Carbon Sequestration from Revegetation:

South Australian Agricultural Regions

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Sugar Gum *Eucalyptus cladocalyx* woodlot at Leighton Forest, SA (Photo: C.R. Neumann)

FOREWORD

The Department of Environment, Water and Natural Resources (DEWNR) is responsible for the management of the State's natural resources, ranging from policy leadership to on-ground delivery in consultation with government, industry and communities.

High-quality science and effective monitoring provides the foundation for the successful management of our environment and natural resources. This is achieved through undertaking appropriate research, investigations, assessments, monitoring and evaluation.

DEWNR's strong partnerships with educational and research institutions, industries, government agencies, Natural Resources Management Boards and the community ensures that there is continual capacity building across the sector, and that the best skills and expertise are used to inform decision making.

Allan Holmes
CHIEF EXECUTIVE
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EXECUTIVE SUMMARY

What the report is about

This study focuses on providing reliable estimates of carbon sequestration rates from revegetation activities using Australian native plants in the low to medium rainfall (250 - 650mm/year) dryland agriculture zones of South Australia. The purpose, design, species composition and carbon sequestration potential of revegetation is extremely diverse. The potential revegetation continuum ranges from the simplicity of woodlot monocultures to the complexity of fully biodiverse plantings. This report aims to address these issues by developing techniques and models that are flexible and robust in a wide range of conditions.

To rapidly assess carbon stocks and sequestration rates across different revegetation types DEWNR have developed reliable techniques to estimate plant biomass from simple plant measurements. The productivity of revegetation sites were surveyed across a wide range of types, environments and ages. This data has been used to quantify and model the relationships between driving variables and carbon sequestration rates.

Resulting productivity models have been applied to the cleared agricultural regions of the State to estimate their carbon sequestration potential using woodlots and tree-dominated environmental plantings. Reference tables, summarising these estimates, have been collated for NRM Regions, rainfall zones and other administrative or environmental zones.

The report also delivers preliminary estimates of carbon stocks currently held in remnant vegetation on public and private lands in the agricultural regions of the State.

Who is the report targeted at?

This report is intended to assist natural resource managers, revegetation and carbon industries, rural landholders, government agencies and researchers to make informed decisions about the potential for revegetation activities and remnant vegetation to contribute to carbon stocks in the agricultural regions of South Australia.

Background

South Australia has the potential to sequester a significant amount of carbon in revegetation and managed remnant vegetation in our agricultural landscapes. Dedicated woody carbon crops, sustainable agroforestry, environmental plantings and managed native plant communities can be used to store atmospheric carbon, deliver economic and environmental benefits, enhance biodiversity and provide greater resilience to climate change for our rural communities.

The influence of climate change on traditional farming businesses, expected expansion of carbon markets, and trends towards more sustainable land use options suggest that future agricultural landscapes will contain greater diversity of land uses, including carbon crops, woodlots, environmental revegetation and conservation. To evaluate the economic and potential expansion of these crops and native plants, land managers and governments require reliable information on the carbon sequestration potential of revegetation and native carbon stocks.

Historically, production rates of a few forestry species have dominated studies of carbon sequestration from revegetation in Australia, with higher rainfall forestry observations being extrapolated into drier regions and to represent mixed species environmental plantings. The production rates of local native species found in environmental plantings are poorly represented in most current models used to estimate carbon sequestration from revegetation. Carbon stocks of remnant vegetation are even more poorly understood or documented.

Department of Environment, Water and Natural Resources (DEWNR) Science Monitoring and Knowledge (SMK) staff have established collaborations with allied researchers and natural resource managers, undertaken numerous surveys of revegetation and remnant vegetation sites over many years, and undertaken investigations into carbon assessment techniques and accounting methodologies to inform and refine our understanding of carbon sequestration from native plants in South Australia.

Aims and Objectives

This report aims to provide reliable techniques and models to assess carbon stocks and sequestration rates from revegetation activities and native plant communities in the agricultural regions of South Australia. Key objectives of this study are:

- Provide regional species lists and identify those species currently used in revegetation activities across the State.
- Develop and refine methods to assess carbon sequestration from Australian native plant species.
- Develop carbon sequestration from revegetation models that are relevant for South Australian agricultural regions and are calibrated to local conditions.
- Report on the regional potential of carbon sequestration by summarising the results of model predictions on cleared agricultural landscapes across the State.
- Improve the reliability of Australian carbon accounting methodologies approved by the Domestic Offset Integrity Commission.

Methods Used

Revegetation Species

Plant information from DEWNR herbarium records and the biological database of South Australia were analysed to identify naturally occurring, structurally dominant and most frequently encountered native plant species for each non-arid NRM Region and rainfall zone. Revegetation activity data from Trees For Life between 1999-2008 were analysed to identify structurally dominant and most frequently planted revegetation species for each NRM Region.

Carbon Assessment Techniques

Quantifying the relationships (allometrics) between simple plant measurements (e.g. height, basal area, crown width) and plant biomass (or carbon content) has been achieved by measuring and destructively sampling the above-ground biomass of 535 individual plant across a range of species, lifeforms, ages and revegetation sites in South Australia. Measurements and destructive samples of above-ground and root biomass for 41 individual plants were also undertaken across 2 sites to create allometric models for root biomass.

Productivity Surveys

Total above-ground plant biomass and carbon content of 264 revegetation sites (132 woodlots, 132 mixed species) of known age and 37 remnant vegetation sites in the agricultural regions of South Australia were assessed using measurements of 36 (monoculture) or 60 (mixed species) plants at each site and applying non-destructive DEWNR allometric models.

Carbon Sequestration Models

Plant density, tree/shrub proportions, revegetation age, remnant average height, climate and soil information from these 301 productivity surveys were analysed to identify key influences on sequestration rates or carbon stocks in remnant vegetation. Stepwise regression modelling techniques were used to identify the best combination of variables to predict carbon sequestration rates or carbon stocks.

More detailed research and analysis on sampling intensity, allometrics and root biomass was conducted by DEWNR and CSIRO on 2 reference sites in SA to update national carbon accounting models.

Regional Carbon Sequestration

Carbon sequestration models were applied to the cleared agricultural regions for 2 common revegetation types (i.e. woodlots & tree dominated environmental plantings) and remnant vegetation. Several administrative and environmental divisions of the State, relevant to wide range of stakeholders, were identified for reporting results.

Results / Key Findings

Revegetation Species

Reference lists of structurally dominant and frequently occurring native plant species have been generated for rainfall zones within each non-arid NRM Region to guide plant selections for future revegetation activities. Dominant plant species used for revegetation, based on Trees For Life data, has also been summarised for each NRM Region. There is high level of concurrence between these lists.

Carbon Assessment Techniques

Several highly significant allometric models have been identified from this applied research (r^2=0.58-0.97). Stemwood volume (derived from height and basal area measurements) provides the single strongest predictor of above-ground plant biomass (r^2=0.95). This model is improved by a further 2% if crown area data is also included. Plant height and crown area data provides the best model for predicting root biomass (r^2=0.86).

