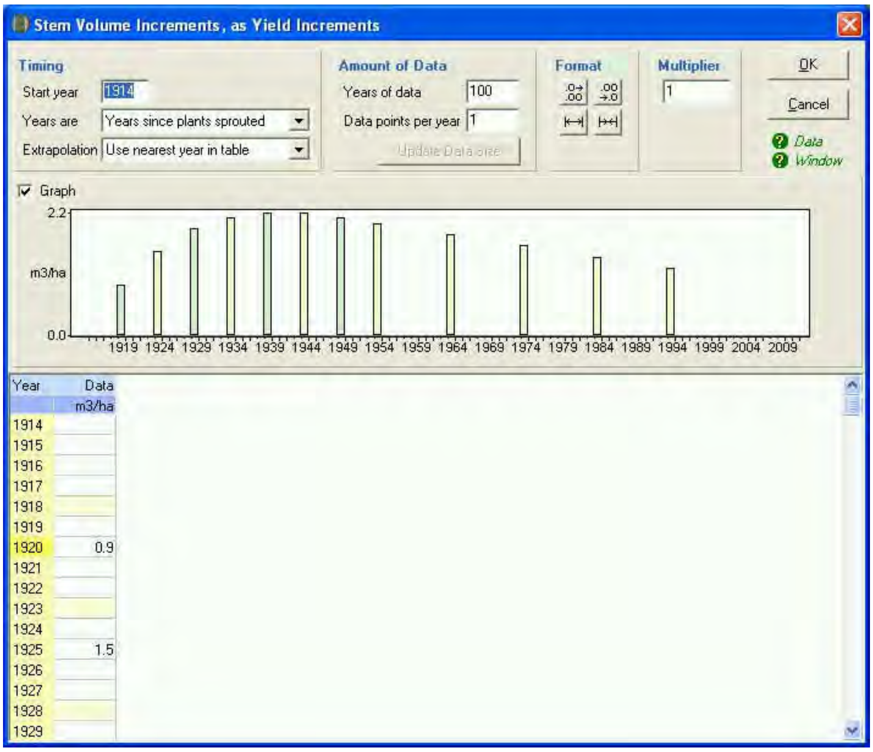


Figure 17. User-defined Stem Wood Increments parameters of the NCAT FullCAM model.

4.4 REGIONAL CARBON SEQUESTRATION RATES

Prior agroforestry and woody crop research in the Upper South East region of SA (Hobbs *et al.* 2006) has demonstrated that significant improvements in woodlot species productivity can be made from more precise matching of species to local site conditions. However, this current study aims to reasonably represent average productivity values for the region by not separating out the most productive sites and species within these analyses. The results presented in following section are likely to provide conservative estimates of potential production rates for the region.

Optimum stocking rates will vary depending on species selections for local conditions, targeted purposes of each plantation/revegetation type and the expected lifespan of revegetation project. Local expertise and planning is required to more precisely define set stocking rates. As a generalisation for the Southern Murray-Darling Basin, we largely concur with locally observed stocking rates (800 tph for woodlots, 1400 for environmental plants) but suggest an optimum stocking rate may be around 20% higher than these observed rates. Higher initial stocking rates should be anticipated for projects with longer life spans to account for natural mortality rates with age.

Productivity models identified in the previously section have been applied to spatial datasets within a geographic information system (ArcGIS 9.3, ESRI 2009) to estimate likely carbon sequestration rates from revegetation in the Southern Murray-Darling Basin region (Figure 18) at a 1 hectare resolution . Figure 19 provides estimated annual carbon sequestration rates for woodlots and environmental plantings based on district average stocking rates for each planting type (Woodlots at 800tph, Environmental Plantings at 1400tph) using BiosEquil model productivity surfaces for SA. Using a standardised plant stocking rate of 1000 tph, the potential differences in the spatial patterns of productivity has been mapped (Figure 20) using 1/ rainfall, 2/ NCAT Forest Productivity Index and 3/ BiosEquil model predictions. These maps also illustrate that significantly more carbon can be sequestered using woodlots species compared to environmental planting if stocking rates are uniform. However, when higher stocking rates are used in environmental plantings there is less difference between carbon sequestration rates between the revegetation types (Figure 19).

Spatial predictions of carbon sequestration rates from woodlots and environmental plantings have been restricted to cleared agricultural areas by masking out locations mapped by SA Department of Environment and Heritage as containing native vegetation, national parks and other conservation reserves, lakes and rivers, and built-up areas of town and cities. The nominated available land is typically dominated by cereal cropping and livestock grazing on cleared landscapes, but also includes other agricultural crops. Summary regional statistics (Figure 18) of expected annual carbon sequestration rates for environmental subregions (Interim Biogeographic Regions of Australia [IBRA]) are presented in Table 12 and more localised district (SA land administration Hundred districts) are presented in Table 13.

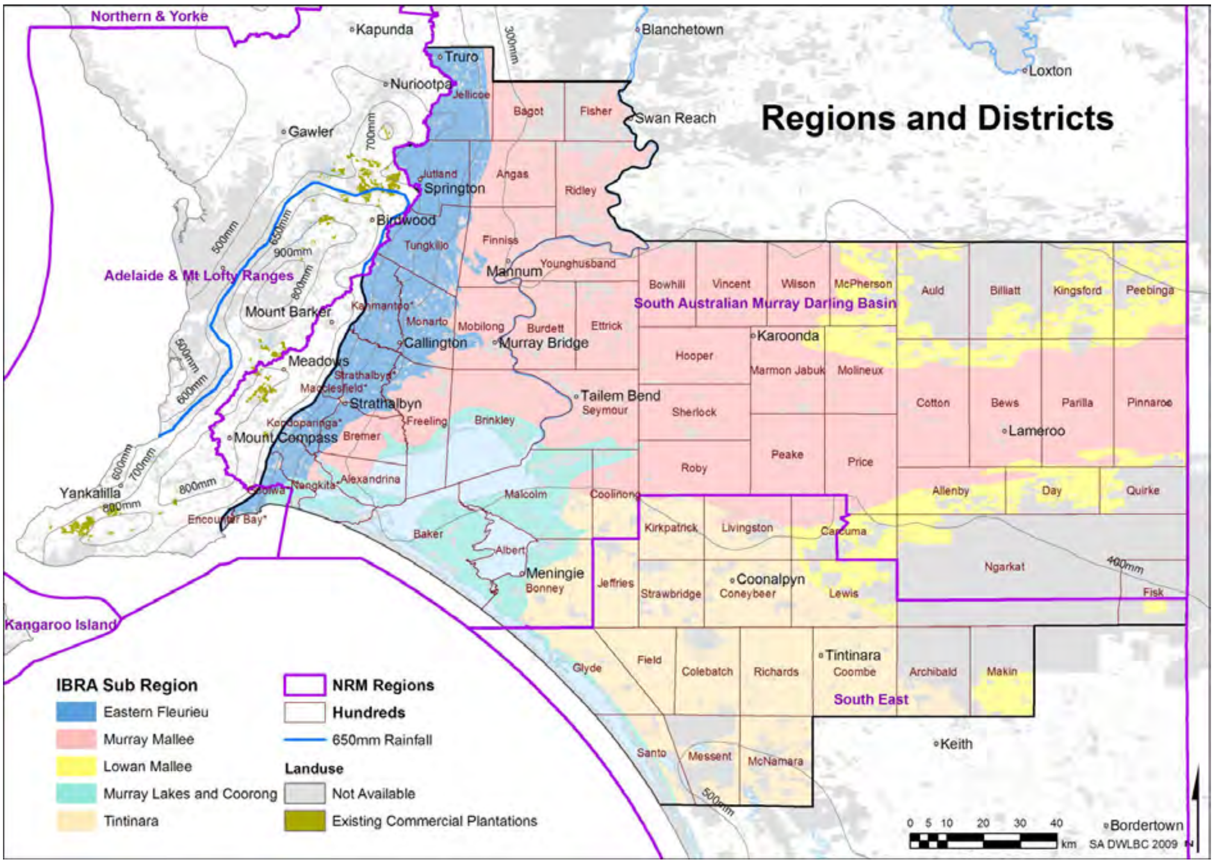


Figure 18. **Environmental and administrative regions within the study area.**

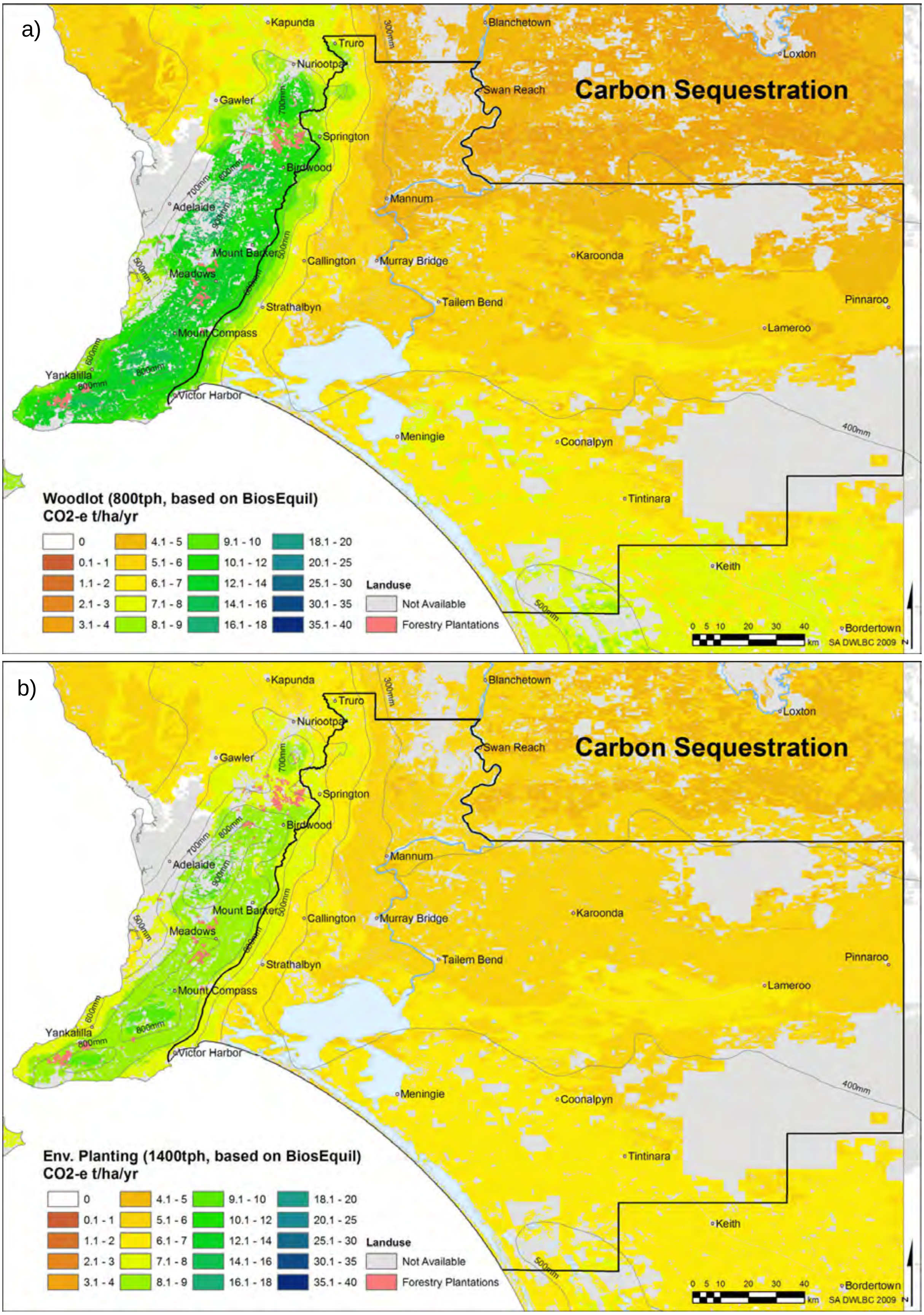
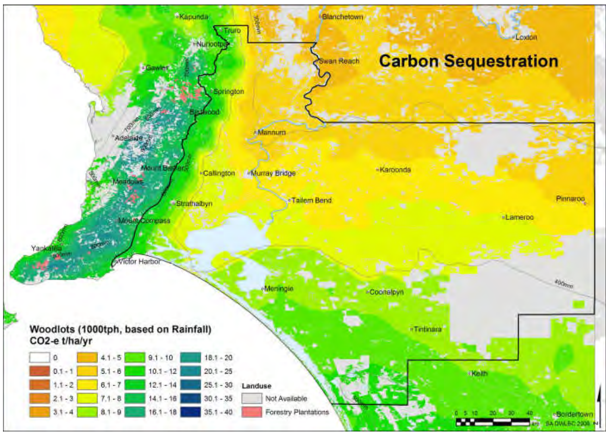


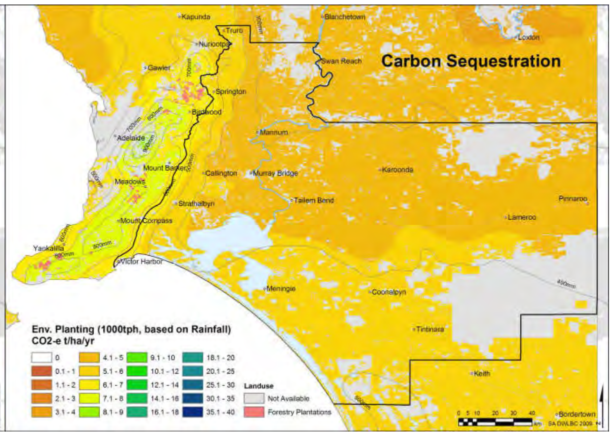
Figure 19. Estimated carbon sequestration rates from a) Woodlot and b) Environmental Planting revegetation types, based on local average planting densities (tree per hectare) by type, in the Southern Murray-Darling Basin region.

a) Average Annual Rainfall

Woodlots

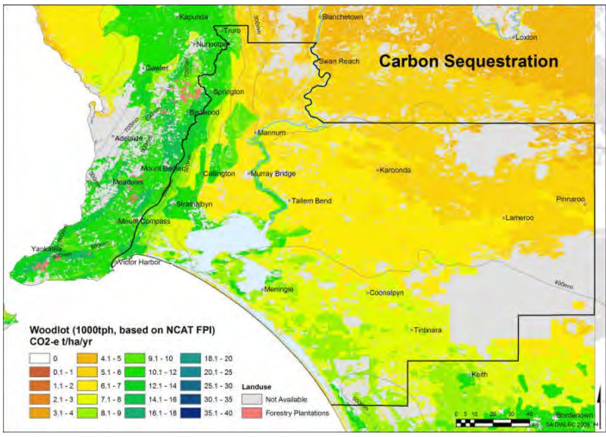


Environmental Planting

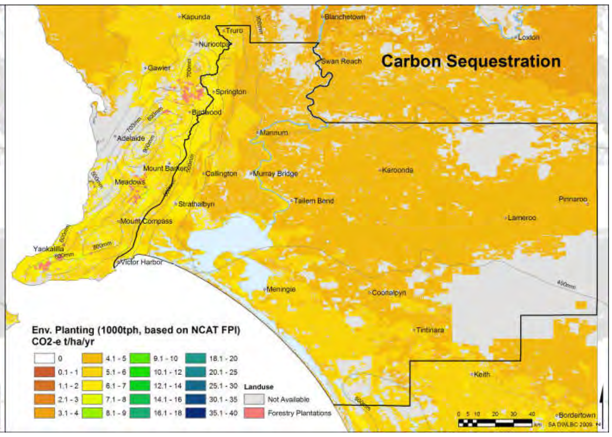


b) NCAT Forest Productivity Index

Woodlots

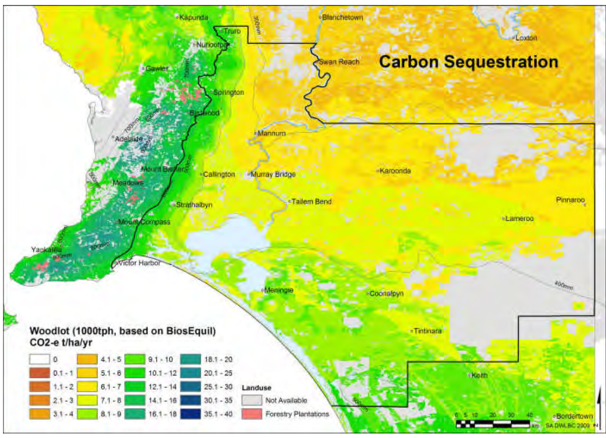


Environmental Planting



c) BiosEquil Model

Woodlots



Environmental Planting

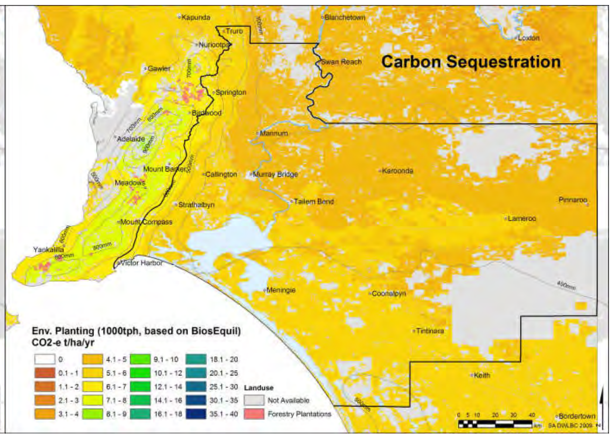


Figure 20. Comparison of estimated carbon sequestration rates using different model types based on a) average annual rainfall, b) NCAT Forestry Productivity Index and c) BiosEquil model predictions for Woodlot and Environmental Planting revegetation types at 1000 tree per hectare planting rate.

Table 12. Regional summaries of total land area, potential agricultural land for carbon sequestration activities (woodlots & environmental plantings), and estimated carbon sequestration rates for IBRA sub-regions in the study area.