Productivity Surveys

The average plant density within all surveyed revegetation sites was 894 plants/ha (at 22 years), 714 plants/ha for woodlot plantings (at 26 years), 1074 plants/ha for environmental plantings (at 17 years) and 669 plants/ha in remnant vegetation. The average above-ground carbon sequestration rate of all revegetation sites was 9.5 tonnes of carbon dioxide equivalents per hectare per year (CO_2-e t/ha/year; mean annual rainfall 429mm/year), 11.4 CO_2-e t/ha/year in woodlots (441mm/year) and 7.6 CO_2-e t/ha/year in environmental plantings (418mm/year). Above-ground plant carbon stocks from remnant vegetation surveys was observed to be around 428 CO_2-e t/ha (515mm/year) on average.

Carbon Sequestration Models

Analysis of relationships between carbon sequestration and planting designs, climates and soils has allowed the development of models to predict average above-ground carbon sequestration rates from revegetation (r^2=0.60) and carbon stocks in remnant vegetation (r^2=0.59) for the agricultural regions of South Australia. Revegetation models have been embedded within a simplified tool (i.e. MS Excel Spreadsheet "*DEWNR Carbon Sequestration from Revegetation Estimator*") that allows individuals to estimate carbon sequestration rates and stocks over time using regional average or localised site data. These models can be applied to climate change scenarios to estimate likely impacts of climate change on carbon sequestration rates.

Collaborative applied research between DEWNR and CSIRO has facilitated a significant improvement in the models used by the National Carbon Accounting System and the Carbon Farming Initiative's Reforestation Modelling Tool.

Regional Carbon Sequestration

This report provides maps of typical sequestration rates for the State and within each Natural Resource Management (NRM) region. Summaries of these predictions for cleared agricultural lands have been tabulated for each NRM Region, rainfall zone, cropping district, State planning division, local government region, biogeographic subregion and revegetation zone. Preliminary estimates of current carbon stocks in publicly and privately managed remnant vegetation is also reported for non-arid NRM Regions.

Recommendations and Conclusions

Those seeking to evaluate the feasibility of developing woody carbon crops, environmental revegetation and biomass industries in agricultural regions of South Australia may be guided by the information contained within this report. Potential productivity in the region can be highly variable and is influenced by species choices, planting designs, land management practices and climatic conditions.

This research provides a valuable step towards understanding carbon sequestration rates from revegetation using woodlots and environmental plantings in South Australia, and provides preliminary estimates of carbon stocks held in remnant vegetation. Land managers, policy makers and investors should consider potential impacts that revegetation could have on agricultural production, rural communities and the environment. It is important that these new industries are targeted in areas where they maximise economic and environmental benefits for whole farm enterprises, regions and South Australia.

ACKNOWLEDGEMENTS

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ABBREVIATIONS

CFI — Carbon Farming Initiative

CO_2-e — carbon dioxide equivalent

CRC — Cooperative Research Centre

CSIRO — Commonwealth Scientific and Industrial Research Organisation

DCCEE — Department of Climate Change and Energy Efficiency (now DOTE)

DEWNR — Department of Environment, Water and Natural Resources

DOA — Department of Agriculture

DOIC — Domestic Offsets Integrity Committee

DOTE — Department of the Environment

DSEWPC — Department of Sustainability, Environment, Water, Population and Communities (now DOTE)

FPI — Forest Productivity Index

GIS — Geographic Information System

IBRA — Interim Biogeographic Regions of Australia

MAI — mean annual increment

NCAT — National Carbon Accounting Toolbox

NRM — Natural Resource Management

NVIS — National Vegetation Information System

PIRSA — Primary Industries and Resources South Australia

RIRDC — Rural Industries Research and Development Corporation

RMT — Reforestation Modelling Tool

TFL — Trees For Life

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1. INTRODUCTION

NATURAL RESOURCE MANAGEMENT AND SEQUESTERING CARBON IN VEGETATION

The integrated management of our natural resources continues to be a high priority for South Australia, as reflected in state policy and legislation. The South Australian Strategic Plan reflects a desire to manage natural resources in an integrated way that will benefit all South Australians. Our state Plan's vision "creates a future shaped by choice, not chance. Keeping our communities strong and vibrant, protecting our rich environment and pursuing shared economic prosperity will provide a better future for South Australians" (Government of South Australia 2011). Being able to fulfil this vision is strongly connected to our ability to manage our natural resources and adapt to the changing climate in our agricultural regions.

The Carbon Farming Initiative (CFI) is an Australian Government program that prescribes the rules and permitted methodologies under which carbon accounting and trading is to be conducted in Australia. Participation in these formal carbon markets requires that revegetation activities conform to Domestic Offsets Integrity Committee (DOIC) approved methodologies and that they pass their "additionally test" (i.e. the carbon sequestered is in addition to what would occur in the absence of the project). For revegetation to gain accreditation and generate Australian Carbon Credit Units (ACCUs) within most existing and proposed Australian carbon trading schemes in Australia, the revegetation must meet the "forest" criteria identified by the Kyoto protocol (Department of Climate Change 2008). A Kyoto-compliant forest is defined as being planted after 1990 with minimum area of 0.2 hectares, tree crown cover of 20 per cent and a mature tree height of 2 metres or more. Carbon stored by smaller plants (<2 metres high) within these forests are included in the total carbon pool for accounting purposes but are typically a small proportion of the total carbon on site.

The increased policy focus on the development of carbon markets provides an economic driver for a range of revegetation activities. The Carbon Farming Initiative in particular provides economic mechanisms to encourage environmental revegetation and the adoption of other woody crops. Such activities can contribute to diverse multipurpose agricultural systems that are productive, sustainable, resilient and adaptable to climate change. 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. Prior research conducted by Department of Environment, Water and Natural Resources (DEWNR) FloraSearch, Future Farm Industries Cooperative Research Centre, Rural Industries Research and Development Corporation and CSIRO has identified the low to medium rainfall agricultural zones (250 - 650mm/year) as having the greatest feasibility for developing carbon markets in Australia (Hobbs *et al.* 2009c).

The SA *Natural Resources Management Act* (Government of South Australia 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 (Government of South Australia 2012) that identifies the organisational structure for NRM groups, and sets out guiding targets, indicators and measures to achieve those goals.

State NRM Plan Vision: We care for the land, water, air and sea that sustain us.

- **Goal 1: People taking responsibility for natural resources and making informed decisions**
- **Goal 2: Sustainable management and productive use of land, water, air and sea.**
- **Goal 3: Improved condition and resilience of natural systems.**

The integration of sustainable reforestation (e.g. habitat restoration, carbon markets & extractive use) with other agricultural production (e.g. grazing and cropping) has the potential to provide more stable landholder returns, contribute to the productive capacity of the land and assist in the sustainable management of our natural resources. Such an approach is likely to improve the prosperity of local rural communities and industries while potentially increasing the extent and condition of native vegetation in these regions. The use of indigenous native species in revegetation activities (commercial or environmental) can minimise the risks 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.