Regions	Annual Rainfall (mm) [range]	Total Land Area (ha)	Potential Agric. Land (ha)	% of Land Area	Carbon Sequestration (CO_2-e t/ha/yr) [range]	
					Woodlots at 800tph	Env.Plant. at 1400tph
IBRA Sub-region (part)						
Fleurieu	469 [313-650]	199,524	181,928	91%	7.49 [4.49-10.83]	6.74 [5.33-8.03]
Murray Mallee	339 [257-440]	992,324	889,548	90%	5.29 [2.98-7.13]	5.75 [4.41-6.61]
Murray Lakes & Coorong	413 [356-579]	141,076	97,131	69%	6.25 [4.40-9.32]	6.21 [5.29-7.49]
Lowan Mallee (N)	311 [282-347]	235,604	120,787	51%	4.53 [2.86-5.53]	5.35 [4.33-5.88]
Lowan Mallee (S)	400 [333-437]	357,271	98,468	28%	5.50 [4.49-6.97]	5.86 [5.34-6.55]
Tintinara	452 [377-521]	494,913	378,428	76%	6.59 [4.64-8.37]	6.37 [5.42-7.12]
NRM Region (part)						
Murray-Darling Basin (S)	365 [258-650]	1,814,839	1,363,283	75%	5.60 [2.86-10.83]	5.89 [4.33-8.03]
South East (N)	446 [375-522]	598,528	397,167	66%	6.49 [4.68-8.37]	6.33 [5.44-7.12]
Study Area	385 [257-650]	2,420,712	1,766,290	73%	5.81 [2.98-10.83]	5.99 [4.33-8.03]

Table 13. District summaries of total land area, potential agricultural land for carbon sequestration activities (woodlots & environmental plantings), and estimated carbon sequestration rates for 70 Hundred regions in the study area.

Hundred	Annual Rainfall (mm)	Total Land Area (ha)	Potential Agric. Land (ha)	% of Land Area	Carbon Sequestration (CO_2-e t/ha/yr)	
					Woodlots at 800tph	Env.Plant. at 1400tph
Alexandrina	395	11,150	9,923	89%	6.10	6.15
Allenby	392	31,076	26,641	86%	5.72	5.97
Angas	308	34,824	31,742	91%	4.83	5.51
Archibald	438	39,632	9,825	25%	6.62	6.39
Auld	313	42,596	10,629	25%	4.58	5.38
Bagot	300	26,056	14,645	56%	4.85	5.53
Baker	409	33,100	21,955	66%	6.38	6.28
Bews	350	56,061	52,988	95%	5.45	5.83
Billiatt	309	42,558	7,641	18%	4.15	5.14
Bonney	446	43,477	37,108	85%	6.54	6.35
Bowhill	316	29,489	25,608	87%	4.96	5.59
Bremer	405	22,552	21,846	97%	6.34	6.25
Brinkley	367	40,939	34,751	85%	5.53	5.87
Burdett	330	30,733	25,350	82%	5.09	5.65
Carcuma	402	35,486	25,598	72%	5.48	5.85
Colebatch	473	34,218	27,539	80%	6.82	6.48
Coneybeer	426	35,346	30,316	86%	6.48	6.32
Coolinong	405	24,720	21,552	87%	6.09	6.14
Coombe	441	45,315	42,137	93%	6.25	6.22

Table 13 (continued) Hundred	Annual Rainfall (mm)	Total Land Area (ha)	Potential Agric. Land (ha)	% of Land Area	Carbon Sequestration (CO_2-e t/ha/yr)	
					Woodlots at 800tph	**Env.Plant. at 1400tph**
Cotton	355	56,056	51,360	92%	5.53	5.87
Day	384	26,929	18,047	67%	5.39	5.81
Encounter Bay*	641	1,013	391	39%	10.35	7.86
Ettrick	338	33,697	27,488	82%	5.26	5.74
Field	473	24,801	23,960	97%	6.83	6.48
Finniss	307	33,185	29,620	89%	4.88	5.55
Fisher	276	22,785	6,654	29%	4.34	5.25
Fisk	405	26,428	1,961	7%	5.79	6.00
Freeling	377	28,734	24,874	87%	5.78	5.99
Glyde	476	31,479	24,615	78%	6.82	6.48
Goolwa*	552	12,063	9,736	81%	8.80	7.29
Hooper	337	38,956	36,980	95%	5.21	5.71
Jeffries	440	24,607	20,894	85%	6.51	6.34
Jellicoe	450	32,772	29,983	91%	7.16	6.61
Jutland	482	26,441	25,933	98%	7.62	6.80
Kanmantoo*	518	19,686	18,308	93%	8.26	7.06
Kingsford	304	42,460	21,936	52%	4.41	5.28
Kirkpatrick	408	25,604	22,965	90%	6.25	6.22
Kondoparinga*	559	10,110	8,685	86%	8.72	7.25
Lewis	417	42,769	29,773	70%	5.86	6.03
Livingston	393	34,114	29,115	85%	5.99	6.09
Macclesfield*	589	3,475	3,240	93%	9.37	7.51
Makin	427	34,935	13,927	40%	5.99	6.10
Malcolm	406	41,145	33,909	82%	6.13	6.16
Marmon Jabuk	347	39,183	37,233	95%	5.17	5.69
McNamara	501	39,535	27,861	70%	7.42	6.74
McPherson	313	34,347	26,863	78%	4.66	5.42
Messent	502	32,592	10,987	34%	7.30	6.69
Mobilong	340	31,007	26,864	87%	5.25	5.73
Molineux	349	38,391	35,990	94%	5.21	5.71
Monarto	393	27,543	24,054	87%	6.21	6.19
Nangkita*	456	16,773	13,105	78%	7.14	6.60
Ngarkat	405	168,712	8,255	5%	5.55	5.88
Parilla	333	56,139	53,374	95%	5.16	5.69
Peake	381	36,546	35,743	98%	5.86	6.04
Peebinga	302	43,071	30,644	71%	4.39	5.27
Pinnaroo	322	56,681	53,441	94%	5.05	5.64
Price	384	41,382	40,205	97%	5.86	6.04
Quirke	358	24,966	4,357	17%	5.04	5.63
Richards	459	38,925	36,717	94%	6.50	6.33
Ridley	283	44,459	29,677	67%	4.50	5.34
Roby	368	37,107	36,517	98%	5.67	5.94
Santo	490	22,049	10,375	47%	7.31	6.69
Seymour	361	42,824	37,233	87%	5.63	5.92
Sherlock	351	38,102	36,032	95%	5.42	5.82
Strathalbyn*	473	21,653	20,659	95%	7.52	6.76
Strawbridge	441	26,752	19,795	74%	6.63	6.39
Tungkillo	451	31,280	28,642	92%	7.27	6.64
Vincent	314	37,124	34,440	93%	4.71	5.45
Wilson	309	32,382	31,264	97%	4.74	5.47
Younghusband	301	27,517	23,808	87%	4.65	5.42

* partial of Hundred district in study region

5. DISCUSSION

5.1 CARBON MARKETS, DRIVERS AND POLICIES

Governments and communities around Australia are concerned about the potential impacts of climate change on the health and prosperity of rural landscapes and communities. Two broad approaches to assist in managing this issue are: 1/ Mitigation - reducing carbon dioxide in the atmosphere by sequestering carbon dioxide in long-term stores (e.g. woody plant biomass in forests and revegetation) or reducing atmospheric emissions from fossil fuels by encouraging the development of renewable energy sources; and 2/ Adaptation - developing agricultural uses, land management practices and industries that can maintain rural prosperity by modifying current production systems to suit changed climatic conditions.

Increasing the proportion of perennial woody vegetation through revegetation and woody biomass industries in agricultural landscapes could significantly reduce atmospheric carbon dioxide through sequestration. This could also reduce fossil fuel emissions though the development of renewable bioenergy crops. Recognition of the potential of revegetation to help address some of the issues of climate change, natural resource management and rural prosperity has led to the considerable support of policies and initiatives in recent years to encourage revegetation activities in South Australia and nationally.

The likely emergence of the Carbon Pollution Reduction Scheme (CPRS) due to commence in 2011, recent expansion of existing carbon offset/credit programs from energy/liquid fuel sectors (e.g. Mandatory Renewable Energy Targets) and informal “green-friendly” markets is expected to increase the demand for carbon crops, agroforestry and environmental plantings in Australia. Current documentation for the CPRS recognises “Kyoto-compliant” revegetation/forestry for carbon accounting purposes. The Australian definition of a forest for the purpose of Kyoto Protocol accounting specifies a minimum area of only 0.2 hectares, tree crown cover of 20 per cent and a tree height of two metres (Department of Climate Change 2008). Many woodlots and environmental plantings in South Australia currently fit these criteria and most future plantings are expected to be designed as “Kyoto-compliant” to meet CPRS and other carbon trading schemes. Carbon is quickly becoming a highly valued product (or co-product) of revegetation and commercial agroforestry.

There is currently great interest and momentum for dedicated carbon sequestration crops, using both monocultures and mixed species environmental plantings of long-lived trees and shrubs. Due to land prices and economic considerations it is expected that many of these new activities will focus on the low to medium rainfall zones (250-650mm/year) on dryland agricultural landscapes that are predominantly used for annual cropping and grazing. Within the Southern Murray-Darling Basin study area the potential area for carbon crops and revegetation on cleared agricultural land equates to 1.76 million hectares or 73% of the total land area.

The growth rate, lifespan and height of plants chosen for carbon sequestration crops influence their viability as compliant carbon crops for most carbon trading schemes. Results from this study suggest that monocultures of woodlot and other commercial species are often more productive than environmental plantings at the same density (trees per hectare). Although many *Acacia* species (wattles) can be highly productive in their early stages, some do not persist over longer timeframes, and most saltbushes for lower rainfall regions (e.g. *Atriplex nummularia*) may not achieve a compliant height class (e.g. ≥ 2m). Plantations of short-lived and lower height species may not be suitable for typical carbon crop contracts.

The economic viability and success of any carbon sequestration plantings is highly dependent on the primary productivity of the species chosen. The work presented in this productivity study provides a solid evaluation of the biomass productivity of a wide range of species grown in Southern Murray-Darling Basin region. Other productivity studies (Bennell *et al.* 2008, Kiddle *et al.* 1987, Boardman 1992, Fairlamb & Bulman 1994) detail a number of tree species which are often more productive than mixed species environmental plantings within lower rainfall environments (350-650mm). Some highly productive species identified in these studies, which are climatically suited to large sections of the Southern Murray-Darling Basin, include Sugar gum (*Eucalyptus cladocalyx*), WA Swamp yate (*E. occidentalis*), SA Blue gum (*E. leucoxylon*), WA Swamp mallet (*E. spathulata*) and WA Blue mallet (*E. gardneri*).

Dedicated carbon crops and extractive-use woody biomass crops provide opportunities to both sequester carbon and/or provide commercial alternatives to existing annual crops/pastures in agricultural landscapes. Many extractive-use woody crop production systems (e.g. pulp/woodfibre, firewood, lumber/posts/poles, fodder shrubs, Eucalyptus oil) will maintain non-extracted components (e.g. root biomass and soil carbon) as carbon stores. Woody biomass extracted for use in bioenergy plants currently has a market value under the Australian Mandatory Renewable Energy Target scheme in addition to the inherent energy (and economic) value of the raw biomass. Many forestry industries in Australia that utilise woody biomass for electricity generation already derive financial returns through this scheme. Future carbon accounting practices are also expected to consider long-term average standing biomass in carbon budgeting.

The majority of existing permanent environmental plantings in South Australia were intended to address a range of natural resource management or other environmental issues, including groundwater recharge, dryland salinity, saline river discharges, wind erosion, biodiversity loss, livestock protection and amenity. In the past, many of these permanent environmental plantings of native trees and shrubs did not have a direct financial benefit to the landholder, but provided longer-term benefits to farming systems and the wider community. The establishment of these plantings were often supported by government/local region grants and incentive schemes. The potential of these revegetation types to attract tradeable carbon credits in the future may help to reduce the level of public subsidisation for these environmental plantings.

The carbon sequestration potential of revegetation may be increased through the use of a greater proportion of fast growing and productive species in the planting mix. This approach may increase the tradeable carbon value of these plantings but may also conflict with other intended values (e.g. biodiversity vs. extractable biomass) of the plantation. Ultimately it is the decision of the investors and planning authorities to determine the right blend of species for any revegetation. Monocultures (or limited species blends) of most productive species may provide substantive increases in tradeable carbon stocks and some natural resource management benefits (e.g. recharge reduction) but have lower biodiversity values.

Mixed species environmental plantings will seldom approach re-creations of natural vegetation communities that existed prior to land clearing for agriculture. While they often contain many of the larger tree and shrub species indigenous to the region, the smaller understorey species are generally not included in planted species mixes. Similarly, the number of local indigenous species planted by land managers can be significantly influenced by nursery stock availability, costs and establishment success of each species. Species preferences and fashions are evident in many environmental plantings. Notably, many Western Australian native species were “fashionable” in the 1970s and are commonly encountered in revegetation from that era. For example, River red gum (*Eucalyptus camaldulensis)*, a desirable woodlot species and locally indigenous plant of creek lines and rivers, is often found planted within mixed environmental plantings away from watercourses.

Without accurate data on planting locations, trees per hectare and survival rates of the plants despatched, the area under revegetation from nursery sales surveys in South Australia (or the Southern Murray-Darling Basin) is not easily quantifiable. Emes *et al.* (2006) suggest a planting density of around a 1000 trees/stems per hectare (tph) but this value appears to be an overestimation of planting density for woodlots (average of ~800 tph from our surveys) and an underestimate for environmental plantings (~1400 tph surveyed). Based on Trees For Life stock distributed to the Southern Murray-Darling Basin region over the last 10 years and our surveyed planting densities, at least 1,000 - 3,000 hectares of revegetation has been established in the region over the last 10 years. This represents a potential of around 10,000 - 17,000 tonnes of carbon dioxide equivalent (CO_2-e) being sequestered annually from revegetation established during the last 10 years in this region.

5.2 CARBON ACCOUNTING, ASSESSMENTS AND MODELS

The Australian Government Department of Climate Change (DCC) has a strong commitment to the use of the National Carbon Accounting Toolbox (NCAT) for carbon accounting purposes in Australia. Further, the NCAT has been identified as the preferred system to support carbon accounting within the Carbon Pollution Reduction Scheme expected to commence in 2011. At present the FullCAM model (and sub-models) within the NCAT has been predominantly populated by parameters drawn from studies of higher rainfall commercial forestry plantations. However, current NCAT parameter sets for lower rainfall species, plantation designs and mixed environmental plantings are largely absent or poorly validated.

The lack of detailed data from low to medium rainfall forestry and environmental plantings has previously hampered the development of suitable NCAT parameter sets for accurate NCAT prediction of carbon balances in the low to medium rainfall regions of Australia. Comparisons between detailed productivity assessments of 70 sites in the Southern Murray-Darling Basin region and FullCAM predictions (using their standard parameter sets) clearly demonstrates that NCAT can severely under-predict carbon sequestration rates in woodlots and environmental planting (27% of observed above-ground carbon sequestration) in lower rainfall regions. While options exist within the NCAT system to manually adjust a range of parameter to make the NCAT predictions match observed data at individual sites, this approach provides very limited opportunities to use the NCAT to successfully predict carbon balances for other plantations and sites.

The NCAT system downloads a set of spatially-variable and site-specific parameters (e.g. climate, soils, maximum aboveground biomass) from a federal Department of Climate Change computer server prior to creating FullCAM time-series predictions of carbon balances. The spatially variable parameter “Maximum aboveground biomass” dominates model predictions to such an extent that variations in other manually entered parameters have virtually no influence on resulting mature age carbon balance predictions. Although this report provides many plantation parameters (e.g. growth rates, stemwood volumes, plant fractions, wood densities) suited for input to the NCAT system, the underlying NCAT/FullCAM programming and front-end design limits the successful inclusion of these new parameters to create more realistic NCAT predictions of carbon balances in South Australia.

Previous studies of plantation productivity in the Southern Murray-Darling Basin (and most other low-mid rainfall areas of Australia) have mainly been limited to the evaluation of stemwood production rates of known forestry and biomass production species planted for industrial purposes driven by economic returns. Biomass productivity and carbon sequestration rates of many species used in mixed environmental plantings are poorly known. Measuring total plant biomass for evaluating or developing these plantings for a secondary carbon sequestration purpose can be a difficult and labour intensive task. To increase the efficiency of determining existing and future plantation productivities, and to evaluate and value-add to previously collected trial site data, current analyses provide reliable quantification of the relationships between simple plant measurements and stemwood volumes, total above-ground biomass and carbon contents (i.e. allometric relationships).

These new allometric relationships provide a foundation for robust and rapid methods of assessing carbon sequestration and woody biomass production rates from environmental revegetation, woody biomass crop and agroforestry activities in lower rainfall regions of South Australia. These relationships can now be applied to data from historical, recent and future surveys of plants at a range of revegetation sites in dryland agricultural regions to more rapidly evaluate and accuracy assess biomass production and carbon sequestration rates from revegetation in dryland agricultural regions of the state. Further, current and future productivity assessments can now be combined with spatial datasets and predictive models to allow landscape scale evaluations of potential carbon sequestration and woody crop production. Such information can provide strong guidance to those seeking to evaluate the potential for developing new plantations for carbon crops and other biomass industries in the Southern Murray-Darling Basin region.

Our analyses show that productivity and carbon sequestration in woodlots and environmental plantings in low to medium rainfall zones of the Southern Murray-Darling Basin region is dominated by planting densities (trees per hectare) and rainfall. Water availability is clearly a limiting factor of plantation growth in this area. Soil fertility was found to have no statistically significant influence on productivity in our study region. This result contrasts those from commercial forestry in higher rainfall regions, where soil fertility is considered an important factor influencing plantation growth. The biomass accumulation rates and other parameters reported here have been applied, using geographic information systems, BiosEquil and FullCAM modelling, to estimate productivity and potential carbon sequestration over the entire Southern Murray-Darling Basin. From our recent studies the expected average carbon sequestration rate of mature woodlots and environmental plantings in the Southern Murray-Darling Basin region is typically within in the range of 5.3 - 7.5 CO_2-e t/ha/year.

Regional models of plantation productivity are a core component of regional industry potential analyses to provide economic evaluations of the viability of carbon sequestration and other woody biomass industries across the dryland agricultural regions of South Australia (e.g. Hobbs 2009, Hobbs *et al.* 2009b, Crossman *et al.* 2010). High resolution spatial analyses of annual and woody crop yields and profitability can help to facilitate a better understanding the optimal productive arrangement of annual and woody crops in a farming enterprise (e.g. Lyle *et al.* 2009). Through a better understanding of the optimal productive arrangement the issue of perceived competition of new crop options can largely be avoided, and economic opportunity costs involved in the movement from existing to alternate land uses can be eliminated or reduced. It is crucial to estimate and compare economic returns and risks of new integrated systems with those from existing annual crops/pastures so that the most profitable and sustainable land use options are adopted for locations within farming enterprises and regions.

5.3 CONCLUSIONS AND RECOMMENDATIONS

Current policies, natural resource management drivers and economic evaluations indicate there are substantial opportunities for carbon sequestration in the dryland agricultural regions of South Australia from revegetation based on woody carbon crops, permanent environmental plantings and extractive agroforestry/biomass industries. Private or corporate investors in revegetation for carbon sequestration in lower rainfall regions of the state, and the extent of government support for those enterprises in the form of incentives, support mechanisms, regional planning and policy development, should be mindful of the very dynamic nature of the carbon markets and their influence on long-term viability.

Recent studies (e.g. Hobbs 2009, Hobbs *et al.* 2009b, Polglase *et al.* 2008, Crossman *et al.* 2010, Lyle *et al.* 2009) show that the scale and profitability of carbon sequestration crops is highly dependant on market prices for carbon sequestration and opportunity costs from existing landuses. Significant pressure on the viability of existing annual crops and pastures could result from high carbon market prices in the future. If uncontrolled by policy and landuse planning, carbon crop reforestation driven by market prices alone may significantly reduce agriculture production in food and fibre industries, provide only marginal biodiversity values, and reduce fresh water resources for consumptive uses in some regions.

Targeted placement of new woody biomass and carbon crop to maximise benefits and profitability of whole farm enterprises and regions should be the goal of any investment in carbon sequestration and woody crops. Broad-scale evaluations of natural resource management drivers, policies, annual and woody crop productivities and farm economics provide useful tools in determining regions with greatest potential for investment in carbon crops.

To promote success of carbon sequestration activities from revegetation in South Australia and minimise risks within these new carbon markets it is recommended that potential investors, planners and government agencies:

1. Clearly define the targeted purpose of revegetation activities (e.g. carbon vs. biodiversity) so the correct species (or species blends), scale of investment, planting designs and locations are adopted. Evaluate the influence on manipulations of plantation designs and spatial/regional priorities on financial and other intended benefits of the revegetation activities.
2. Construct a business plan for any investment in revegetation, incorporating realistic information on expected capital, establishment and maintenance costs, carbon sequestration production rates, carbon markets, management/financial/ environmental risks, property management plans and zoning/policy restrictions.

3. Exercise caution in relying on forecasts of potential carbon sequestration from existing Nation Carbon Accounting Toolbox (NCAT) models or other predictions, especially in low to medium rainfall regions. Current information clearly demonstrates a high degree of variation in carbon sequestration rates from plantations and revegetation activities in lower rainfall regions resulting from a range of unknown species, management and environmental factors. Always utilise reliable plantation assessment techniques to accurately determine quantities of carbon sequestered from revegetation for carbon accounting purposes.
4. Thoroughly evaluate local site conditions, seek expert advice and select most appropriate species for revegetation activities to maximise production rates, meet other targeted purposes, and minimise risks.
5. Support investments in further research to more accurately assess and predict carbon sequestration rates in mature revegetation plantations across the state, including a greater diversity of species, plantation types and locations. Support spatial/regional and natural resource management priority evaluations of the optimal placement of revegetation activities within agricultural landscapes of the state.

APPENDICES

APPENDIX A. REVEGETATION SPECIES

Revegetation species used in the Southern Murray-Darling Basin region, based on recent Trees For Life plant records for the region (1999-2008).

Species by Height Class	Total Plants Last 10 Years
Height Class: Tall	**1,136,782**
Acacia euthycarpa	2,162
Acacia longifolia ssp. sophorae	12,786
Acacia retinodes	14,448
Acacia stenophylla	150
Allocasuarina verticillata	142,803
Banksia marginata	10,460
Bursaria spinosa	23,577
Callitris gracilis	29,537
Casuarina pauper	310
Eucalyptus arenacea	671
Eucalyptus baxteri	14,692
Eucalyptus camaldulensis	115,809
Eucalyptus cosmophylla	11,970
Eucalyptus diversifolia	9,428
Eucalyptus dumosa	38,375
Eucalyptus fasciculosa	149,197
Eucalyptus largiflorens	30,061
Eucalyptus leucoxylon	129,513
Eucalyptus odorata	38,761
Eucalyptus oleosa	31,240
Eucalyptus porosa	59,291
Eucalyptus rugosa	740
Eucalyptus socialis	63,136
Eucalyptus viminalis	30,478
Melaleuca halmaturorum	49,245
Melaleuca lanceolata	105,802
Pittosporum angustifolium	22,140

Species by Height Class	Total Plants Last 10 Years
Height Class: Moderately Tall	**807,311**
Acacia argyrophylla	8,700
Acacia brachybotrya	33,784
Acacia calamifolia	21,673
Acacia cupularis	9,668
Acacia dodonaeifolia	10,650
Acacia hakeoides	12,385
Acacia ligulata	26,289
Acacia microcarpa	21,776
Acacia montana	6,650
Acacia notabilis	949
Acacia oswaldii	4,743
Acacia paradoxa	39,350
Acacia pycnantha	107,173
Acacia rigens	14,153
Acacia verticillata	199
Allocasuarina muelleriana	22,931
Allocasuarina striata	8,997
Callistemon brachyandrus	206
Callistemon rugulosus	39,858
Callitris canescens	2,497
Callitris rhomboidea	516
Callitris verrucosa	5,226
Dodonaea viscosa	71,591
Eucalyptus brachycalyx	21,828
Eucalyptus calycogona	27,648
Eucalyptus cyanophylla	482
Eucalyptus gracilis	51,282
Eucalyptus incrassata	43,188
Eucalyptus leptophylla	36,347
Eucalyptus phenax	17,861
Hakea leucoptera	21
Hakea mitchellii	379
Hakea rostrata	1,723
Hardenbergia violacea	7,765
Leptospermum continentale	18,147
Leptospermum coriaceum	2
Leptospermum lanigerum	18,735
Melaleuca acuminata	31,275
Melaleuca brevifolia	7,752
Melaleuca decussata	16,868
Melaleuca uncinata	36,044

APPENDIX A. REVEGETATION SPECIES

Species by Height Class	Total Plants Last 10 Years
Height Class: Medium	**132,938**
Acacia acinacea	26,595
Acacia colletioides	37
Acacia farinosa	1,528
Acacia leiophylla	585
Acacia myrtifolia	24,068
Acacia nyssophylla	1,298
Acacia rupicola	1,907
Acacia sclerophylla	7,310
Acacia spinescens	2,877
Acacia wilhelmiana	4,005
Allocasuarina mackliniana	1,416
Atriplex rhagodioides	9
Banksia ornata	3,229
Cassinia tegulata	75
Cullen australasicum	429
Gahnia sieberiana	3,176
Hakea carinata	934
Hakea rugosa	776
Melaleuca wilsonii	4,026
Olearia decurrens	96
Olearia floribunda	283
Olearia pannosa	6,669
Olearia pimeleoides	302
Olearia ramulosa	8,991
Rhagodia candolleana	8,191
Rhagodia parabolica	3,918
Senna artemisioides	8,800
Xanthorrhoea australis	224
Xanthorrhoea quadrangulata	951
Xanthorrhoea semiplana	10,234

Species by Height Class	Total Plants Last 10 Years
Height Class: Low	**68,138**
Arthropodium strictum	1,128
Atriplex semibaccata	9,381
Atriplex stipitata	981
Atriplex suberecta	1,310
Atriplex vesicaria	355
Austrostipa elegantissima	918
Austrostipa eremophila	11
Austrostipa mollis	338
Austrostipa nitida	8
Austrostipa scabra	612
Austrostipa semibarbata	604
Carex tereticaulis	28
Chloris truncata	275
Chrysocephalum apiculatum	307
Clematis microphylla	8,232
Dianella revoluta	54
Dodonaea baueri	575
Einadia nutans	4
Enchylaena tomentosa	10,556
Helichrysum scorpioides	383
Juncus pallidus	5,701
Kennedia prostrata	3,733
Maireana brevifolia	88
Maireana erioclada	37
Microlaena stipoides	9,011
Olearia axillaris	103
Olearia muelleri	277
Rhagodia crassifolia	5,483
Rhagodia spinescens	134
Senecio quadridentatus	66
Vittadinia blackii	1,929
Vittadinia cuneata	2,097
Vittadinia dissecta	178
Vittadinia gracilis	2,017
Vittadinia sp.	1,000
Xerochrysum bracteatum	223
local seed sources (species unknown)	**230,534**
All plants	**2,375,702**

APPENDIX B. PRODUCTIVITY AND CARBON SEQUESTRATION

Plantation growth and carbon sequestration rates from mixed-species and single-species plantings observed in the Southern Murray-Darling Basin region.

	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
Species	Rain [mm]	NCAT Model – Max. Dry matter [t/ha]	NCAT Forest Productivity Index	BiosEquil Model [t C/ha/yr]	Age	TPH	StandType [Block, WindBreak,,Random/Natural	Observations	Height [m]	Stem Volume MAI [m³/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]	Stemwood	Bark	Branches	Leaf
Mixed species																	
A. pycnantha/microcarpa, +6sp	364	68.8	5.0	2.4	18.0	6736	BL	86	4.0	1.56	3.647	1.81	6.64	0.39	0.07	0.37	0.17
Acacia calamifolia								1	2.2	0.43	0.3%			0.34	0.07	0.37	0.22
Acacia microcarpa								22	4.4	1.85	28.7%			0.40	0.07	0.36	0.17
Acacia paradoxa								1	2.9	1.13	0.8%			0.39	0.08	0.33	0.20
Acacia pycnantha								52	3.8	1.35	59.9%			0.39	0.06	0.39	0.16
Allocasuarina verticillata								1	3.7	0.26	0.4%			0.21	0.03	0.59	0.17
Dodonaea viscosa ssp. cuneata								2	3.7	0.65	0.9%			0.45	0.08	0.31	0.17
Eucalyptus incrassata								6	4.3	2.03	5.8%			0.33	0.18	0.23	0.26
Eucalyptus leucoxylon								1	6.0	7.75	2.6%			0.43	0.17	0.17	0.23
Allo. verticillata, E. leucoxylon, +1sp	403	95.9	6.2	2.9	33.0	310	BL	60	6.0	1.00	1.069	0.53	1.95	0.72	0.11	0.08	0.09
Allocasuarina verticillata								38	5.7	0.74	63.0%			0.73	0.11	0.09	0.08
Callitris gracilis								7	5.7	1.67	24.9%			0.77	0.12	0.06	0.06
Eucalyptus leucoxylon								15	7.2	1.13	14.8%			0.67	0.11	0.08	0.14
Allo. verticillata, E. socialis, +7sp	399	49.9	4.2	1.3	15.0	1492	WB	36	4.8	1.99	3.447	1.71	6.28	0.56	0.09	0.18	0.16
Acacia rigens								2	2.7	3.84	10.7%			0.48	0.09	0.25	0.17
Allocasuarina verticillata								14	5.6	2.32	43.6%			0.63	0.10	0.17	0.11
Callitris gracilis								1	2.6	0.13	0.3%			0.33	0.05	0.45	0.17
Dodonaea viscosa ssp. spathulata								3	3.1	0.17	0.9%			0.40	0.08	0.32	0.20
Eucalyptus camaldulensis								1	8.5	4.93	3.2%			0.53	0.15	0.13	0.20
Eucalyptus incrassata								4	4.0	1.65	11.1%			0.50	0.08	0.20	0.22
Eucalyptus leptophylla								1	2.9	0.15	0.3%			0.23	0.18	0.29	0.29

Species	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
	Rain [mm]	NCAT Model – Max. Dry matter [t/ha]	NCAT Forest Productivity Index	BiosEquil Model [t C/ha/yr]	Age	TPH	StandType [Block, WindBreak,,Random/Natural	Observations	Height [m]	Stem Volume MAI [m³/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]	Stemwood	Bark	Branches	Leaf
Eucalyptus oleosa								2	5.0	1.72	3.9%			0.49	0.11	0.18	0.22
Eucalyptus socialis								8	5.1	1.77	22.8%			0.53	0.08	0.19	0.20
Callitris gracilis, E. camaldulensis, +12sp	335	92.3	6.0	1.7	18.0	1981	BL	60	8.9	24.43	13.939	6.91	25.37	0.73	0.10	0.07	0.10
Acacia argyrophylla								5	3.9	10.59	9.3%			0.57	0.11	0.19	0.13
Acacia montana								1	2.7	0.89	0.2%			0.43	0.08	0.30	0.19
Acacia retinodes								7	7.1	17.81	20.9%			0.75	0.11	0.07	0.06
Acacia rigens								1	2.8	0.49	0.1%			0.49	0.10	0.25	0.16
Acacia sclerophylla								1	2.7	0.19	0.0%			0.39	0.08	0.33	0.20
Callitris gracilis								18	5.9	2.54	8.8%			0.68	0.10	0.13	0.09
Dodonaea viscosa ssp. angustisima								2	3.0	2.45	1.0%			0.47	0.09	0.26	0.17
Eucalyptus camaldulensis								9	18.2	17.30	7.8%			0.79	0.08	0.04	0.09
Eucalyptus cladocalyx								1	13.0	59.72	3.5%			0.72	0.10	0.06	0.12
Eucalyptus fasciculosa								4	10.0	26.27	7.2%			0.66	0.12	0.08	0.15
Eucalyptus incrassata								2	7.0	2.61	1.0%			0.56	0.10	0.17	0.18
Eucalyptus largiflorens								1	12.5	9.40	0.5%			0.76	0.09	0.05	0.10
Eucalyptus leucoxylon								7	13.8	22.25	9.9%			0.68	0.11	0.07	0.13
Melaleuca brevifolia								1	3.2	0.44	0.1%			0.49	0.10	0.25	0.16
Callitris gracilis, E. leucoxylon/por., +6sp	376	109.4	6.8	2.2	31.9	280	BL	60	7.0	1.27	1.385	0.69	2.52	0.70	0.11	0.10	0.10
Brachychiton populeneus								1	2.7	0.03	0.1%			0.36	0.06	0.41	0.17
Callitris gracilis								22	5.5	0.28	12.0%			0.66	0.10	0.14	0.10
Eucalyptus campaspe								2	7.3	1.35	1.9%			0.64	0.12	0.09	0.15
Eucalyptus gardneri								1	9.2	3.71	6.5%			0.72	0.11	0.09	0.08
Eucalyptus gomphocephala								2	10.8	1.50	1.9%			0.68	0.11	0.07	0.14
Eucalyptus leucoxylon								14	6.9	0.73	8.2%			0.59	0.13	0.10	0.17
Eucalyptus phenax								2	5.8	0.96	3.4%			0.66	0.11	0.12	0.12
Eucalyptus porosa								9	8.8	2.24	28.9%			0.69	0.11	0.10	0.10
Eucalyptus spathulata								7	9.3	3.97	36.6%			0.74	0.11	0.08	0.07
Callitris gracilis, E. platypus/dund., +7sp	362	48.7	4.1	1.7	18.9	227	WB	60	7.2	2.92	2.647	1.31	4.82	0.72	0.11	0.09	0.09
Allocasuarina verticillata								1	7.0	2.38	2.1%			0.75	0.11	0.07	0.07

Species	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
	Rain [mm]	NCAT Model – Max. Dry matter [t/ha]	NCAT Forest Productivity Index	BiosEquil Model [t C/ha/yr]	Age	TPH	StandType [Block, WindBreak,,Random/Natural]	Observations	Height [m]	Stem Volume MAI [m³/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]	Stemwood	Bark	Branches	Leaf
Callitris gracilis								13	5.0	1.31	15.1%			0.75	0.11	0.07	0.07
Eucalyptus camaldulensis								5	8.1	2.20	3.7%			0.68	0.11	0.07	0.13
Eucalyptus dundasii								8	10.8	2.98	7.6%			0.71	0.11	0.06	0.12
Eucalyptus leptophylla								3	4.8	0.57	1.8%			0.61	0.10	0.14	0.14
Eucalyptus leucoxylon								6	10.9	7.19	11.2%			0.79	0.08	0.04	0.09
Eucalyptus platypus								10	10.6	6.07	55.1%			0.73	0.11	0.09	0.07
Eucalyptus socialis								4	4.2	0.42	1.9%			0.59	0.09	0.16	0.16
Melaleuca halmaturorum								5	2.9	0.31	1.5%			0.53	0.10	0.22	0.15
Melaleuca lanceolata								5	3.0	0.94	4.4%			0.56	0.11	0.19	0.14
Casuarina cunninghamiana, +5sp	465	116.6	7.1	3.0	14.9	675	WB	39	5.4	1.61	2.176	1.08	3.96	0.64	0.11	0.14	0.11
Acacia pycnantha								6	3.4	0.26	4.0%			0.49	0.08	0.29	0.14
Allocasuarina verticillata								3	4.0	0.37	2.9%			0.48	0.07	0.30	0.15
Casuarina cunninghamiana								24	5.6	2.08	95.0%			0.67	0.10	0.13	0.09
Corymbia maculata								1	7.3	0.67	0.6%			0.55	0.14	0.12	0.19
Eucalyptus cladocalyx								4	7.2	0.64	2.2%			0.56	0.14	0.11	0.18
Eucalyptus leucoxylon								1	7.4	1.15	0.8%			0.62	0.13	0.09	0.16
E. camald., Cas. cunninghamiana, +1sp	585	115.3	7.0	3.0	14.9	754	WB	60	6.1	1.68	1.529	0.76	2.78	0.58	0.12	0.15	0.15
Casuarina cunninghamiana								23	6.1	0.92	40.2%			0.60	0.09	0.19	0.12
Eucalyptus camaldulensis								36	6.0	2.23	60.1%			0.57	0.14	0.11	0.18
Eucalyptus sideroxylon								1	6.2	0.19	0.2%			0.42	0.17	0.18	0.23
E. camald./largiflorens, A. ligulata, +6sp	387	47.2	4.1	1.4	11.9	1309	BL	60	4.6	3.69	4.579	2.27	8.34	0.55	0.11	0.18	0.15
Acacia calamifolia								7	2.3	1.03	4.6%			0.47	0.09	0.26	0.17
Acacia ligulata								25	4.9	4.08	57.1%			0.54	0.11	0.21	0.14
Acacia rigens								3	2.4	1.07	2.1%			0.46	0.09	0.27	0.18
Callitris canescens								1	5.8	5.22	3.0%			0.52	0.10	0.22	0.15
Dodonaea viscosa ssp. angustisima								6	1.5	0.08	0.5%			0.33	0.07	0.38	0.22
Eucalyptus camaldulensis								8	6.8	4.76	10.0%			0.55	0.14	0.12	0.18
Eucalyptus largiflorens								8	7.3	7.90	19.8%			0.63	0.12	0.09	0.16
Eucalyptus oleosa								1	2.8	0.10	0.2%			0.21	0.03	0.30	0.45