This current research project addresses South Australia's 2012 NRM Plan through 'Goal 2: Guiding Target 6: Monitoring and evaluating the condition of our natural resources' by ensuring current and future assessments of carbon stocks in native vegetation (revegetation and remnant) are accurate and reliable on which to base future NRM planning and investment decisions.

This research also contributes to meeting a number of the Guiding Targets of Goal 1 and 3:

- Better informing people about carbon sequestration rates across the state that improves their capacity to make informed NRM decisions (Goal 1, Guiding Target 1).
- Improve the accuracy of carbon sequestration models to facilitate improved capacity for organisations and institutions to better manage natural resources (Goal 1, Guiding Target 3).
- Increase the level of confidence in carbon sequestration predictions to encourage commercial investment in new native plantings (Goal 3, Guiding Target 8).
- Increase the level of understanding about carbon sequestration potentials presented by above-ground vegetation in different sections of the landscape (Goal 3, Guiding Target 11).

This work is also consistent with South Australia's Greenhouse Strategy, "Tackling Climate Change: South Australia's Greenhouse Strategy 2007-2020" (Government of South Australia 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.

FILLING THE KNOWLEDGE GAP

There is a growing need to efficiently evaluate and predict carbon sequestration rates from environmental plantings and sustainable woody crops in the low to medium rainfall (250 - 650mm/year) dryland agriculture zones of South Australia. A key objective of this project is to reduce the knowledge gap by increasing the representation, accuracy and reliability of biomass productivity data for revegetation activities in SA and to calibrate carbon accounting models used for carbon accounting and trading schemes (e.g. Carbon Farming Initiative, CFI; DCCEE 2011). Without this crucial 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 carbon trading schemes, or credibly support investments in the development of carbon markets in South Australia.

The sequestration rates of revegetation using native species woodlots and environmental plantings are poorly known in many parts of Australia (Stucley *et al.* 2004, Waterworth *et al.* 2007, Polglase *et al.* 2008, Paul *et al.* 2012). This knowledge gap is particularly acute in the case of environmental plantings and plantings in low to medium rainfall areas where there has been little economic impetus toward acquiring such information in the past. While there has been progress toward closing this gap in recent years the lack of accurate data remains an impediment to adoption. This project aims to deliver critical information and develop methodologies for evaluating and predicting carbon sequestration rates in sustainable woody crops and environmental revegetation plantings in agricultural regions of South Australia (Figure 2).

Photo: C.R. Neumann

Figure 1. Some of the oldest revegetation in the state can be found in the Mid-North region of South Australia (120 year old River Box *Eucalyptus largiflorens* woodlot plantation at Bundaleer Forest).

This project builds on the knowledge and understanding developed by DEWNR from prior research in the Murray-Darling Basin, the Mid-North and Upper South East regions of South Australia (Hobbs *et al.* 2010, Neumann *et al.* 2010, and Hobbs *et al.* 2009b). Recent surveys of additional NRM regions and new analyses have allowed the development of more reliable and representative carbon sequestration estimates for the agricultural regions of the State.

Older age plantations were a deliberate focus of this project as they better represent peak standing biomass associated with mature sites (Figure 1). Carbon sequestration rates in younger age reforestation may be accelerated due to soil water and nutrient stores resulting from previous land use for crops and pastures. Thus data gathered from younger age sites may misrepresent the long-term carbon sequestration rate because extrapolation of young age growth rates to represent older plantations can significantly inflate and misrepresent estimates of peak standing biomass. Comparisons between older age revegetation and naturally occurring remnant vegetation communities may provide some estimates of differences in their long-term carbon stocks. The peak standing biomass of natural systems may be correlated to peak standing biomass expected from mature revegetation but insufficient data is available to reliably test this hypothesis. It is likely that this premise is flawed at some locations and that revegetation of agricultural lands, with added nutrient status from past cropping/grazing history, has significantly increased the site's potential for carbon sequestration.

DEWNR's Science Monitoring and Knowledge (SMK) Ecology team have undertaken complex research into plant and landscape ecology to develop robust carbon sequestration assessment methodologies, expand databases of species and revegetation community productivity, and create parameter sets for carbon modelling programs. The work contributes significantly to the feasibility assessment and development of effective carbon markets at both state and national levels. This report outlines current research, applied science and collaborations that have reduced important gaps in the State and Nation's knowledge base.