Species	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
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Eucalyptus socialis								1	3.8	1.07	1.0%			0.41	0.06	0.24	0.29
E. camaldulensis/leucoxylon	370	47.2	4.1	1.6	15.0	600	BL	60	6.6	1.68	1.215	0.60	2.21	0.55	0.14	0.12	0.18
Eucalyptus camaldulensis								31	7.5	2.10	61.7%			0.57	0.14	0.11	0.18
Eucalyptus leucoxylon								29	5.5	1.28	39.1%			0.53	0.14	0.13	0.19
E. camaldulensis/oleosa, +6sp	387	47.2	4.1	1.4	9.9	1104	BL	60	4.5	2.76	3.591	1.78	6.54	0.54	0.10	0.18	0.19
Acacia rigens								10	4.0	1.64	13.7%			0.59	0.09	0.20	0.12
Allocasuarina muelleriana								7	2.4	1.11	9.3%			0.49	0.10	0.25	0.16
Allocasuarina verticillata								2	4.9	3.00	4.8%			0.61	0.09	0.18	0.11
Eucalyptus camaldulensis								14	6.5	7.04	30.7%			0.59	0.13	0.11	0.17
Eucalyptus cyanophylla								1	3.4	0.26	0.5%			0.27	0.04	0.29	0.40
Eucalyptus incrassata								2	3.6	0.61	1.6%			0.38	0.06	0.25	0.31
Eucalyptus oleosa								14	4.4	2.05	26.6%			0.53	0.08	0.19	0.21
Eucalyptus socialis								10	4.1	1.10	11.8%			0.46	0.07	0.22	0.26
E. camald./tricarpa/cladocalyx, +4sp	478	108.2	6.7	2.9	20.9	1376	BL	60	13.0	10.39	6.001	2.98	10.92	0.66	0.12	0.08	0.14
Eucalyptus camaldulensis								21	12.1	6.80	24.1%			0.63	0.13	0.09	0.16
Eucalyptus cladocalyx								12	14.8	23.53	39.6%			0.71	0.11	0.06	0.12
Eucalyptus leucoxylon								6	13.5	8.82	8.1%			0.67	0.12	0.08	0.14
Eucalyptus platypus								2	8.5	4.21	4.3%			0.58	0.09	0.17	0.17
Eucalyptus sideroxylon								6	14.6	9.56	9.5%			0.64	0.12	0.08	0.15
Eucalyptus spathulata								1	14.0	15.50	2.5%			0.65	0.12	0.08	0.15
Eucalyptus tricarpa								12	12.3	7.73	15.6%			0.63	0.12	0.09	0.16
E. cladocalyx/camaldulensis	478	101.7	6.4	2.9	21.9	1210	BL	36	16.3	9.42	5.316	2.64	9.68	0.66	0.12	0.08	0.14
Eucalyptus camaldulensis								18	15.1	7.83	43.3%			0.64	0.12	0.08	0.15
Eucalyptus cladocalyx								18	17.4	10.94	56.4%			0.67	0.11	0.07	0.14
E. cladocalyx/camaldulensis, +1sp	478	102.2	6.5	2.9	21.9	1257	BL	60	14.6	9.63	5.373	2.67	9.78	0.66	0.12	0.08	0.14
Eucalyptus camaldulensis								30	14.7	10.64	55.7%			0.66	0.12	0.08	0.14
Eucalyptus cladocalyx								29	14.8	8.95	44.3%			0.67	0.11	0.08	0.14
Eucalyptus phenax								1	3.0	0.17	0.1%			0.41	0.06	0.24	0.29
E. diversifolia/incrassata, +4sp	460	64.8	4.8	1.7	17.0	1119	BL	60	5.5	6.32	9.775	4.85	17.79	0.65	0.10	0.13	0.12

Species	Site Detail				Field Survey										Proportion of Above-ground Dry Biomass			
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Allocasuarina verticillata								2	4.2	1.43	0.7%			0.69	0.11	0.12	0.09
Eucalyptus diversifolia								35	6.2	8.67	80.5%			0.66	0.10	0.12	0.11
Eucalyptus incrassata								18	4.2	1.44	7.8%			0.54	0.08	0.18	0.20
Eucalyptus leptophylla								2	3.3	1.25	0.9%			0.48	0.07	0.21	0.24
Eucalyptus leucoxylon								2	7.3	22.97	5.2%			0.60	0.13	0.10	0.17
Eucalyptus platypus								1	5.2	7.80	2.0%			0.70	0.11	0.10	0.09
E. fasciculosa, A. pycnantha/ret., +5sp	465	113.4	7.0	3.0	16.9	636	WB	72	5.7	1.25	1.458	0.72	2.65	0.62	0.11	0.14	0.13
Acacia pycnantha								24	5.2	0.65	25.6%			0.61	0.09	0.18	0.11
Acacia retinodes								12	5.8	2.55	43.5%			0.70	0.11	0.11	0.08
Allocasuarina verticillata								5	4.9	0.81	7.2%			0.57	0.09	0.22	0.13
Eucalyptus camaldulensis								6	5.9	0.97	5.5%			0.45	0.16	0.17	0.22
Eucalyptus fasciculosa								19	6.2	0.99	13.6%			0.54	0.14	0.13	0.19
Eucalyptus leucoxylon								3	8.1	3.59	6.8%			0.59	0.13	0.10	0.17
Eucalyptus viminalis ssp. cygnetensis								1	8.2	3.53	2.2%			0.61	0.13	0.10	0.16
Melaleuca lanceolata								2	1.6	0.06	0.3%			0.39	0.08	0.33	0.20
E. fasciculosa, A. retinodes/pycn., +3sp	585	128.7	7.6	3.0	14.9	2010	BL	70	5.8	4.18	3.787	1.88	6.89	0.57	0.12	0.16	0.15
Acacia pycnantha								20	4.4	0.38	8.6%			0.35	0.05	0.43	0.16
Acacia retinodes								14	5.7	2.63	23.0%			0.64	0.10	0.16	0.10
Allocasuarina verticillata								4	4.9	0.82	2.7%			0.47	0.07	0.31	0.14
Eucalyptus fasciculosa								27	6.9	8.09	55.5%			0.59	0.13	0.11	0.17
Eucalyptus leucoxylon								3	8.9	13.60	11.7%			0.54	0.14	0.12	0.19
Melaleuca lanceolata								2	2.2	0.55	0.8%			0.46	0.09	0.28	0.18
E. fasciculosa, A. retinodes/pycn., +4sp	585	128.7	7.6	3.0	14.9	1372	WB	70	6.1	7.23	5.128	2.54	9.34	0.66	0.11	0.11	0.13
Acacia pycnantha								20	3.7	0.43	6.6%			0.38	0.06	0.40	0.16
Acacia retinodes								18	5.9	3.01	23.5%			0.67	0.10	0.13	0.09
Allocasuarina verticillata								3	3.6	0.20	0.5%			0.32	0.05	0.46	0.17
Corymbia maculata								9	9.4	10.86	13.6%			0.71	0.10	0.06	0.12
Eucalyptus fasciculosa								17	7.8	9.48	31.2%			0.63	0.12	0.09	0.15
Eucalyptus viminalis ssp. cygnetensis								2	8.0	3.14	1.1%			0.62	0.13	0.09	0.16

Species	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
	Rain [mm]	NCAT Model – Max. Dry matter [t/ha]	NCAT Forest Productivity Index	BiosEquil Model [t C/ha/yr]	Age	TPH	StandType [Block, WindBreak,,Random/Natural	Observations	Height [m]	Stem Volume MAI [m³/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]	Stemwood	Bark	Branches	Leaf
Melaleuca lanceolata								1	1.3	0.06	0.0%			0.34	0.07	0.37	0.22
E. fasciculosa, M. lanceolata, +3sp	554	120.4	7.3	2.9	16.9	2959	WB	36	5.7	8.99	6.608	3.28	12.03	0.60	0.12	0.11	0.16
Allocasuarina verticillata								3	6.5	5.67	10.9%			0.69	0.11	0.12	0.09
Eucalyptus camaldulensis								2	10.3	11.32	5.5%			0.65	0.12	0.08	0.15
Eucalyptus fasciculosa								18	6.4	11.36	59.2%			0.58	0.13	0.11	0.18
Eucalyptus leucoxylon								4	8.7	19.82	20.6%			0.62	0.13	0.09	0.16
Melaleuca lanceolata								9	1.8	0.47	3.5%			0.42	0.08	0.31	0.19
E. fasciculosa/leuco., Allo. vertic., +3sp	546	129.5	7.7	2.8	18.0	1119	BL	60	9.5	10.38	7.350	3.65	13.38	0.71	0.10	0.08	0.11
Allocasuarina verticillata								13	7.7	3.60	16.8%			0.66	0.10	0.14	0.10
Callistemon rugulosus								1	2.4	0.11	0.1%			0.39	0.08	0.33	0.20
Eucalyptus camaldulensis								6	10.8	31.33	33.0%			0.81	0.07	0.03	0.08
Eucalyptus fasciculosa								26	9.5	6.60	29.0%			0.66	0.12	0.09	0.13
Eucalyptus leucoxylon								13	11.5	10.91	16.4%			0.70	0.11	0.07	0.13
Eucalyptus odorata								1	9.5	4.30	0.6%			0.61	0.13	0.10	0.16
E. gracilis/porosa/incrassata, +7sp	340	46.3	4.0	1.6	15.0	473	BL	60	4.4	1.91	2.549	1.26	4.64	0.59	0.10	0.15	0.16
Acacia oswaldii								2	3.3	0.56	1.1%			0.54	0.11	0.21	0.15
Callitris gracilis								1	2.7	0.92	1.0%			0.51	0.10	0.23	0.16
Eucalyptus calycogona								1	3.0	0.40	0.6%			0.49	0.08	0.20	0.23
Eucalyptus camaldulensis								5	8.5	2.58	5.1%			0.64	0.12	0.09	0.15
Eucalyptus gracilis								20	4.7	1.01	18.5%			0.59	0.10	0.15	0.16
Eucalyptus incrassata								14	3.4	1.68	31.3%			0.51	0.08	0.19	0.21
Eucalyptus largiflorens								1	9.3	3.19	1.1%			0.67	0.11	0.07	0.14
Eucalyptus leucoxylon								2	4.0	1.14	2.7%			0.58	0.09	0.16	0.17
Eucalyptus porosa								12	3.7	1.14	15.4%			0.61	0.09	0.15	0.15
Melaleuca lanceolata								2	2.5	0.46	1.0%			0.51	0.10	0.23	0.16
E. gracilis/socialis/incrassata, +7sp	317	46.0	4.0	1.4	16.0	531	WB	60	3.7	1.44	4.228	2.10	7.70	0.66	0.10	0.12	0.12
Callistemon brachyandrus								6	2.7	0.71	2.9%			0.49	0.10	0.25	0.17
Eucalyptus calycogona								7	4.0	1.28	32.2%			0.75	0.12	0.07	0.06
Eucalyptus cyanophylla								7	3.4	0.96	5.0%			0.55	0.08	0.18	0.19

Species	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
	Rain [mm]	NCAT Model – Max. Dry matter [t/ha]	NCAT Forest Productivity Index	BiosEquil Model [t C/ha/yr]	Age	TPH	StandType [Block, WindBreak,,Random/Natural	Observations	Height [m]	Stem Volume MAI [m³/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]	Stemwood	Bark	Branches	Leaf
Eucalyptus gracilis								8	4.3	1.82	10.3%			0.59	0.09	0.16	0.16
Eucalyptus incrassata								7	4.0	1.02	5.0%			0.56	0.09	0.17	0.18
Eucalyptus leptophylla								6	3.6	1.59	5.7%			0.60	0.09	0.15	0.16
Eucalyptus odorata								4	3.4	1.31	3.8%			0.57	0.09	0.17	0.18
Eucalyptus oleosa								4	4.7	1.74	4.8%			0.60	0.09	0.15	0.15
Eucalyptus socialis								9	3.7	1.99	22.7%			0.65	0.10	0.13	0.13
Melaleuca lanceolata								2	2.7	1.33	1.6%			0.55	0.11	0.20	0.14
E. grandis/camaldulensis	478	102.2	6.5	2.9	21.9	1600	BL	36	18.9	14.83	8.152	4.04	14.84	0.67	0.11	0.07	0.14
Eucalyptus camaldulensis								12	17.9	13.46	28.9%			0.69	0.11	0.07	0.13
Eucalyptus grandis								24	19.3	14.64	68.1%			0.66	0.12	0.08	0.14
E. incrassata, Allo. verticillata, +12sp	369	51.3	4.2	1.8	16.0	908	BL	61	3.9	1.52	2.741	1.36	4.99	0.54	0.09	0.19	0.18
Acacia pycnantha								2	3.1	0.10	0.4%			0.28	0.04	0.51	0.17
Allocasuarina verticillata								10	4.9	0.63	6.7%			0.59	0.09	0.20	0.12
Banksia ornata								1	3.7	1.34	1.3%			0.49	0.10	0.24	0.16
Dodonaea viscosa								7	3.3	1.47	10.0%			0.51	0.10	0.23	0.16
Eucalyptus diversifolia								1	3.3	3.42	3.6%			0.60	0.09	0.15	0.15
Eucalyptus dumosa								2	4.5	1.87	4.1%			0.57	0.09	0.17	0.17
Eucalyptus incrassata								14	3.6	1.49	25.7%			0.51	0.08	0.20	0.22
Eucalyptus leptophylla								7	3.2	1.06	9.2%			0.50	0.08	0.20	0.22
Eucalyptus leucoxylon								2	5.5	4.72	4.3%			0.54	0.14	0.12	0.19
Eucalyptus odorata								2	4.9	1.70	3.7%			0.59	0.09	0.16	0.16
Eucalyptus oleosa								6	4.1	3.48	22.4%			0.59	0.09	0.16	0.16
Eucalyptus phenax								5	4.2	0.99	5.8%			0.54	0.08	0.18	0.20
Eucalyptus socialis								1	3.7	2.54	3.2%			0.51	0.08	0.20	0.22
Pittosporum phylliraeoides								1	3.0	0.36	0.4%			0.49	0.10	0.25	0.16
E. incrassata/A. ligulata, +8sp	399	49.1	4.1	1.3	15.0	1383	BL	60	3.2	0.97	1.896	0.94	3.45	0.47	0.08	0.24	0.20
Acacia ligulata								11	2.7	0.66	10.8%			0.49	0.10	0.25	0.16
Acacia rigens								2	2.4	0.59	1.8%			0.47	0.09	0.27	0.17
Allocasuarina muelleriana								9	2.4	0.49	7.4%			0.44	0.09	0.29	0.18