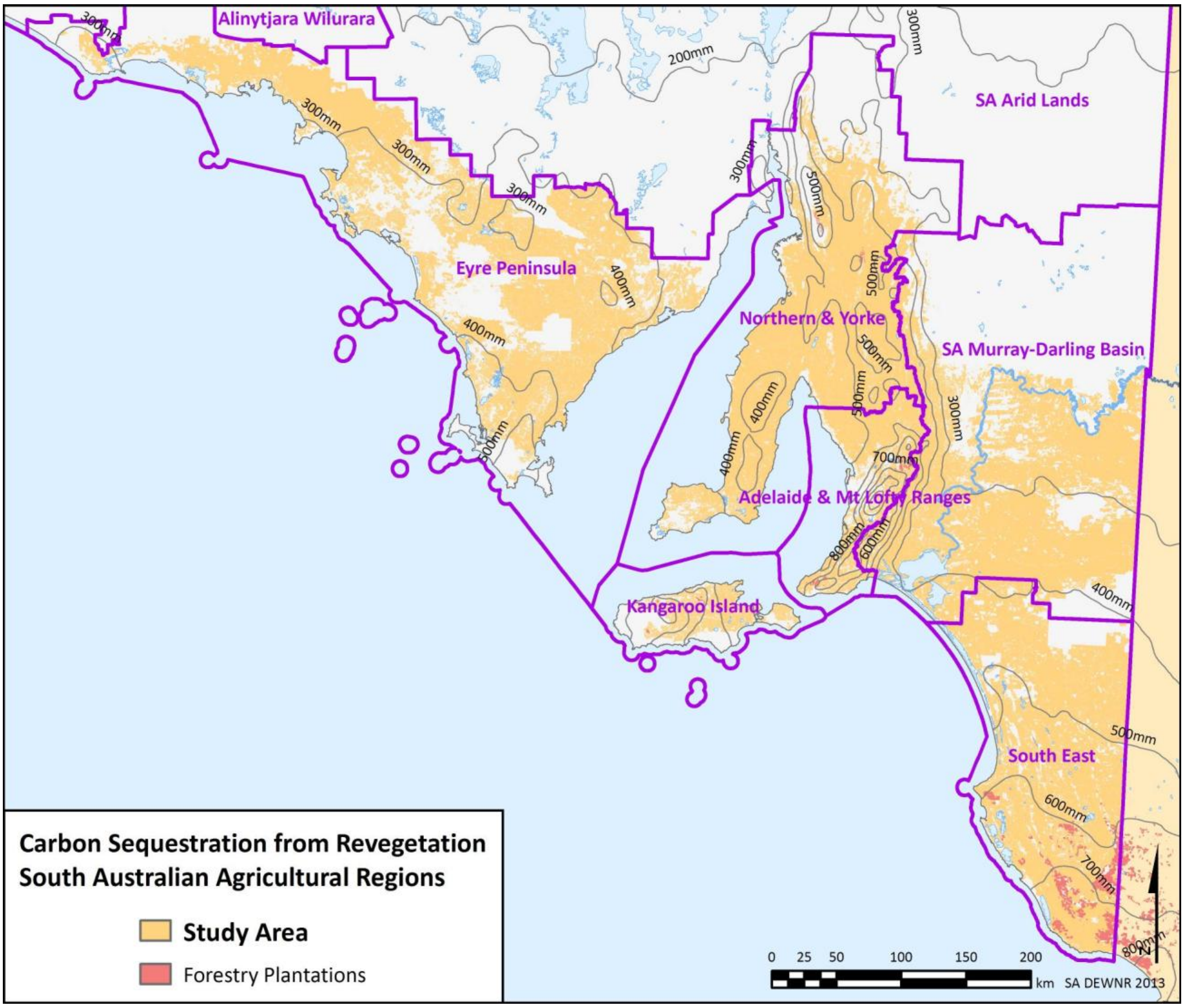

Figure 2. Carbon Sequestration from Revegetation project study area, including Natural Resource Management (NRM) Regions boundaries.

PURPOSE OF REVEGETATION

Large parts of South Australia's landscapes have been cleared of native vegetation for agricultural use. The growing of crops and grazing of livestock in these regions provides essential food and fibre commodities and industries and contributes to the wealth and prosperity of the state. However, in some landscapes agricultural uses have led to detrimental natural resource management issues (e.g. changes in biodiversity, water balances, soil health). In the future, under changing climates and commodity markets some current agricultural pursuits will become less viable and opportunities for reforestation, new agricultural industries, or blends of sustainable land uses will arise (Hobbs *et al.* 2009abc, Polglase *et al.* 2008, 2013, Paul *et al.* 2013a).

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 improve biodiversity outcomes; reduce groundwater recharge, dryland salinity, saline river discharges, wind erosion and drought risk; and increase landscape sustainability, livestock production, economic diversification and the stability of financial returns.

Environmental plantings for biodiversity purposes can provide multiple benefits to both endemic living organisms (e.g. provision of habitats) and landholders (e.g. sequestration of tradeable carbon stocks). This current study assists in the selection of revegetation species by identifying common local native species, and species typically used in revegetation activities in recent years. The location and prioritisation of new biodiverse revegetation projects, and species chosen, should be guided by a sound understanding of how well these new plant communities contribute to local and regional ecological processes and purposes.

South Australia has a long history of commercial softwood (pines) and hardwood (eucalypt) forestry containing some of the oldest forestry reserves in Australia (Figure 2, Figure 1). Blue Gum (*Eucalyptus globulus*) and Sugar Gum (*Eucalyptus cladocalyx*) are the main hardwood species used in these production forests. Both eucalypt species readily resprout (coppice) from stumps after harvest. The living roots and stumps are maintained and the regrowth is periodically harvested without the need to replant. This process is similar to that in commercial oil mallee plantations and other short rotation woody crops proposed as feed stocks for biofuel production. Within these production systems significant amounts of biomass (i.e. carbon) is maintained in the stump and roots of the parent trees. The recognition of the carbon sequestered in these systems and its inclusion in carbon trading schemes would add to the viability of many of these forestry enterprises.

The potential of revegetation to offset carbon emissions and produce tradeable commodities has emerged in recent years, especially with the introduction of the carbon pricing mechanism on July 1st 2012 under the Australian Government's Carbon Farming Initiative. Environmental and other perennial plantings are simple methods to offset carbon emissions. Some perennial plantings could even be used to reduce fossil fuel use by providing renewable fuel sources (Stucley *et al.* 2004, Zorzetto & Chudleigh 1999, Hague *et al.* 2002, Harper *et al.* 2007).

CARBON ASSESSMENTS

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

For physical revegetation site assessment of carbon sequestration (i.e. inventory) the whole plant biomass is required rather than the simple estimates of stemwood volumes used in classical forestry. To estimate whole plant biomass, site productivity can be rapidly assessed using reliable relationships (allometrics) between plant measurements and biomass developed by measuring and destructively harvesting representative individual plants and species. By harvesting a small number of individuals of a species and exploring their 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 can be applied to similar individuals. Using this method a set of simple measurements can be identified and applied without the need for further destructive sampling.

Allometric relationships quantified in this study were developed by combining data from recent destructive surveys with similar information collected from previous South Australian studies (Hobbs *et al.* 2005, Hobbs *et al.* 2006, Hobbs *et al.* 2010, Neumann *et al.* 2010, Neumann *et al.* 2011). Stemwood volume calculations were chosen for allometric relationships as they are most comparable with the process-based stemwood models used in the National Carbon Accounting Toolbox (NCAT, DCCEE 2009), Full Carbon Accounting Model (FullCAM, Richards & Evans 2000, Richards *et al.* 2005, Waterworth *et al.* 2007) and the Reforestation Modelling Tool (RMT, DCCEE 2011). In most instances physical and time constraints limit assessments to the above-ground components of plant biomass, the exception being two sites at Moorlands (near Tailem Bend) where collaboration with CSIRO and the Australian Government Department of the Environment (DOTE) enabled root zone excavations and below-ground measurements to be obtained. Local level assessments of productivity can also be amalgamated to provide greater accuracy in regional productivity estimates and carbon sequestration potential.

CARBON ACCOUNTING

The Australian Government has invested strongly over the past decade in building Australia's National Carbon Accounting System (NCAS) with the aim of providing a standard method of accounting for greenhouse gas emissions and ensuring credibility under international agreements on greenhouse gas emissions. The National Carbon Accounting Toolbox (NCAT) is part of that system and enables land managers to track greenhouse gas emissions to and removals from the atmosphere. As part of that function the toolbox houses the FullCAM point-based model that allows land managers to estimate carbon sequestration in their reforestation projects. In 2011, the Carbon Farming Initiative (CFI) was created to further enhance a land manager's ability to participate in new carbon markets and included the release of the Reforestation Modelling Tool (RMT) which was based on the same point-based modelling approach as the NCAT (i.e. FullCAM) with a revised interface.

These predictive models aim to quantify Australia's greenhouse gas emissions and carbon sinks associated with Australian land systems for international obligations on carbon accounting. In June 2012, the DOIC instated DOTE's primary methodology (i.e. CFI Reforestation Modelling Tool, RMT) for carbon accounting in environmental plantings. It is currently the only available cost-effective and approved methodology for use in South Australia.