	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
Species	Rain [mm]	NCAT Model – Max. Dry matter [t/ha]	NCAT Forest Productivity Index	BiosEquil Model [t C/ha/yr]	Age	TPH	StandType [Block, WindBreak,,Random/Natural	Observations	Height [m]	Stem Volume MAI [m³/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]	Stemwood	Bark	Branches	Leaf
Allocasuarina verticillata								3	5.3	1.51	7.3%			0.57	0.09	0.21	0.13
Callitris canescens								1	2.0	0.88	1.4%			0.46	0.09	0.28	0.18
Callitris gracilis								1	2.9	1.42	2.5%			0.51	0.08	0.27	0.14
Callitris verrucosa								7	3.2	0.82	12.0%			0.44	0.07	0.35	0.15
Dodonaea viscosa ssp. spathulata								4	3.1	0.40	2.7%			0.42	0.08	0.30	0.19
Eucalyptus incrassata								16	3.8	1.46	40.4%			0.47	0.08	0.21	0.24
Eucalyptus socialis								6	3.1	0.41	7.8%			0.41	0.06	0.24	0.29
E. incrassata/leptophylla, +7sp	357	49.9	4.2	1.9	28.9	2801	WB	60	3.9	1.16	2.214	1.10	4.03	0.48	0.08	0.21	0.23
Allocasuarina muelleriana								2	2.7	0.66	1.8%			0.47	0.09	0.27	0.17
Allocasuarina verticillata								1	5.5	0.53	0.8%			0.52	0.08	0.26	0.14
Eucalyptus brachycalyx								2	5.8	5.71	15.5%			0.58	0.09	0.16	0.17
Eucalyptus incrassata								37	4.0	0.93	50.3%			0.44	0.09	0.22	0.26
Eucalyptus leptophylla								11	4.2	2.14	36.0%			0.51	0.08	0.20	0.22
Melaleuca acuminata								1	2.3	0.11	0.2%			0.43	0.09	0.29	0.19
Melaleuca lanceolata								2	2.1	0.25	0.8%			0.39	0.08	0.33	0.20
Melaleuca uncinata								4	2.6	0.47	1.6%			0.45	0.09	0.28	0.18
E. largiflorens, Allo. verticillata, +3sp	322	77.7	5.4	1.8	17.0	1150	BL	60	4.7	1.25	1.271	0.63	2.31	0.48	0.13	0.19	0.19
Allocasuarina verticillata								17	3.8	0.23	12.1%			0.44	0.07	0.34	0.15
Callitris gracilis								3	3.3	0.34	2.7%			0.52	0.08	0.26	0.14
Eucalyptus camaldulensis								3	7.8	6.76	17.0%			0.61	0.13	0.09	0.16
Eucalyptus largiflorens								31	5.2	1.67	64.7%			0.46	0.16	0.16	0.22
Eucalyptus odorata								6	4.1	0.53	5.3%			0.37	0.17	0.21	0.25
E. largiflorens/cladocalyx	330	39.0	3.7	1.2	98.0	390	BL	60	7.0	0.28	0.189	0.09	0.34	0.58	0.14	0.11	0.17
Eucalyptus cladocalyx								8	6.7	0.23	11.2%			0.58	0.14	0.11	0.18
Eucalyptus largiflorens								52	7.0	0.28	88.9%			0.58	0.14	0.11	0.17
E. leucoxylon, +2sp	557	127.2	7.6	2.6	16.0	620	WB	36	5.4	2.37	1.903	0.94	3.46	0.61	0.13	0.11	0.15
Allocasuarina verticillata								4	5.8	2.13	17.9%			0.73	0.11	0.08	0.07
Eucalyptus leucoxylon								31	5.4	2.41	76.0%			0.57	0.14	0.11	0.18
Melaleuca brevifolia								1	2.4	0.47	1.2%			0.46	0.09	0.28	0.18

Species	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
	Rain [mm]	NCAT Model – Max. Dry matter [t/ha]	NCAT Forest Productivity Index	BiosEquil Model [t C/ha/yr]	Age	TPH	StandType [Block, WindBreak,,Random/Natural]	Observations	Height [m]	Stem Volume MAI [m³/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]	Stemwood	Bark	Branches	Leaf
E. leucoxylon, +3sp	403	117.9	7.2	2.9	33.0	527	BL	60	5.3	0.77	0.727	0.36	1.32	0.56	0.13	0.14	0.18
Eucalyptus fasciculosa								4	5.0	0.48	8.4%			0.55	0.08	0.18	0.19
Eucalyptus gracilis								3	5.2	0.14	1.1%			0.40	0.17	0.19	0.24
Eucalyptus leucoxylon								52	5.4	0.85	89.9%			0.56	0.13	0.13	0.18
Eucalyptus odorata								1	5.8	0.59	1.0%			0.56	0.14	0.11	0.18
E. leucoxylon, A. ligulata/brachy., +3sp	350	49.6	4.2	1.7	15.9	1471	BL	60	3.9	2.00	2.481	1.23	4.52	0.53	0.12	0.19	0.17
Acacia brachybotrya								11	1.8	0.45	6.5%			0.43	0.08	0.30	0.19
Acacia ligulata								22	2.9	1.98	63.7%			0.53	0.10	0.22	0.15
Callitris verrucosa								2	4.2	0.80	2.1%			0.53	0.08	0.25	0.13
Dodonaea viscosa								6	3.3	0.95	7.0%			0.45	0.09	0.28	0.18
Eucalyptus cladocalyx								1	7.4	2.28	1.1%			0.58	0.14	0.11	0.18
Eucalyptus leucoxylon								18	6.4	1.87	16.8%			0.55	0.14	0.12	0.19
E. leucoxylon, Cal. gracilis, +2sp	379	52.9	4.3	2.2	32.9	230	BL	60	7.8	1.51	1.310	0.65	2.38	0.75	0.12	0.05	0.08
Callitris gracilis								11	8.2	2.43	55.6%			0.81	0.12	0.03	0.04
Eucalyptus astringens								1	11.3	6.15	3.2%			0.80	0.08	0.04	0.09
Eucalyptus leptophylla								1	6.9	0.35	0.3%			0.54	0.15	0.12	0.19
Eucalyptus leucoxylon								47	7.7	1.18	39.6%			0.67	0.12	0.08	0.14
E. leucoxylon, Cal. gracilis, +8sp	379	54.4	4.4	2.2	32.9	242	BL	60	6.0	0.64	0.542	0.27	0.99	0.65	0.11	0.10	0.14
Allocasuarina verticillata								1	2.2	0.03	0.2%			0.39	0.06	0.38	0.16
Callitris gracilis								9	5.4	0.36	15.0%			0.69	0.11	0.11	0.09
Eucalyptus dumosa								1	5.5	0.34	0.9%			0.52	0.15	0.13	0.20
Eucalyptus fasciculosa								3	3.3	0.08	1.0%			0.43	0.16	0.17	0.23
Eucalyptus leucoxylon								36	6.9	0.87	69.7%			0.67	0.12	0.08	0.14
Eucalyptus microcarpa								1	7.2	0.77	1.4%			0.63	0.12	0.09	0.15
Eucalyptus oleosa								2	4.0	0.18	2.2%			0.53	0.08	0.19	0.20
Eucalyptus phenax								3	5.2	0.44	5.5%			0.57	0.11	0.15	0.17
Eucalyptus socialis								2	5.9	0.33	3.7%			0.57	0.09	0.17	0.17
Pittosporum phylliraeoides								2	3.2	0.04	0.6%			0.45	0.07	0.33	0.15
E. leucoxylon, Cal. gracilis, A. ret., +5sp	335	90.2	5.9	1.7	18.0	683	BL	60	9.9	7.01	5.233	2.60	9.53	0.73	0.11	0.07	0.10

	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
Species	**Rain [mm]**	**NCAT Model – Max. Dry matter [t/ha]**	**NCAT Forest Productivity Index**	**BiosEquil Model [t C/ha/yr]**	**Age**	**TPH**	**StandType [Block, WindBreak,,Random/Natural**	**Observations**	**Height [m]**	**Stem Volume MAI [m^3/ha/yr]**	**Dry Biomass [t/ha/yr]**	**Carbon [t/ha/yr]**	**CO_2e [t/ha/yr]**	**Stemwood**	**Bark**	**Branches**	**Leaf**
Acacia brachybotrya								1	3.5	1.51	0.8%			0.53	0.10	0.22	0.15
Acacia notabilis								1	3.0	0.21	0.1%			0.46	0.09	0.27	0.18
Acacia retinodes								8	8.1	5.68	19.6%			0.78	0.12	0.05	0.05
Callitris gracilis								15	6.4	2.80	25.2%			0.76	0.12	0.07	0.06
Eucalyptus dumosa								3	5.0	0.34	0.7%			0.44	0.09	0.22	0.25
Eucalyptus fasciculosa								4	12.5	8.40	6.4%			0.69	0.10	0.08	0.12
Eucalyptus largiflorens								1	15.0	3.77	0.7%			0.67	0.12	0.08	0.14
Eucalyptus leucoxylon								27	12.7	10.95	47.7%			0.71	0.10	0.06	0.12
E. leucoxylon/camaldulensis	315	40.0	3.7	1.3	9.0	384	BL	60	5.7	1.65	1.330	0.66	2.42	0.52	0.15	0.13	0.20
Eucalyptus camaldulensis								28	5.4	1.54	44.5%			0.51	0.15	0.14	0.20
Eucalyptus leucoxylon								32	5.9	1.74	55.3%			0.53	0.15	0.13	0.19
E. leucoxylon/camaldulensis, +1sp	376	48.6	4.1	1.6	24.0	300	WB	36	11.8	7.68	3.463	1.72	6.30	0.77	0.09	0.05	0.09
Eucalyptus camaldulensis								16	13.9	8.32	46.5%			0.77	0.09	0.05	0.10
Eucalyptus diversifolia								2	10.0	3.49	8.3%			0.71	0.11	0.10	0.09
Eucalyptus leucoxylon								18	10.1	7.24	42.8%			0.79	0.08	0.04	0.09
E. leucoxylon/cladocalyx/tricarpa, +2sp	478	106.5	6.7	2.9	20.9	1134	WB	36	12.4	9.35	6.075	3.01	11.06	0.67	0.11	0.09	0.13
Eucalyptus cladocalyx								10	14.3	9.93	23.4%			0.70	0.11	0.07	0.13
Eucalyptus leucoxylon								13	10.3	6.20	23.1%			0.62	0.13	0.10	0.16
Eucalyptus platypus								4	11.3	9.22	26.7%			0.66	0.10	0.12	0.11
Eucalyptus sideroxylon								3	15.3	21.65	14.6%			0.72	0.10	0.06	0.12
Eucalyptus tricarpa								6	12.8	6.79	10.9%			0.65	0.12	0.08	0.15
E. leucoxylon/gracilis/incrassata, +10sp	357	46.2	4.0	1.9	28.9	279	WB	60	6.4	1.19	1.457	0.72	2.65	0.67	0.11	0.11	0.12
Acacia calamifolia								2	5.2	0.41	1.5%			0.53	0.10	0.22	0.15
Allocasuarina verticillata								2	6.2	0.64	4.4%			0.77	0.12	0.06	0.06
Eucalyptus diversifolia								1	2.8	0.04	0.1%			0.33	0.05	0.27	0.35
Eucalyptus fasciculosa								5	6.6	0.62	2.2%			0.61	0.13	0.10	0.16
Eucalyptus gracilis								8	7.6	1.63	17.8%			0.68	0.11	0.11	0.11
Eucalyptus incrassata								8	5.2	0.58	7.0%			0.59	0.11	0.14	0.16
Eucalyptus leptophylla								3	6.0	0.95	3.8%			0.61	0.10	0.14	0.15

Species	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
	Rain [mm]	NCAT Model – Max. Dry matter [t/ha]	NCAT Forest Productivity Index	BiosEquil Model [t C/ha/yr]	Age	TPH	StandType [Block, WindBreak,,Random/Natural	Observations	Height [m]	Stem Volume MAI [m³/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]	Stemwood	Bark	Branches	Leaf
Eucalyptus leucoxylon								8	9.0	1.56	8.4%			0.68	0.11	0.07	0.13
Eucalyptus oleosa								7	7.0	2.23	26.6%			0.70	0.11	0.10	0.09
Eucalyptus phenax								2	6.0	1.09	4.1%			0.64	0.10	0.13	0.13
Eucalyptus porosa								3	3.1	0.19	1.3%			0.51	0.09	0.19	0.21
Eucalyptus socialis								7	6.8	1.26	16.5%			0.64	0.10	0.13	0.13
Melaleuca lanceolata								4	3.5	0.45	3.1%			0.54	0.11	0.21	0.14
E. leucoxylon/largiflorens, +12sp	382	58.4	4.5	2.1	17.0	3441	BL	60	5.9	7.65	6.144	3.05	11.18	0.56	0.13	0.14	0.18
Acacia argyrophylla								3	3.7	2.34	3.5%			0.46	0.09	0.28	0.17
Callitris gracilis								5	3.9	1.52	4.0%			0.54	0.08	0.26	0.13
Eucalyptus brachycalyx								1	4.4	0.75	0.6%			0.38	0.06	0.25	0.31
Eucalyptus camaldulensis								1	5.3	2.06	0.6%			0.40	0.17	0.19	0.24
Eucalyptus fasciculosa								4	5.4	1.10	1.7%			0.41	0.13	0.21	0.25
Eucalyptus largiflorens								7	7.4	2.82	3.6%			0.59	0.13	0.11	0.17
Eucalyptus leptophylla								4	5.6	1.88	2.6%			0.37	0.17	0.21	0.25
Eucalyptus leucoxylon								24	7.1	14.80	65.0%			0.58	0.13	0.11	0.17
Eucalyptus oleosa								1	6.5	10.09	5.7%			0.50	0.08	0.20	0.22
Eucalyptus platypus								3	5.4	6.56	4.5%			0.50	0.15	0.14	0.20
Eucalyptus socialis								1	5.4	0.87	0.5%			0.51	0.08	0.20	0.22
Leptospermum laevigatum								3	2.5	0.49	0.8%			0.39	0.08	0.33	0.20
Melaleuca armillaris ssp. armillaris								1	4.8	1.98	0.8%			0.67	0.10	0.13	0.10
Melaleuca lanceolata								2	2.5	0.30	0.4%			0.34	0.07	0.38	0.22
E. leucoxylon/porosa/calycogona, +7sp	376	111.2	6.9	2.2	32.9	235	BL	60	7.2	1.04	0.962	0.48	1.75	0.69	0.11	0.09	0.11
Allocasuarina verticillata								9	5.4	0.48	10.8%			0.73	0.11	0.09	0.07
Callitris gracilis								4	7.3	0.82	7.9%			0.76	0.12	0.06	0.06
Eucalyptus calycogona								11	6.2	0.45	17.3%			0.64	0.11	0.12	0.13
Eucalyptus fasciculosa								1	10.0	1.19	1.2%			0.65	0.12	0.08	0.15
Eucalyptus gomphocephala								1	11.6	2.99	2.6%			0.71	0.11	0.06	0.12
Eucalyptus leucoxylon								16	7.9	1.46	21.6%			0.68	0.11	0.07	0.14
Eucalyptus porosa								14	8.1	1.29	26.2%			0.67	0.11	0.10	0.12

Species	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
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Eucalyptus torquata								1	7.1	1.71	4.5%			0.69	0.11	0.11	0.10
Melaleuca armillaris ssp. armillaris								1	5.0	0.46	1.2%			0.68	0.10	0.12	0.09
Melaleuca lanceolata								2	6.5	1.31	6.1%			0.78	0.12	0.05	0.05
E. microcarpa/brockwayii/calycog., +8sp	379	54.9	4.4	2.2	32.9	295	BL	60	7.9	2.10	1.379	0.68	2.51	0.70	0.10	0.08	0.12
Brachychiton populeneus								2	3.5	0.03	0.2%			0.40	0.06	0.38	0.16
Callitris gracilis								5	5.2	0.35	3.3%			0.67	0.10	0.13	0.10
Eucalyptus brockwayii								13	12.4	5.47	39.3%			0.77	0.09	0.05	0.10
Eucalyptus calycogona								13	6.3	0.57	13.6%			0.60	0.10	0.14	0.16
Eucalyptus cyanophylla								8	7.9	1.19	12.5%			0.66	0.11	0.11	0.12
Eucalyptus dundasii								1	10.2	3.88	2.3%			0.72	0.10	0.06	0.12
Eucalyptus incrassata								1	7.3	1.21	2.3%			0.67	0.10	0.12	0.11
Eucalyptus leucoxylon								1	1.8	0.02	0.1%			0.29	0.18	0.26	0.28
Eucalyptus microcarpa								11	6.6	1.03	14.8%			0.65	0.11	0.11	0.13
Eucalyptus occidentalis								1	15.2	16.86	8.2%			0.81	0.08	0.03	0.08
Eucalyptus torquata								4	6.6	0.95	3.7%			0.63	0.11	0.11	0.15
E. occidentalis/leucoxylon, +3sp	364	43.1	3.9	1.5	19.0	351	BL	60	9.7	1.74	1.216	0.60	2.21	0.61	0.13	0.10	0.16
Eucalyptus astringens								3	6.5	0.84	2.8%			0.52	0.15	0.13	0.20
Eucalyptus dundasii								4	11.4	1.86	6.1%			0.64	0.12	0.09	0.15
Eucalyptus leucoxylon								22	9.9	1.77	33.7%			0.61	0.13	0.10	0.16
Eucalyptus occidentalis								24	10.8	1.99	42.3%			0.61	0.13	0.10	0.16
Eucalyptus porosa								7	5.7	1.02	13.9%			0.59	0.10	0.15	0.16
E. occidentalis/megacornuta, +1sp	460	60.5	4.6	1.7	15.0	756	WB	60	8.4	6.69	3.994	1.98	7.27	0.64	0.12	0.09	0.15
Eucalyptus megacornuta								25	7.6	7.10	44.3%			0.64	0.12	0.09	0.15
Eucalyptus occidentalis								27	9.2	7.13	46.9%			0.64	0.12	0.09	0.15
Eucalyptus tereticornis								8	8.0	3.57	8.2%			0.58	0.14	0.11	0.18
E. odorata/camaldulensis, +5sp	474	68.6	5.0	2.6	12.0	2211	BL	60	6.7	6.31	5.687	2.82	10.35	0.53	0.13	0.16	0.19
Acacia argyrophylla								5	3.4	1.61	3.9%			0.50	0.10	0.24	0.16
Acacia ligulata								7	4.4	2.26	7.4%			0.52	0.10	0.23	0.15
Eucalyptus camaldulensis								19	6.6	5.84	29.1%			0.48	0.16	0.15	0.21