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 (Waterworth *et al.* 2007). However, other native woody crop species and environmental plantings in medium to lower rainfall regions (<650mm) are less well represented in these systems. Consequently, a number of users of the system (DOTE, CSIRO, DEWNR, SA Water, Greening Australia and Canopy) have called for additional information collections and sampling to produce a more comprehensive dataset for use in carbon accounting models. Previous DEWNR studies have illustrated that currently available national models can severely under predict (i.e. on average only 27% of observed rates) carbon sequestration rates in low to medium rainfall regions (Hobbs *et al.* 2009a, Hobbs *et al.* 2010). The national models currently limit our ability to accurately quantify growth rates of revegetation in the agricultural regions of our State. The South Australian Government requires better evidence of the difference between local growth rates and current national models, and realises the benefit of contributing local calibration data to improve the quality and representativeness of future national carbon models for our State.

DEWNR has previously invested resources and developed collaborations with the Future Farm Industries (FFI) CRC and the Rural Industry Research and Development Corporation (RIRDC) to undertake studies on carbon sequestration rates and evaluation techniques from areas within SA (Mid-North - Neumann *et al.* 2011; Southern Murray-Darling Basin - Neumann *et al.* 2011, Hobbs *et al.* 2010; Upper South East - Hobbs *et al.* 2006, 2009a; River Murray Dryland Corridor - Hobbs & Bennell 2005). DEWNR's SMK Ecology team has collaborated extensively with CSIRO in recent years on other national studies of native plant growth rates and carbon sequestration modelling (Paul *et al.* 2012, 2013b, Polglase *et al.* 2008). From these investments and collaborations DEWNR has developed a strong capacity to undertake scientifically rigorous evaluations of carbon sequestration rates of native plant species in South Australia.

While the ultimate objective of this work is to develop a comprehensive understanding of carbon sequestration rates of all vegetation in South Australia, it will only progress by gathering the best available information from past surveys, develop cost-effective and sound methodologies for future surveys, and provide spatial estimates of anticipated sequestration from a variety of different forms of revegetation. Landscapes currently utilised for dryland agriculture in the low to medium rainfall regions (250-650mm/year) have strong potential for investments in revegetation for carbon sequestration, sustainable woody crop production and beneficial environmental outcomes (Hobbs *et al.* 2009abc, Polglase *et al.* 2008, 2013, Paul *et al.* 2013a).

AIMS AND OBJECTIVES

This report aims to provide reliable techniques and models to assess carbon stocks and sequestration rates from revegetation activities and native plant communities in the agricultural regions of South Australia. Key objectives of this study are:

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- Develop and refine methods to assess carbon sequestration from Australian native plant species.
- Develop carbon sequestration from revegetation models that are relevant for South Australian agricultural regions and are calibrated to local conditions.
- Report on the regional potential of carbon sequestration by summarising the results of model predictions on cleared agricultural landscapes across the State.
- Improve the reliability of Australian carbon accounting methodologies approved by the Domestic Offset Integrity Commission.

2. LOCAL REVEGETATION SPECIES AND ACTIVITIES

LOCAL NATIVE SPECIES

There are many biodiversity and practical site-suitability benefits of utilising common local native species for revegetation and carbon sequestration activities. This of course is affected by ease of propagation, targeted diversity of plant species and complexity of plant strata being created. To determine the most common local native species suited for each Natural Resource Management (NRM) region an analysis of regional species frequency was conducted using plant records from the DEWNR State Herbarium and biological survey databases (DEWNR eFloraSA 2012).

To make the output from the database more meaningful species lists were divided into height strata classes based on literature searches of maximum recorded height by species. All plants with a maximum recorded height <2 metres were excluded as they do not meet the requirements of Kyoto forest species. Although the carbon stored by smaller plants (<2 metres) are recognised in carbon accounts within forests, they are typically only a minor contributor to the total carbon pool at sites within agricultural regions. These generalised height classes (e.g. Tall, Moderately Tall, Medium) are designed to be a guide for the selection of overstorey, midstorey and taller understorey plants for revegetation projects. Variations in plant height across their environmental range and location made it difficult to classify species into an exact stratum position (e.g. a midstorey tree at one site may become the main overstorey species at another depending on the species mix and environment).

The 60 most common trees and taller shrubs for each NRM Region are tabulated in Appendix A - Regional Species Lists (Table 33 to Table 38). These tables also provide information on the distribution of species by rainfall zones within each NRM Region. 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.

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 (28% of total). Fortunately, Trees For Life targets species production for well-defined zones in South Australia (Figure 3). A list of species for each of these zones is available each year and landholders are encouraged to place orders for seedlings based on those lists. 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.).

Due to differences between NRM Region and TFL zone boundaries in some parts of the state (Figure 3), it is difficult to perfectly determine which species has been used and the total number of TFL plants used in all NRM Regions. To provide species lists and estimates of the number of plants used in revegetation for each NRM Region the data from each TFL zone was therefore assigned to the dominant NRM Region in which it is located (Table 1, Appendix B - Revegetation Species). Far North and North East Pastoral TFL zones partially overlap with southern NRM Regions but this data was excluded from southern NRM Regional tallies and nominally classified as "Arid Zone" for this report.

As anticipated, there is a high degree of concurrence between NRM regional species lists from DEWNR frequency data and TFL distribution data. The greatest differences tend to be for species that are easiest to propagate in nursery conditions and the dominance of upper storey tree species used in TFL revegetation.

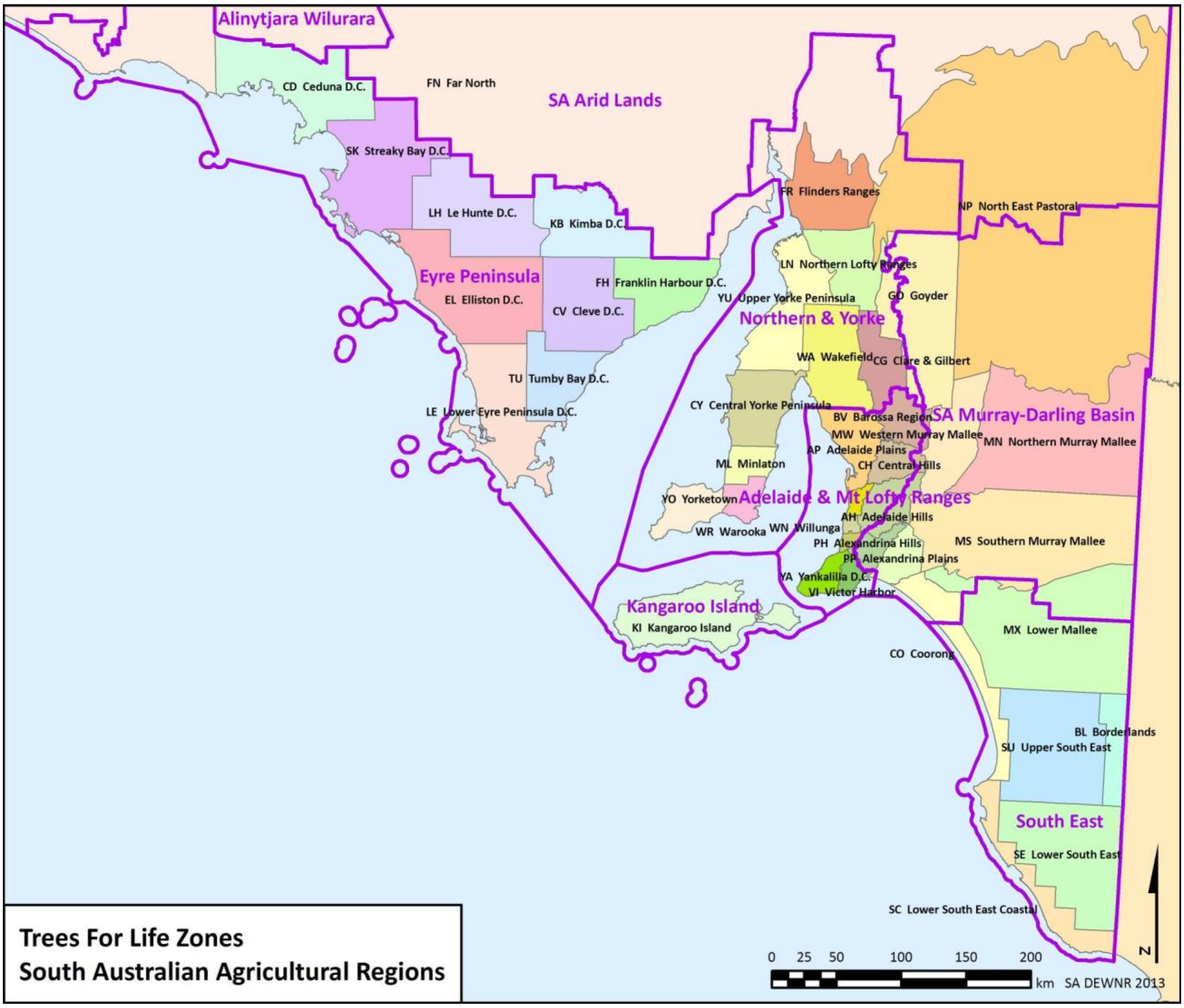


Figure 3. Trees For Life zones and NRM boundaries in the agricultural regions of South Australia.

REVEGETATION ACTIVITIES

DEWNR has 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 (Sheppard and Wilson 2007). Results of these surveys for the period between 1999 and 2006 are collated and presented in Table 1, Table 2 and Table 3. From this data, on average, approximately 6,038 ha of farm forestry and revegetation was planted annually, with indigenous environmental plantings (~4,185 ha/year) and saltbush (~851 ha/year) dominating revegetation activities in lower rainfall regions.

No precise information exists on the area that has been revegetated in the agricultural lands of South Australia in recent years. Using the planting density estimates provided in Sheppard and Wilson (2007) of 1000 stems per hectare, and Trees For Life plant sales and distribution data (Figure 4), it is estimated that a minimum of ~15,600 hectares of environmental revegetation has been planted in the region over the last 15 years (~1,040 hectares per year) from Trees For Life Tree Scheme stocks.

Table 1. Top 50 most commonly planted species and proportion for each South Australian NRM Region, based on 10 years of Trees For Life plant seedling (Tree Scheme) distribution data (1999 - 2008).

Height Class	Trees For Life Revegetation Dominant Species (1999-2008)	NRM Region* AMLR	EP	KI	NY	SAMD	SE	*Arid*[#]	10 Year Total
Tall	Eucalyptus leucoxylon	46%		4%	13%	15%	22%		677,825
	Eucalyptus camaldulensis	36%	8%	2%	17%	25%	10%	*2%*	634,300
	Allocasuarina verticillata	37%	7%	4%	18%	23%	11%	*<1%*	603,425
	Eucalyptus fasciculosa	51%		5%		25%	19%		442,575
	Melaleuca lanceolata	19%	10%	2%	23%	32%	11%	*2%*	441,375
	Eucalyptus porosa	22%	9%		36%	31%	1%	*1%*	259,525
	Eucalyptus socialis	12%	5%		35%	39%	5%	*3%*	223,625
	Eucalyptus odorata	33%	5%		31%	27%	3%	*1%*	215,075
	Acacia melanoxylon	73%		<1%		11%	15%		202,450
	Eucalyptus viminalis	72%		5%		9%	13%		174,200
	Melaleuca halmaturorum	10%	22%	8%	7%	23%	30%		164,975
	Eucalyptus oleosa	9%	16%		32%	38%	2%	*3%*	145,175
	Callitris gracilis	35%	6%	3%	20%	35%	2%		114,350
	Eucalyptus dumosa	7%	18%		9%	47%	14%	*4%*	112,525
	Bursaria spinosa	59%	3%	2%	14%	17%	5%	*1%*	111,000
	Eucalyptus obliqua	72%		3%		13%	13%		82,550
	Pittosporum angustifolium	29%	7%		25%	35%	2%	*2%*	80,250
	Acacia retinodes	94%			6%				80,150
	Eucalyptus largiflorens	11%				86%	2%	*<1%*	76,625
	Eucalyptus cosmophylla	69%		17%		14%			71,125
	Eucalyptus baxteri	62%		3%		10%	25%		68,700
	Banksia marginata	61%		3%	9%	9%	17%		66,100
	Eucalyptus petiolaris		100%						61,525
	Acacia provincialis	77%		4%		19%			61,175
	Eucalyptus diversifolia		21%	15%	14%		51%		60,075
Mod-Tall	Acacia pycnantha	49%	4%	2%	14%	21%	9%		438,550
	Dodonaea viscosa	47%	5%	1%	13%	26%	7%	*1%*	261,225
	Eucalyptus gracilis	14%	12%		26%	41%	4%	*3%*	189,000
	Acacia paradoxa	71%	1%	2%	9%	15%	2%		181,300
	Callistemon rugulosus	6%	11%	9%	20%	24%	30%		129,225
	Eucalyptus incrassata	11%	11%		26%	36%	15%	*1%*	115,500
	Acacia ligulata	26%	11%	1%	19%	41%		*1%*	105,275
	Leptospermum continentale	76%		2%		10%	13%		105,000
	Allocasuarina muelleriana	64%	5%	3%	8%	14%	6%		102,300
	Acacia oswaldii	17%	17%		29%	32%		*6%*	97,175
	Eucalyptus brachycalyx	15%	13%		28%	43%			95,500
	Eucalyptus leptophylla	5%	13%	4%	18%	53%	7%	*<1%*	89,700
	Melaleuca decussata	79%	6%		1%	14%			88,500
	Callistemon sieberi	77%				23%			87,475
	Melaleuca acuminata	16%	13%	2%	32%	36%			87,175
	Acacia hakeoides	18%	8%		36%	32%	3%	*3%*	80,400
	Leptospermum lanigerum	74%		3%		16%	7%		78,025
	Acacia notabilis	37%	12%		42%	7%		*2%*	75,950
	Melaleuca uncinata		21%	9%	12%	43%	15%		74,000
	Acacia calamifolia	14%	19%	<1%	18%	44%	1%	*4%*	64,900
	Eucalyptus calycogona	14%	10%		19%	56%			62,275
Medium	Acacia myrtifolia	79%	2%	1%	2%	9%	7%		133,025
	Acacia acinacea	62%			10%	26%	2%		114,100
	Rhagodia parabolica	29%	6%		46%	17%		*1%*	102,900
	Xanthorrhoea semiplana	83%	3%	4%		9%	1%		58,550
Tall	Total Tall (n=53)	37%	7%	4%	15%	23%	13%	*1%*	5,620,975
Mod-Tall	Total Mod-Tall (n=66)	36%	8%	2%	16%	29%	7%	*1%*	3,205,525
Medium	Total Medium (n=52)	51%	5%	2%	17%	18%	6%	*1%*	859,400
Med-Low	Total Med-Low (n=23)	56%	4%	<1%	11%	24%	3%	*2%*	131,650
Low	Total Low (n=14)	61%	8%	<1%	8%	21%	1%	*<1%*	106,950
Ground	Total Ground (n=21)	57%	4%	<1%	14%	25%	<1%	*<1%*	133,350
Undefined	Total Undefined native species	46%	5%	4%	10%	25%	8%	*1%*	920,850
All	**Grand Total (n=229)**	**39%**	**7%**	**3%**	**15%**	**25%**	**10%**	***1%***	**10,978,70**