Species	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
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Eucalyptus fasciculosa								2	6.8	12.01	6.0%			0.50	0.15	0.14	0.20
Eucalyptus incrassata								2	5.6	1.34	1.7%			0.49	0.07	0.21	0.23
Eucalyptus leucoxylon								5	7.3	5.68	6.0%			0.56	0.14	0.12	0.18
Eucalyptus odorata								20	8.4	8.89	38.3%			0.55	0.14	0.12	0.18
E. odorata/incrassata, A. pycnantha, +8sp	443	61.1	4.7	1.8	19.0	2778	BL	68	5.4	5.77	7.664	3.80	13.95	0.63	0.11	0.13	0.14
Acacia microcarpa								3	2.8	1.17	1.2%			0.46	0.09	0.27	0.18
Acacia pycnantha								16	5.6	6.62	29.0%			0.74	0.11	0.09	0.06
Acacia retinodes								2	4.3	7.95	4.4%			0.73	0.11	0.09	0.07
Eucalyptus arenacea								4	6.0	12.23	10.6%			0.58	0.12	0.14	0.16
Eucalyptus diversifolia								1	4.7	4.08	1.5%			0.57	0.09	0.17	0.18
Eucalyptus incrassata								8	5.1	1.34	3.9%			0.45	0.10	0.21	0.24
Eucalyptus leptophylla								1	3.6	0.54	0.3%			0.36	0.06	0.26	0.32
Eucalyptus leucoxylon								1	5.5	1.43	0.3%			0.41	0.17	0.18	0.24
Eucalyptus odorata								21	5.1	5.67	31.0%			0.58	0.10	0.15	0.17
Eucalyptus porosa								6	6.2	4.80	10.1%			0.53	0.09	0.18	0.20
Eucalyptus viminalis ssp. cygnetensis								5	7.8	11.42	7.5%			0.59	0.13	0.11	0.18
E. oleosa/brachycalyx, +2sp	335	57.2	4.5	1.7	17.9	385	BL	60	5.1	1.31	1.533	0.76	2.79	0.59	0.09	0.15	0.17
Eucalyptus brachycalyx								20	4.7	0.65	27.5%			0.54	0.08	0.18	0.20
Eucalyptus cladocalyx								10	6.9	3.80	22.4%			0.68	0.11	0.07	0.14
Eucalyptus oleosa								21	5.0	0.98	40.4%			0.58	0.09	0.16	0.17
Eucalyptus socialis								9	4.4	0.49	9.4%			0.53	0.08	0.19	0.20
E. porosa, +2sp	403	117.5	7.1	2.9	33.0	4202	BL	60	3.3	1.08	2.191	1.09	3.99	0.44	0.10	0.22	0.25
Eucalyptus fasciculosa								7	3.1	0.56	4.2%			0.34	0.18	0.23	0.26
Eucalyptus leucoxylon								7	3.3	0.78	7.3%			0.34	0.14	0.24	0.28
Eucalyptus porosa								46	3.3	1.21	89.3%			0.45	0.09	0.22	0.25
E. porosa, Bursaria spinosa, +10sp	317	44.4	3.9	1.4	17.0	1590	WB	60	4.4	6.24	6.739	3.34	12.27	0.63	0.10	0.14	0.13
Acacia calamifolia								3	2.6	1.27	1.6%			0.50	0.10	0.24	0.16
Allocasuarina verticillata								2	3.8	0.22	0.4%			0.29	0.04	0.50	0.17
Bursaria spinosa								17	3.0	0.82	6.0%			0.48	0.09	0.26	0.16

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Callitris gracilis								6	3.8	1.26	4.3%			0.46	0.07	0.32	0.15
Eucalyptus camaldulensis								4	8.1	24.98	11.2%			0.75	0.09	0.05	0.11
Eucalyptus dumosa								3	5.9	16.98	19.9%			0.66	0.10	0.12	0.11
Eucalyptus fasciculosa								1	3.7	1.40	0.7%			0.55	0.08	0.18	0.19
Eucalyptus incrassata								4	4.1	2.86	5.5%			0.47	0.09	0.21	0.23
Eucalyptus leucoxylon								4	6.3	15.60	15.1%			0.65	0.11	0.11	0.13
Eucalyptus porosa								15	5.3	4.01	21.5%			0.63	0.10	0.13	0.14
Melaleuca lanceolata								1	2.9	0.86	0.3%			0.52	0.10	0.22	0.15
E. porosa/fasciculosa, Allo. verticill., +8sp	332	84.2	5.7	2.0	17.0	580	WB	61	4.7	0.97	1.118	0.55	2.04	0.56	0.12	0.16	0.17
Acacia brachybotrya								1	3.6	0.56	1.4%			0.49	0.10	0.25	0.16
Acacia ligulata								2	2.8	0.37	2.1%			0.44	0.09	0.29	0.19
Acacia pycnantha								2	3.4	0.12	0.9%			0.44	0.07	0.34	0.16
Allocasuarina verticillata								9	4.2	0.68	15.1%			0.62	0.10	0.17	0.11
Callitris verrucosa								5	4.1	0.53	7.0%			0.58	0.09	0.21	0.12
Eucalyptus fasciculosa								13	4.4	0.65	12.3%			0.47	0.14	0.16	0.22
Eucalyptus globulus								1	2.9	0.08	0.2%			0.25	0.18	0.28	0.28
Eucalyptus leucoxylon								8	6.9	2.05	18.9%			0.59	0.12	0.12	0.17
Eucalyptus odorata								5	4.7	0.64	4.2%			0.47	0.16	0.16	0.21
Eucalyptus porosa								14	5.3	1.46	39.4%			0.57	0.11	0.15	0.17
Melaleuca lanceolata								1	2.4	0.10	0.3%			0.42	0.08	0.31	0.19
E. porosa/gracilis/socialis, +3sp	321	43.8	3.9	1.7	14.0	1836	WB	60	4.3	2.58	5.730	2.84	10.43	0.53	0.08	0.19	0.20
Eucalyptus dumosa								6	3.7	1.27	9.2%			0.53	0.08	0.19	0.21
Eucalyptus gracilis								11	4.6	2.29	15.4%			0.50	0.08	0.20	0.22
Eucalyptus incrassata								12	3.6	1.42	11.2%			0.47	0.07	0.21	0.25
Eucalyptus leptophylla								8	4.6	3.07	14.5%			0.52	0.08	0.19	0.21
Eucalyptus porosa								11	4.8	4.54	28.9%			0.59	0.09	0.16	0.17
Eucalyptus socialis								12	4.1	2.40	20.1%			0.51	0.08	0.19	0.21
E. porosa/leucoxylon, +5sp	339	45.1	4.0	1.6	12.0	447	WB	63	3.5	1.82	2.852	1.41	5.19	0.59	0.09	0.16	0.16
Acacia calamifolia								1	2.2	0.37	0.4%			0.43	0.08	0.30	0.19

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Acacia pycnantha								6	2.6	0.25	1.7%			0.52	0.08	0.26	0.13
Eucalyptus camaldulensis ssp. obtusa								3	6.0	1.31	1.6%			0.56	0.14	0.12	0.18
Eucalyptus cladocalyx								1	7.2	9.30	2.7%			0.69	0.11	0.07	0.13
Eucalyptus leucoxylon								20	3.6	1.03	19.7%			0.58	0.09	0.16	0.17
Eucalyptus platypus								2	4.8	4.73	8.3%			0.67	0.10	0.12	0.11
Eucalyptus porosa								30	3.1	2.30	67.7%			0.58	0.09	0.17	0.17
E. viminalis ssp. cygnetensis, +9sp	443	62.5	4.7	1.8	19.0	1990	BL	67	7.9	15.80	12.352	6.13	22.48	0.68	0.11	0.09	0.12
Acacia pycnantha								14	5.2	6.31	16.1%			0.70	0.11	0.11	0.09
Acacia retinodes								3	8.0	10.79	5.5%			0.75	0.11	0.07	0.07
Eucalyptus arenacea								4	9.2	42.19	11.0%			0.68	0.11	0.07	0.14
Eucalyptus diversifolia								2	5.2	1.97	0.9%			0.57	0.09	0.17	0.17
Eucalyptus incrassata								2	4.3	1.48	0.5%			0.45	0.11	0.20	0.25
Eucalyptus leucoxylon								8	10.5	24.12	12.2%			0.69	0.11	0.07	0.13
Eucalyptus obliqua								2	7.5	11.84	1.6%			0.66	0.12	0.08	0.14
Eucalyptus odorata								8	6.4	9.86	13.2%			0.63	0.10	0.14	0.14
Eucalyptus porosa								6	6.4	16.62	16.1%			0.68	0.11	0.11	0.10
Eucalyptus viminalis ssp. cygnetensis								18	10.6	18.87	21.7%			0.69	0.11	0.07	0.13
M. lanceolata, +7sp	375	116.1	7.1	2.2	16.9	807	WB	36	4.8	3.15	4.165	2.07	7.58	0.59	0.11	0.16	0.14
Allocasuarina verticillata								2	3.9	1.58	3.5%			0.64	0.10	0.16	0.10
Eucalyptus fasciculosa								2	4.2	0.54	0.9%			0.38	0.17	0.20	0.25
Eucalyptus incrassata								5	5.9	2.90	11.0%			0.59	0.11	0.14	0.16
Eucalyptus leptophylla								6	7.2	5.42	25.3%			0.65	0.11	0.11	0.12
Eucalyptus phenax								6	5.4	2.19	11.0%			0.58	0.11	0.14	0.16
Eucalyptus platypus								1	3.7	3.36	4.4%			0.54	0.08	0.18	0.19
Melaleuca acuminata								1	3.3	1.76	1.7%			0.56	0.11	0.19	0.14
Melaleuca lanceolata								13	3.6	2.90	37.4%			0.56	0.11	0.19	0.14

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Single species																	
Acacia calamifolia	371	50.6	4.2	2.1	6.0	756	RN	6	2.0	1.62	2.810	1.39	5.11	0.48	0.09	0.26	0.17
Acacia hakeoides	371	51.9	4.3	2.1	3.7	752	RN	6	1.3	0.90	2.570	1.27	4.68	0.50	0.10	0.24	0.16
Acacia hakeoides	371	51.6	4.2	2.1	2.0	2226	RN	6	1.2	2.46	5.291	2.62	9.63	0.39	0.08	0.33	0.20
Acacia ligulata	261	22.9	3.0	1.1	13.8	1111	BL	30	2.7	1.71	2.916	1.45	5.31	0.52	0.10	0.23	0.15
Acacia ligulata	261	22.9	3.0	1.1	13.8	484	BL	3	3.2	1.01	2.073	1.03	3.77	0.53	0.10	0.22	0.15
Acacia montana	371	51.3	4.2	2.1	6.0	738	RN	6	2.1	1.82	3.117	1.55	5.67	0.49	0.10	0.25	0.17
Acacia myrtifolia	585	129.2	7.7	3.0	8.0	114	WB	6	1.5	0.03	0.135	0.07	0.25	0.43	0.09	0.29	0.19
Acacia pycnantha	340	44.9	4.0	1.9	13.8	2778	BL	60	3.7	2.70	5.053	2.51	9.20	0.56	0.09	0.23	0.13
Acacia rigens	357	48.9	4.1	1.9	31.2	197	BL	3	2.8	0.28	0.430	0.21	0.78	0.54	0.11	0.21	0.15
Callitris verrucosa	357	46.7	4.0	1.9	31.3	140	BL	3	4.6	0.51	0.729	0.36	1.33	0.58	0.11	0.18	0.13
Casuarina cunninghamiana	585	121.8	7.3	3.0	14.9	828	BL	36	6.3	1.59	2.682	1.33	4.88	0.65	0.10	0.15	0.10
Dodonaea viscosa	261	22.9	3.0	1.1	13.8	2251	BL	30	2.6	0.85	1.596	0.79	2.91	0.44	0.09	0.29	0.18
Dodonaea viscosa	261	22.9	3.0	1.1	13.8	633	BL	3	2.9	0.65	1.122	0.56	2.04	0.48	0.09	0.26	0.17
Eucalyptus baxteri	585	130.9	7.7	3.0	8.0	226	WB	6	3.6	0.69	0.835	0.41	1.52	0.52	0.15	0.13	0.20
Eucalyptus camaldulensis	362	49.1	4.1	1.7	7.6	142	BL	30	5.7	0.58	0.495	0.25	0.90	0.50	0.15	0.14	0.21
Eucalyptus camaldulensis	460	65.4	4.9	1.7	10.0	580	WB	36	13.8	31.37	14.142	7.01	25.74	0.75	0.09	0.05	0.10
Eucalyptus camaldulensis	376	48.5	4.1	1.6	15.0	995	BL	36	15.5	16.45	8.382	4.16	15.26	0.70	0.11	0.07	0.13
Eucalyptus camaldulensis	376	50.8	4.2	1.6	7.7	1027	WB	30	9.6	9.78	6.549	3.25	11.92	0.59	0.13	0.10	0.17
Eucalyptus camaldulensis	460	65.4	4.9	1.7	10.7	513	WB	33	11.4	10.62	5.717	2.84	10.41	0.68	0.11	0.07	0.14
Eucalyptus cladocalyx	557	131.6	7.8	2.6	17.9	2277	BL	36	13.0	15.43	9.126	4.53	16.61	0.64	0.12	0.09	0.15
Eucalyptus cladocalyx	460	64.2	4.8	1.7	14.0	778	BL	36	10.2	5.98	3.708	1.84	6.75	0.62	0.13	0.09	0.16
Eucalyptus cladocalyx	460	71.9	5.1	1.7	6.7	419	WB	30	5.0	1.79	1.558	0.77	2.84	0.49	0.15	0.15	0.21
Eucalyptus cladocalyx	460	68.6	5.0	1.7	6.7	789	WB	30	6.4	4.02	3.378	1.68	6.15	0.50	0.15	0.14	0.20
Eucalyptus cladocalyx	339	39.5	3.7	1.2	98.0	281	BL	36	10.7	0.49	0.275	0.14	0.50	0.66	0.12	0.08	0.14
Eucalyptus cladocalyx	465	120.2	7.3	3.0	14.9	502	BL	36	12.1	3.45	2.195	1.09	3.99	0.61	0.13	0.10	0.16
Eucalyptus cladocalyx	460	65.1	4.8	1.7	6.7	793	BL	33	5.6	2.82	2.539	1.26	4.62	0.48	0.16	0.15	0.21
Eucalyptus cladocalyx	460	64.8	4.8	1.7	10.7	440	BL	30	14.9	13.44	6.757	3.35	12.30	0.71	0.10	0.06	0.12

Species	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
	Rain [mm]	NCAT Model – Max. Dry matter [t/ha]	NCAT Forest Productivity Index	BiosEquil Model [t C/ha/yr]	Age	TPH	StandType [Block, WindBreak,,Random/Natural]	Observations	Height [m]	Stem Volume MAI [m³/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]	Stemwood	Bark	Branches	Leaf
Eucalyptus cyanophylla	261	22.9	3.0	1.1	13.4	555	BL	30	3.6	1.02	2.042	1.01	3.72	0.52	0.08	0.19	0.21
Eucalyptus diversifolia	460	64.8	4.8	1.7	12.7	1279	RN	3	5.5	5.17	9.333	4.63	16.99	0.58	0.09	0.16	0.17
Eucalyptus dumosa	323	46.4	4.0	1.6	30.0	1091	RN	6	4.9	1.36	2.468	1.22	4.49	0.56	0.09	0.17	0.18
Eucalyptus dumosa	387	46.3	4.0	1.4	12.0	836	BL	31	3.8	0.90	1.988	0.99	3.62	0.47	0.07	0.21	0.24
Eucalyptus globulus	460	65.4	4.9	1.7	10.7	898	BL	33	12.5	11.01	6.448	3.20	11.74	0.64	0.12	0.09	0.15
Eucalyptus gomphocephala	460	68.4	5.0	1.7	12.0	334	WB	6	12.4	20.32	8.744	4.34	15.92	0.77	0.09	0.04	0.10
Eucalyptus gracilis	357	51.9	4.3	1.9	31.2	329	BL	3	10.0	3.35	4.939	2.45	8.99	0.71	0.11	0.10	0.08
Eucalyptus gracilis	261	22.9	3.0	1.1	14.3	554	BL	30	3.4	0.59	1.334	0.66	2.43	0.48	0.07	0.21	0.24
Eucalyptus incrassata	357	51.9	4.3	1.9	31.2	208	BL	3	5.8	0.65	1.086	0.54	1.98	0.63	0.10	0.14	0.13
Eucalyptus incrassata	374	47.3	4.1	1.5	8.0	1120	BL	30	3.7	1.89	4.273	2.12	7.78	0.46	0.07	0.22	0.25
Eucalyptus largiflorens	261	22.9	3.0	1.1	14.4	392	BL	30	4.5	0.98	0.797	0.40	1.45	0.52	0.15	0.14	0.20
Eucalyptus leptophylla	261	22.9	3.0	1.1	13.4	1133	BL	30	2.0	0.41	1.213	0.60	2.21	0.37	0.06	0.25	0.32
Eucalyptus leptophylla	357	46.7	4.0	1.9	31.3	153	BL	3	6.6	1.00	1.549	0.77	2.82	0.68	0.10	0.11	0.10
Eucalyptus leucoxylon	379	54.9	4.4	2.2	32.9	568	BL	36	6.3	1.01	0.717	0.36	1.31	0.56	0.14	0.11	0.18
Eucalyptus leucoxylon	339	45.1	4.0	1.6	14.0	405	WB	36	4.6	1.77	2.501	1.24	4.55	0.60	0.10	0.14	0.16
Eucalyptus leucoxylon	361	43.5	3.9	1.3	99.0	235	BL	36	8.3	0.32	0.188	0.09	0.34	0.64	0.12	0.09	0.15
Eucalyptus loxophleba ssp. lissophloia	318	40.1	3.7	1.2	8.0	2094	BL	36	4.8	3.06	5.489	2.72	9.99	0.44	0.10	0.21	0.25
Eucalyptus occidentalis	460	68.5	5.0	1.7	6.7	603	WB	30	10.2	8.04	5.279	2.62	9.61	0.60	0.13	0.10	0.17
Eucalyptus occidentalis	460	68.6	5.0	1.7	6.7	762	WB	32	8.2	5.57	4.273	2.12	7.78	0.54	0.15	0.12	0.19
Eucalyptus occidentalis	460	64.2	4.8	1.7	5.7	708	BL	34	9.8	13.54	8.607	4.27	15.67	0.61	0.13	0.09	0.16
Eucalyptus occidentalis	460	68.5	5.0	1.7	6.5	645	WB	6	12.1	12.20	7.557	3.75	13.76	0.62	0.13	0.09	0.16
Eucalyptus oleosa	261	22.9	3.0	1.1	10.4	403	BL	30	3.2	0.35	0.836	0.41	1.52	0.44	0.07	0.23	0.27
Eucalyptus oleosa	357	49.9	4.2	1.9	28.9	1736	BL	36	5.0	1.21	2.431	1.21	4.43	0.52	0.08	0.19	0.21
Eucalyptus oleosa	387	47.2	4.1	1.4	6.8	1585	BL	30	3.0	2.15	5.222	2.59	9.51	0.43	0.07	0.23	0.27
Eucalyptus oleosa	357	49.9	4.2	1.9	28.9	3325	WB	36	5.0	1.41	2.996	1.49	5.45	0.47	0.08	0.21	0.24
Eucalyptus oleosa	357	47.6	4.1	1.9	31.2	224	BL	3	6.4	1.14	1.781	0.88	3.24	0.67	0.10	0.12	0.11
Eucalyptus polybractea	318	39.3	3.7	1.2	8.0	1872	BL	36	4.2	4.28	9.096	4.51	16.56	0.49	0.08	0.20	0.23
Eucalyptus porosa	387	47.2	4.1	1.4	6.7	1522	BL	33	3.9	5.23	10.590	5.25	19.28	0.52	0.08	0.19	0.21