Source: Trees For Life (2009). * NRM Regions: Adelaide & Mt Lofty Ranges (AMLR); Eyre Peninsula (EP); Kangaroo Island (KI); Northern & Yorke (NY); SA Murray-Darling Basin (SAMDB); South East (SE). [#]includes SA Arid Lands & Alinytjara Wilurara NRM Regions, and arid parts of other NRM Regions.

Table 2. Estimated area of revegetation and commercial forestry types established in South Australia (1999-2006).

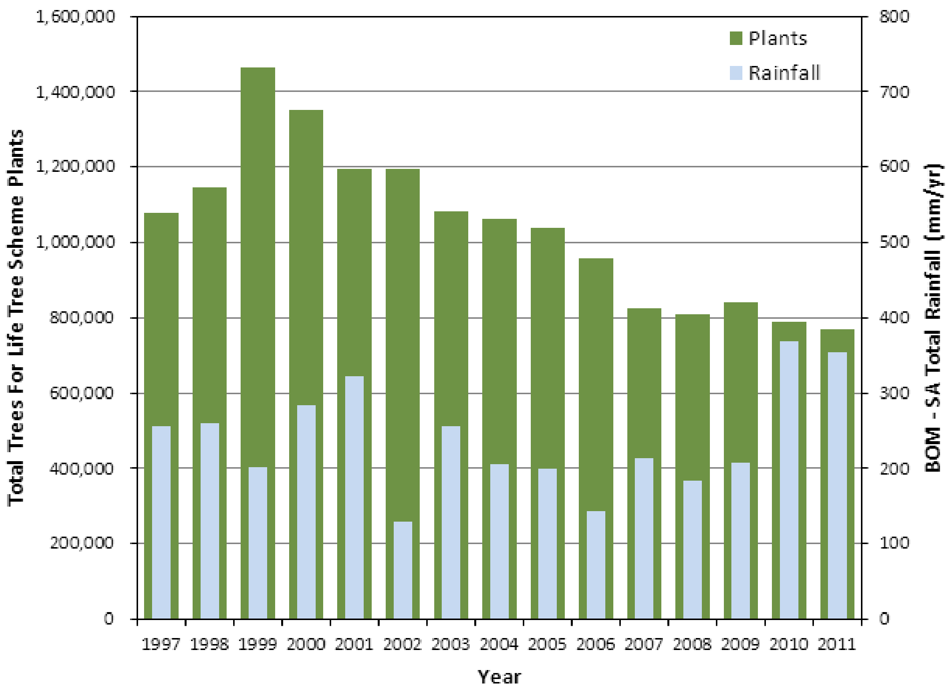
Type of revegetation	Revegetation and Commercial Forestry (ha/year)							
	1999	2000	2001	2002	2003	2004	2005	2006
Indigenous	3,770	4,050	3,910	4,060	4,540	5,130	4,630	3,390
Native (non indigenous)	1,050	380	790	330	100	190	920	230
Native Grasses	10	20	40	60	20	30	30	50
Farm Forestry	0	630	250	450	440	510	60	170
Saltbush	1,490	1,210	1,300	320	1,090	580	640	180
Tagasaste	570	210	70	10	50	10	10	0
Product Species (e.g. broombush)	20	50	10	100	30	70	30	10
Industrial Forestry – Hardwood	2,940	21,130	6,730	6,010	590	6,640	1,120	1,300
Industrial Forestry – Softwood	3,050	2,940	90	890	560	590	4,430	3,800
Total	12,900	30,620	13,190	12,230	7,420	13,750	11,870	9,130

Source: Sheppard and Wilson (2007).

Table 3. Estimated area of revegetation and commercial forestry by agricultural region established in South Australia (1999-2006).

Region	Revegetation and Commercial Forestry (ha/year)							
	1999	2000	2001	2002	2003	2004	2005	2006
Eyre Peninsula	1,240	1,010	530	460	1,170	660	1,020	430
Northern Agricultural Districts	460	650	490	490	510	350	640	320
Adelaide Plains	100	270	230	70	110	90	730	50
Metropolitan Area	510	70	220	300	70	420	410	460
Murray Mallee	400	960	840	630	800	1,260	770	420
Mount Lofty Ranges/Kangaroo Is.	2,340	6,500	2,290	3,180	2,010	8,740	4,080	2,420
South East	6,660	20,930	7,330	6,640	1,740	1,370	2,950	3,890
Unspecified region	1,190	230	1,260	460	1,010	860	1,270	1,140
Total	12,900	30,620	13,190	12,230	7,420	13,750	11,870	9,130

Source: Sheppard and Wilson (2007).



Source: TFL Tree Scheme Data 1997-2008, TFL (2012), BOM (2012).

Figure 4. Trees For Life Tree Scheme Plant distributions and average rainfall for South Australia (1997-2011).

3. CARBON ASSESSMENT METHODS

ASSESSING PLANT BIOMASS

The potential of revegetation to sequester carbon in medium to lower rainfall regions (i.e. < 650mm/year) has been difficult to evaluate due to a lack of productivity data for many native species and mixed environmental plantings. To significantly bolster the currently limited datasets this study has undertaken productivity surveys and destructive sampling from a range of revegetation sites and species within South Australia. Additionally, in recent years DEWNR have also undertaken limited surveys of the carbon sequestered in remnant vegetation for comparison with results attained from revegetation sites.

This study also focussed on delivering more reliable allometric models used to convert non-destructive measurements of plantation growth to more accurate estimates of carbon sequestration. Allometric studies have included measuring and destructive sampling many plants so that relationships (allometric models) between simple plant measurements (e.g. height, crown area, stem basal area, stemwood volume, plant volume, foliage density) and above-ground plant biomass (and carbon content) could be determined. Additional information was collected from these 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 requirements of several carbon accounting models.