Species	Site Detail				Field Survey									Proportion of Above-ground Dry Biomass			
	Rain [mm]	NCAT Model – Max. Dry matter [t/ha]	NCAT Forest Productivity Index	BiosEquil Model [t C/ha/yr]	Age	TPH	StandType [Block, WindBreak,,Random/Natural]	Observations	Height [m]	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]	Stemwood	Bark	Branches	Leaf
Eucalyptus salmonophoia	330	39.4	3.7	1.2	95.0	942	BL	36	18.7	2.37	1.259	0.62	2.29	0.69	0.11	0.07	0.13
Eucalyptus socialis	357	46.2	4.0	1.9	26.1	444	WB	3	5.6	1.82	3.795	1.88	6.91	0.66	0.10	0.12	0.11
Eucalyptus socialis	261	22.9	3.0	1.1	14.4	1936	BL	30	3.8	3.11	6.306	3.13	11.48	0.52	0.08	0.19	0.21
Eucalyptus viminalis	460	64.8	4.8	1.7	5.7	526	BL	33	10.0	10.83	6.600	3.27	12.01	0.63	0.13	0.09	0.16
Eucalyptus viminalis ssp. cygnetensis	460	64.8	4.8	1.7	9.0	561	BL	36	12.9	13.04	7.103	3.52	12.93	0.68	0.11	0.07	0.14
Eucalyptus viminalis ssp. cygnetensis	585	130.9	7.7	3.0	9.0	597	WB	6	7.6	5.80	4.599	2.28	8.37	0.62	0.13	0.09	0.16
Leptospermum continentale	546	141.2	8.2	2.8	7.0	339	RN	6	1.6	0.06	0.213	0.11	0.39	0.38	0.08	0.34	0.21
Melaleuca armillaris ssp. armillaris	362	51.3	4.2	2.0	11.0	122	WB	6	2.7	0.44	1.063	0.53	1.93	0.71	0.11	0.10	0.08
Melaleuca lanceolata	357	47.4	4.1	1.9	31.2	458	BL	3	4.0	1.56	2.257	1.12	4.11	0.58	0.11	0.18	0.13
Melaleuca lanceolata	261	22.9	3.0	1.1	12.5	319	BL	30	2.2	0.38	0.641	0.32	1.17	0.49	0.10	0.25	0.17
Melaleuca uncinata	357	50.6	4.2	1.9	16.3	585	WB	3	2.3	0.36	0.651	0.32	1.18	0.46	0.09	0.27	0.18
Pittosporum phylliraeoides	357	47.6	4.1	1.9	16.2	460	WB	3	2.5	0.38	0.657	0.33	1.20	0.48	0.09	0.26	0.17
Senna artemisioides ssp. coriacea	261	22.9	3.0	1.1	13.4	2254	BL	30	1.7	0.44	0.917	0.45	1.67	0.40	0.08	0.32	0.20
Senna artemisioides ssp. coriacea	261	22.9	3.0	1.1	13.4	3518	BL	3	1.6	0.70	1.481	0.73	2.70	0.40	0.08	0.32	0.20
Viminaria juncea	639	88.8	5.9	2.8	7.0	1057	RN	6	4.7	2.61	4.663	2.31	8.49	0.59	0.09	0.20	0.12

APPENDIX C. NATIONAL CARBON ACCOUNTING TOOLBOX SIMULATIONS

Use of NCAT FullCAM Software

The first step to creating a simulation or model run with the FullCAM Version 3.1 software is to select the main menu item ‘Document’ and ‘New Plot’ to open the FullCAM Plot module and create a new plot file. Subsequent saving of the Plot file is done via the main menu ‘File’ and ‘Save’ or ‘Save As’ options. When all Plot module data entry is finalised the user can then select ‘Simulate’ and ‘Run Plot Simulation’ to complete the FullCAM simulation and view and/or store model outputs. Plot files can later be stored, edited and re-run with new parameter, species and location settings.

The FullCAM Plot module is designed around eleven windows accessible via menu buttons at the top of screen. The first of these is 'About' (Figure 21) where you define the name of the model run, include descriptive information and set model editing security for the file. The second window, 'Configuration' (Figure 22) requires the user to make a number of choices. At this point under the plot category 'Multilayer forest system' is chosen as the most representative of the options available. The others being: Forest mulch; Forest soil; Agricultural mulch; Agricultural soil; Multilayer agricultural system and; Multilayer mixed (forestry and agricultural) system. Soil and mineral information is included in the model run and set the tree production method to 'Tree yield formula'.

The third window, 'Timing' (Figure 23) allow the entry of the planting date and the end date for the simulation of the site. Once that was done users proceeded to the fourth window, 'Data Builder' (Figure 24). The 'Data Builder' box must be ticked at this point so that the program can access the internet to download the required default parameter sets. The latitude and longitude of the site is now required prior to downloading the spatial data relating to soils, climate and productivity indicies.

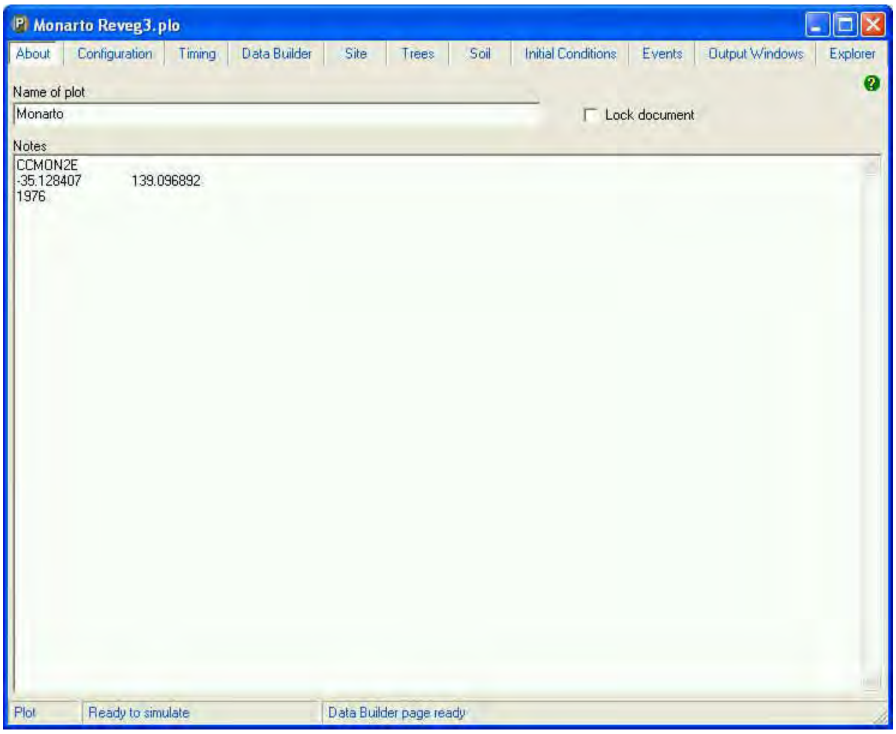

Figure 21. The 'About' window designed for naming, notes and security.

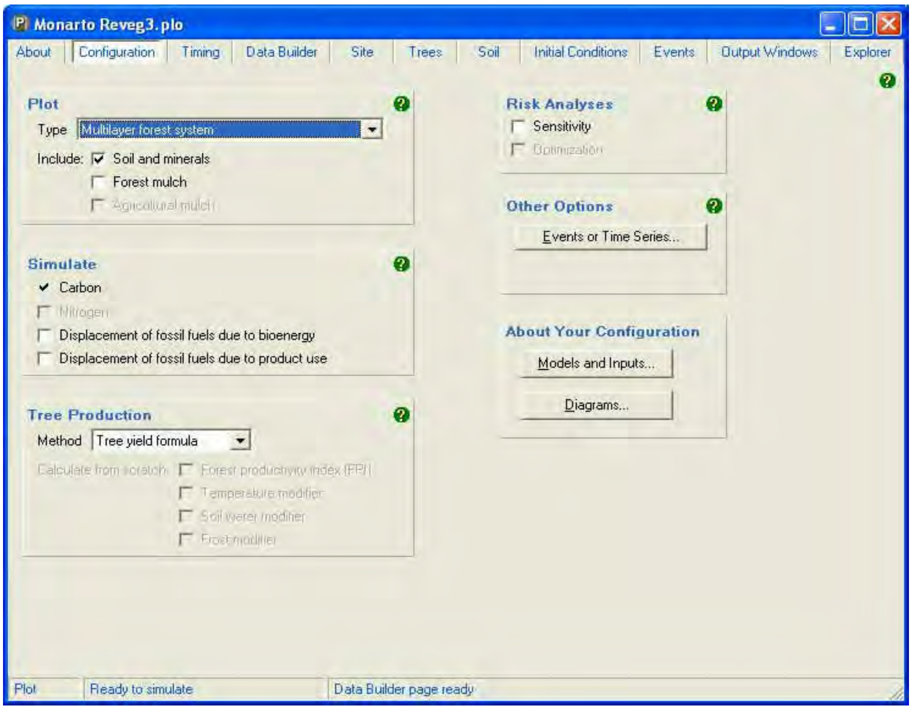

Figure 22. The 'Configuration' window offers the opportunity to tailor the model outputs to pre-existing criteria.

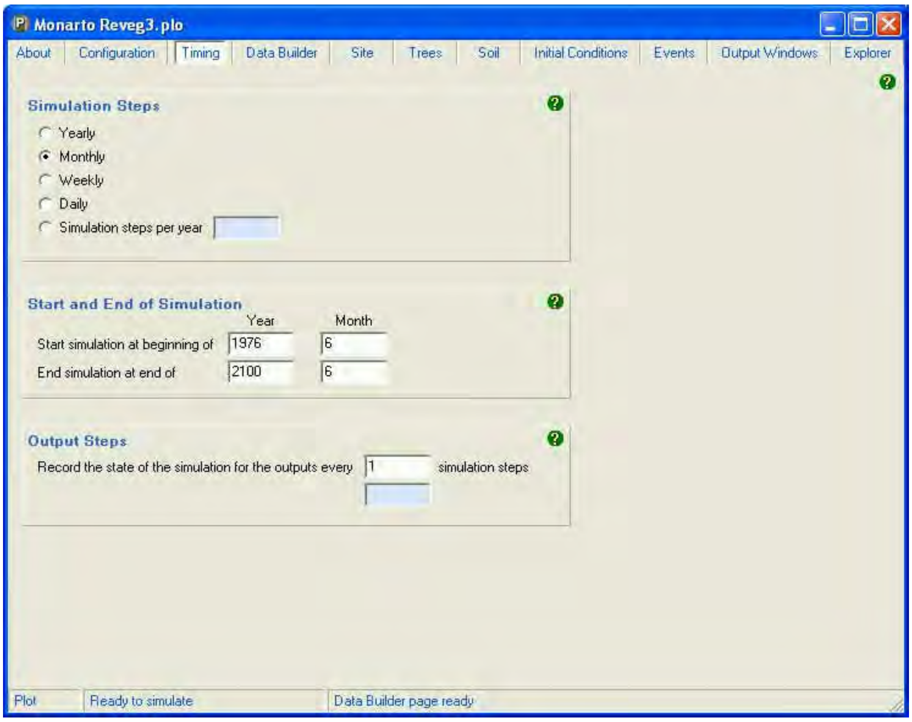

Figure 23. The 'Timing' window allows the entry of the planting date and the end date for the simulation of the site

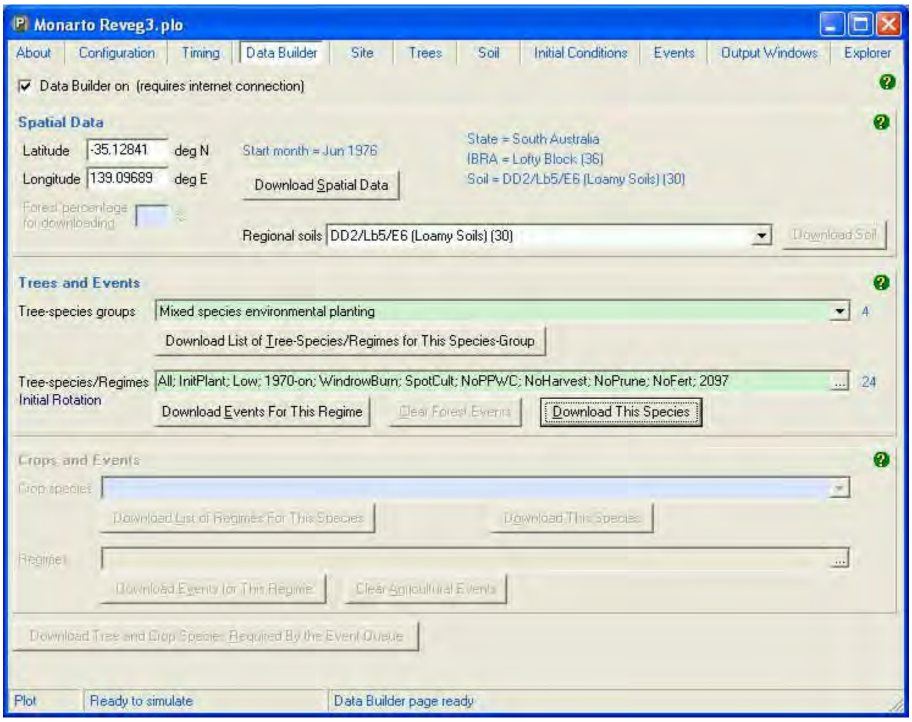

Figure 24. The 'Data Builder' window allows the entry of location data and the down loading of data specific to that site and the system chosen for that site.

Once the spatial data for the latitude and longitude had been down loaded the default soil for each site is accepted. Users then proceed to the 'Tree species groups' box and select 'Mixed species environmental planting' from the drop down list, as the most appropriate category. In every case examined the list consisted of: 'Eucalyptus globulus (Tasmanian blue gum)'; 'Local species' and; 'Pinus radiata (Radiata Pine)' as well as the 'Mixed species environmental planting' group used in simulations.

With the 'Mixed species environmental planting' group selected the list of tree-species/regimes for this species-group are downloaded. At this point the most appropriate of the available selections (All; InitPlant; Low; 1970-on; WindrowBurn; StripCult; NoPPWC; NoHarvest; NoPrune; NoFert; 2099-recommended) was used for each subsequent simulation, downloading the information for this species.

In the next step the 'Site' window (Figure 25) is chosen. Within this window the 'Area' option a point model is selected rather than indicating a specific area. No other input is required at this point but the simulation's calculated 'Maximum Aboveground Biomass [tdm/ha]' figure is displayed.

The next window is 'Trees' (Figure 26). Under 'Select a Species' selections closely matched choices from 'Data Builder' (Mixed species environmental planting [1970-present All initial Plantation low: on-commercial planting; No prune] 2099). At this point it is interesting to note that the carbon percentages under the plant menu in 'Properties of the Species' are exactly the same as those for Eucalyptus globulus (Figure 27). However, the stem density of the mixed species environmental plantings is set at the single figure of 750.0 kg dm/m^3 (Figure 28) (for E. globulus it varies over time, reflecting the amount of extra research data available for that individual species.) No modifications from the default settings found in the 'Soil' and; 'Initial Condition' windows were made.

Within the following 'Events' (Figure 29) window the planting date was inserted for the simulation and ensured that no other events were listed. At this point the 'Output Window' (Figure 30) and selected all outputs generated by the simulation. The simulation is completed by selecting “Run Plot Simulation (F9)” option on the main menu before reviewing and saving the outputs (Figure 31). The last window, 'Explorer' can be ignored as it is simply a navigation tool.

This step-by-step guide of how the FullCAM Version 3.1 software has been used to simulate carbon balances for our survey sites provides an overview of the core considerations to be addressed in FullCAM evaluations of revegetation sites. For further information and explanation of the many ways the program can be used readers should review the Department of Climate Change website where the complete FullCAM Carbon Accounting Model (Version 3.1) User Manual (Richards *et al.* 2005) can be accessed.

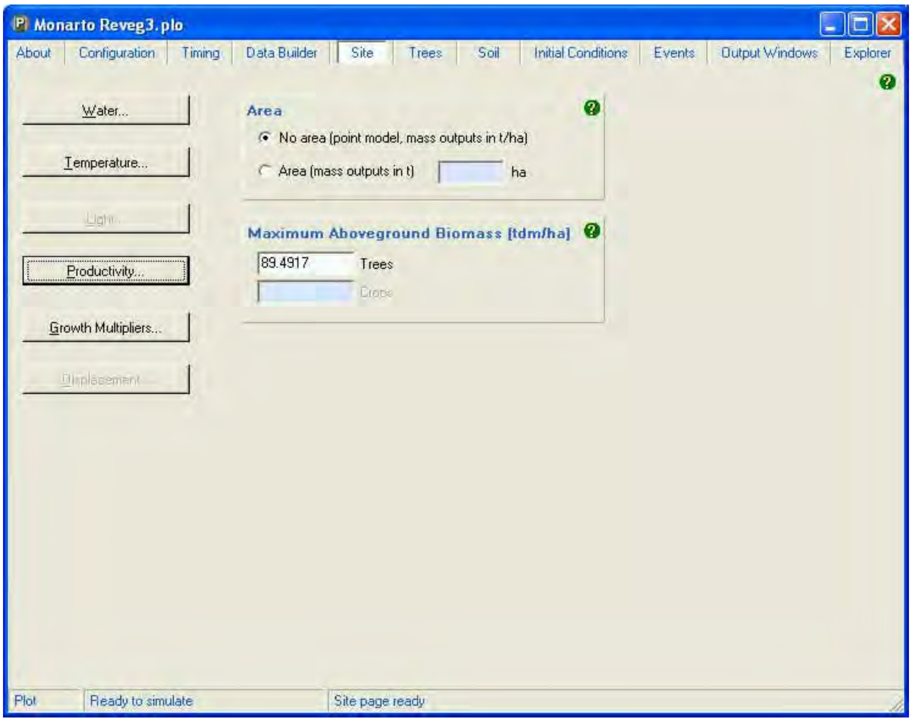

Figure 25. The 'Site' window allows an area or point model to be set and displays the 'Maximum Aboveground Biomass' figure generated for the specific site.

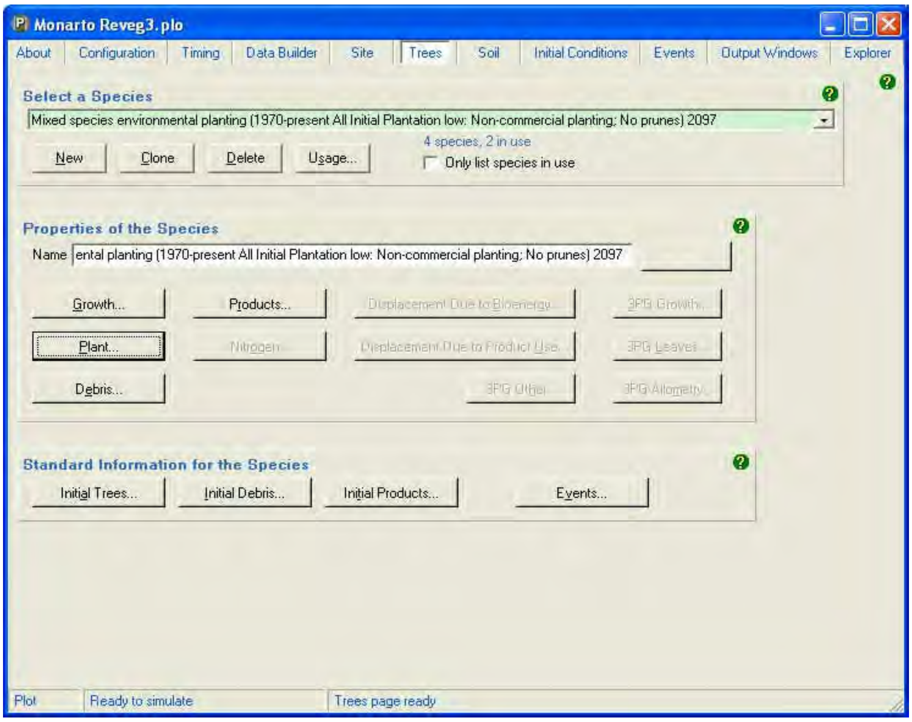

Figure 26. The 'Trees' window displays the selected planting system and gives access to other background plant and growth data.

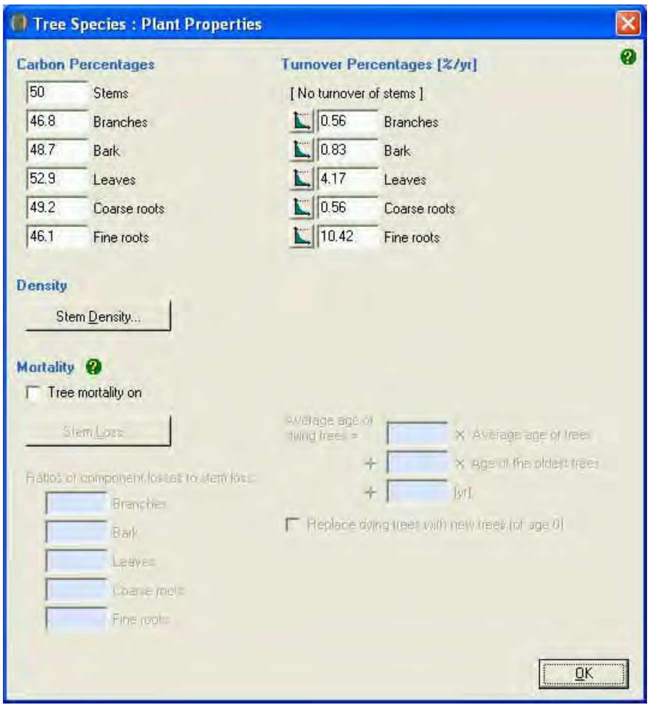

Figure 27. **The 'Plant Properties' sub-window displays the carbon and turnover percentages used by the model and is accessed via the plant button on the 'Trees; window.**

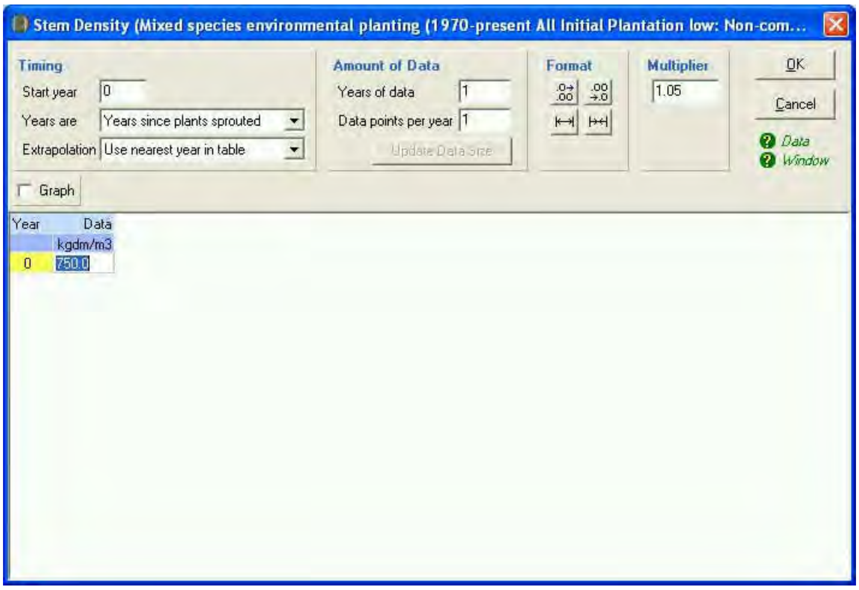

Figure 28. **The 'Stem Density' sub-window displays the wood density figures used by the model and is accessed via the plant button on the 'Plant Properties' sub-window.**

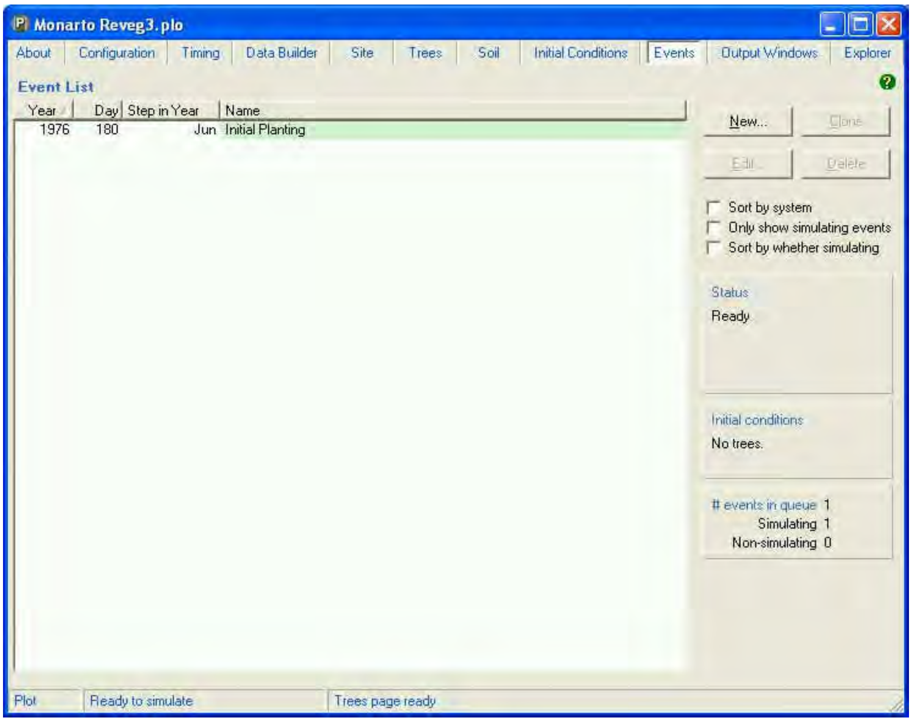

Figure 29. The 'Events' window allows the user to enter and model the effects of external events on production.

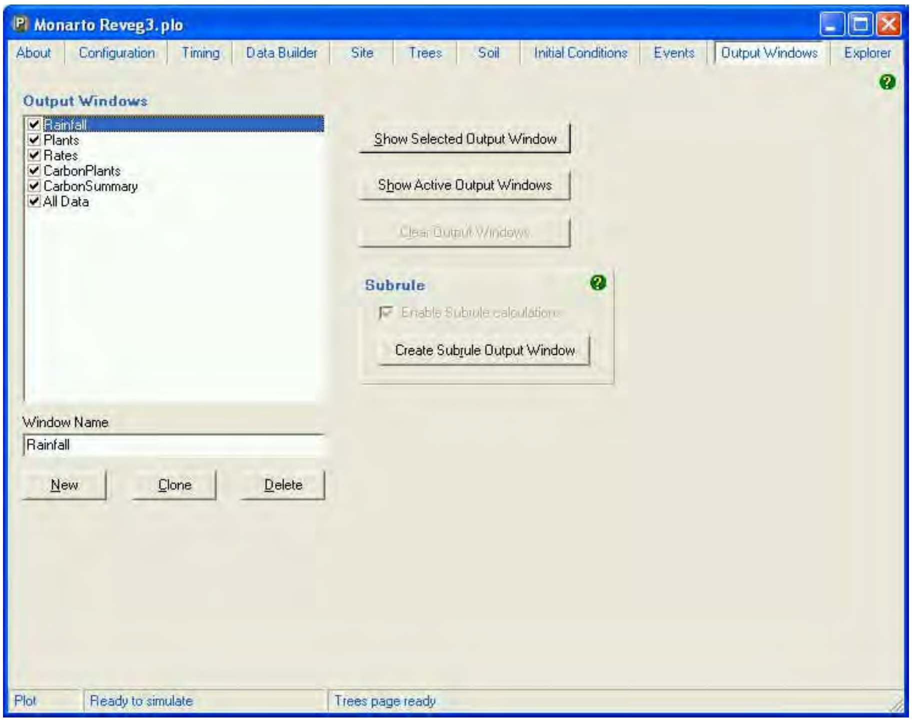

Figure 30. The 'Output' window allows the user to tailor the types of outputs delivered by the model.

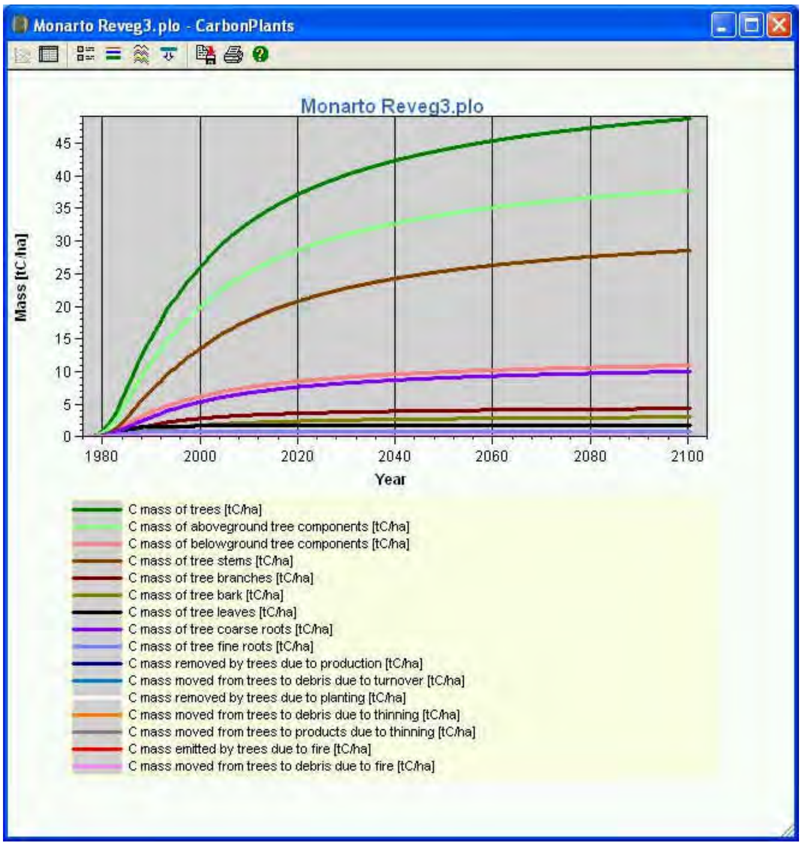

Figure 31. An example output window displaying modelled plant carbon sequestration rates.

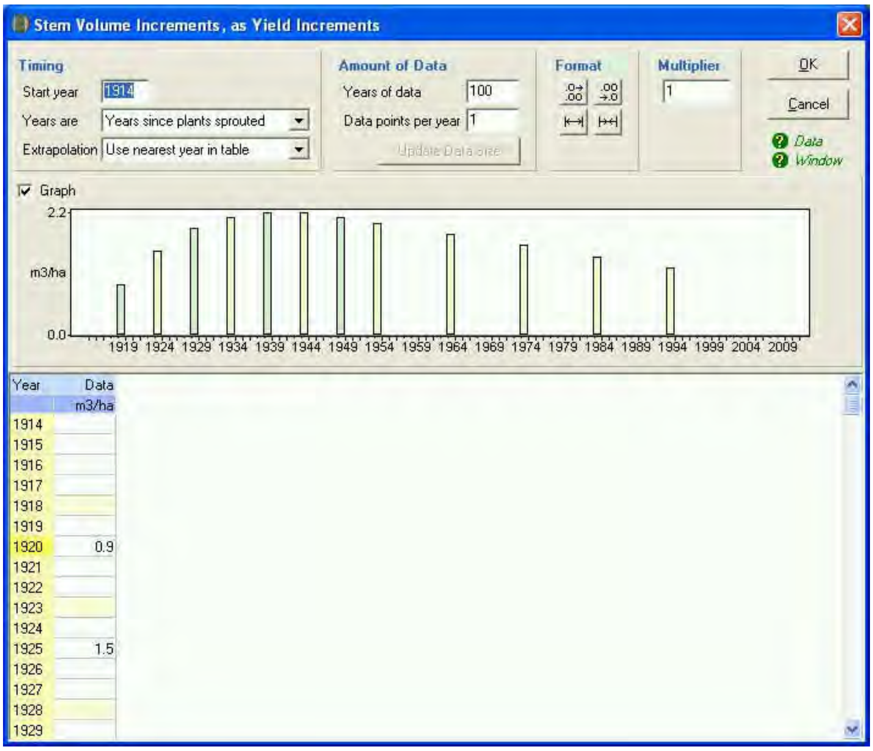

Figure 32. Stem Wood Increments sub-screen where the user can enter their own stem wood volume data if running the program in the incremental mode.

GLOSSARY

3-PG — a growth model for predicting forest growth (Physiological Processes Predicting Growth model of Landsberg & Waring (1997).

ArcGIS — a geographic information system developed by ESRI that integrates hardware, software, and data for capturing, managing, analysing, and displaying all forms of spatial information.

BiosEquil (BE) — a steady state biosphere model used for the assessment of carbon, nitrogen, phosphorus and water in Australian landscapes (Raupach *et al.* 2001).

CABALA — a growth model for predicting forest growth (CArbon BALAnce; Battaglia *et al.* 2004).

CO_2e — carbon dioxide equivalent.

CRC — Cooperative Research Centre.

CSIRO — Commonwealth Scientific and Industrial Research Organisation (Australian Federal Government)/

DCC — Department of Climate Change. (Australian Federal Government)

DEH — Department for Environment and Heritage (Government of South Australia).

DWLBC — Department of Water, Land and Biodiversity Conservation (Government of South Australia).

FPI — Forest Productivity Index. An index of climate and soil parameters that influence forest productivity. (Landsberg & Kesteven 2001).

FullCAM — fully integrated Carbon Accounting Model for estimating and predicting all biomass, litter and soil carbon pools in forest and agricultural systems (Department of Climate Change 2005).

GIS — Geographic Information System; computer software linking geographic data (for example land parcels) to textual data (soil type, land value, ownership). It allows for a range of features, from simple map production to complex data analysis.

IBRA — Interim Biogeographic Regions of Australia; regions containing similar landscapes, climates and native ecosystems (Department of the Environment, Water, Heritage and the Arts 2009).

Indigenous species — a species that occurs naturally in a region.

MAI — mean annual increment; typically used to describe growth of stemwood volumes in forestry.

Model — a conceptual or mathematical means of understanding elements of the real world that allows for predictions of outcomes given certain conditions.

NCAT — National Carbon Accounting Toolbox. A Model that estimate changes in emissions resulting from changed land management actions, such as forest establishment and harvesting, soil cultivation, fire management and fertiliser application (Richards *et al.* 2005).

NRM — Natural Resources Management; all activities that involve the use or development of natural resources and/or that impact on the state and condition of natural resources, whether positively or negatively.

PIRSA — Primary Industries and Resources South Australia (Government of South Australia).

RIRDC — Rural Industries Research and Development Corporation (Australian Federal Government).

TFL — Trees For Life is a not-for-profit South Australian community environmental organisation and significant provider of native plant for revegetation in the state.

tph — trees per hectare; average number of trees planted per unit area.

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