At present the dominant Carbon Farming Initiative (CFI) Domestic Offset Integrity Committee (DOIC) approved methodology for carbon accounting in "Environmental Plantings" is the CFI Reforestation Modelling Tool (RMT) (DOTE 2013). This tool is based on models developed within the National Carbon Accounting Toolbox (NCAT) and FullCAM. The accuracy of the carbon accounting models within NCAT FullCAM rely heavily on the quality of species/site parameters that drive model calculations. In the current version of 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 medium to lower rainfall regions of SA (Hobbs *et al.* 2010). For most medium to 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 a greater degree of accuracy than that obtained from the default settings.

To improve the predictions of the NCAT FullCAM model in South Australia DEWNR collaborated with CSIRO under a project funded by the Australian Government Department of the Environment (DOTE) to calibrate NCAT models for Environmental Planting and Mallee systems. Soon to be released updates to NCAT and RMT now include data from South Australian surveys of carbon sequestration in revegetation (Paul *et al.* 2012). The Moorlands Case Study (located near Tailem Bend and detailed in Appendix F) was a key part of this collaboration and provided an opportunity to attain more detailed survey data (including root biomass data) to test methodologies currently used in South Australia.

Current DOIC approved or submitted CFI methods to assess carbon sequestration from revegetation (DOTE 2013) that are based on ground survey and sampling include: 1) extensive and costly surveys with detailed sampling surveys, permanent plots and localised destructive sampling for large scale revegetation projects (e.g. CO_2 Australia); 2) a more cost effective reduced sampling approach and reliance on robust allometric models to assess carbon sequestration in environmental plantings (e.g. Carbon Conscious Limited).

Many of the revegetation efforts by landholders fall into the small to medium scale. Revegetation efforts of this size are largely financially unviable if burdened by an extensive on-ground monitoring program that would most likely to cost more to assess than the economic value of the carbon crop growing at a site.

Given these facts the intent of the cost effective approach (i.e. rapid sampling and robust allometrics) is currently viewed as the most applicable.

Most existing assessments of revegetation (plantation forestry or environmental plantings) productivity are focussed on assessing stem basal area and often height. These measures are suitable for estimating stemwood volumes for classical forestry where the focus is on recoverable solid timber. For carbon sequestration assessments and many other biomass industries the focus is on the whole plant biomass including stem, branches, bark, twigs, leaves and sometimes roots. New or revised methods to rapidly and reliably assess both total dry biomass and carbon content of whole plants are now required.

ABOVE-GROUND BIOMASS

Allometrics is a commonly used technique to non-destructively assess plantation biomass 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 (1.3m) or basal area calculations (and sometimes including tree height) to estimate stemwood volumes or biomass, with models often being species specific (Snowdon *et al.* 2000, 2002, Grierson 2000, Kiddle *et al.* 1987, Paul *et al.* 2013b). 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. To maintain consistency with NCAT FullCAM modelling parameters and RMT the current analyses have mainly focussed on relationships between stemwood volume (or stem mass) and above-ground plant dry biomass.

Biometrics and Sampling

In recent years DEWNR staff have destructively sampled a wide range of known age agroforestry and local native species in dryland agricultural regions of South Australia to evaluate relationships between simple plant measurements and above-ground biomass in plants (Neumann *et al.* 2010, Hobbs *et al.* 2010, Hobbs *et al.* 2006, Hobbs & Bennell 2005). Plant species were chosen to represent those species most highly ranked for agroforestry development (Hobbs *et al.* 2009a) and environmental plantings for the region (Hobbs *et al.* 2010). The species selected included forestry tree species, small trees, 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 (total 407 individuals). In a collaborative project for DOTE, DEWNR and CSIRO staff have also gathered destructive data on a further 128 individual plants as part of the Moorlands case study (see later sections of this report), including below-ground biomass for 41 individual plants. A total of 535 individual plants have been measured, sampled and weighed from these studies.

Individual plant measurements included maximum height, crown width (typically across & along row), distance to neighbouring plants (typically ≥2m high, 4 directions), 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). Foliage density classes were expressed as a percentage 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 (i.e. stem area) 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 - conical 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 at 70°C 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 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 elemental carbon content was calculated from the sum of dry biomass fractions and a generic conversion factor of 0.496 (Stein & Tobiasen 2007). Carbon dioxide equivalent was calculated from the elemental carbon and conversion factor of 3.67 (based on the atomic weights of C and O).

A total of 535 individual plants (190 trees, 267 mallees, 78 shrubs) from 68 sites were measured and destructively sampled for the combined biometric studies (Table 46). These represent 44 species and include 2 generic species groupings (24 Eucalypts, 20 non-Eucalypts) and 3 lifeform types (16 tree, 14 mallee, 14 shrub forms). Commonly used revegetation and agroforestry species were sampled more than once (e.g. SA mallees - *Eucalyptus incrassata*, *E. leptophylla*, *E. porosa*, *E. socialis*; Sugar Gum - *E. cladocalyx*; Swamp Yate - *E. occidentalis*; 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 4.8 years on an agroforestry trial at Murray Bridge to a maximum of 42 years for some trees and mallees at Monarto (average site age 16.2 years).

Table 46 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 stemwood area observations), wood density and foliage density.

Allometric Models of Above-ground Biomass

Allometric relationships between simple measurements of height, crown area, stem basal area, leaf density, stemwood volume, plant volume and observations of total dry biomass were plotted, explored visually and tested using linear and non-linear regressions (see Figure 5 for some examples of this analysis). Interactions between these simple measurements and lifeform or plant genera groupings were also evaluated. Stepwise multivariate regression modelling methods were used to identify clusters of biometric parameters that significantly improved the fit of models over any single variable model.

Simple regression analysis identifies Stemwood Volume (r^2=0.92) and Basal Area (r^2=0.91) are the most significantly correlated single variables to above-ground plant biomass (Figure 5). As single variable predictors they fit the dry biomass data equally well. A review of regression residuals shows that Stemwood Volume is a more reliable predictor of plant biomass for medium to larger plants and Basal Area appears more reliable for smaller plants. Height (r^2=0.59), Crown Area (r^2=0.83), Plant Volume (r^2=0.85) and Plant Volume x Foliage Density (r^2=0.89) are all significantly related to plant biomass but are less robust than Stemwood Volume or Basal Area as predictors.

For more detailed linear regression and multivariate stepwise modelling analyses any variables that were not normally distributed were transformed using natural logarithms prior to analysis. Care was also taken to minimise the inclusion of variables that are auto-correlated. Two distinct pathways emerged: 1) using Stemwood Volume as the leading variable; and 2) using Basal Area as the leading variable. Table 4 shows improvement in Stemwood Volume and Basal Area models from the addition of significant explanatory variable. Note that additions of statistically significant third and fourth variables in these models do improve model fit, but principles of parsimony recommend that only the first two variables be used in each model. The interaction of height and crown area in the Basal Area model provides a more significant predictor than crown area alone. The best single variable and recommended multivariate allometric models of above-ground plant biomass are presented in Table 5.

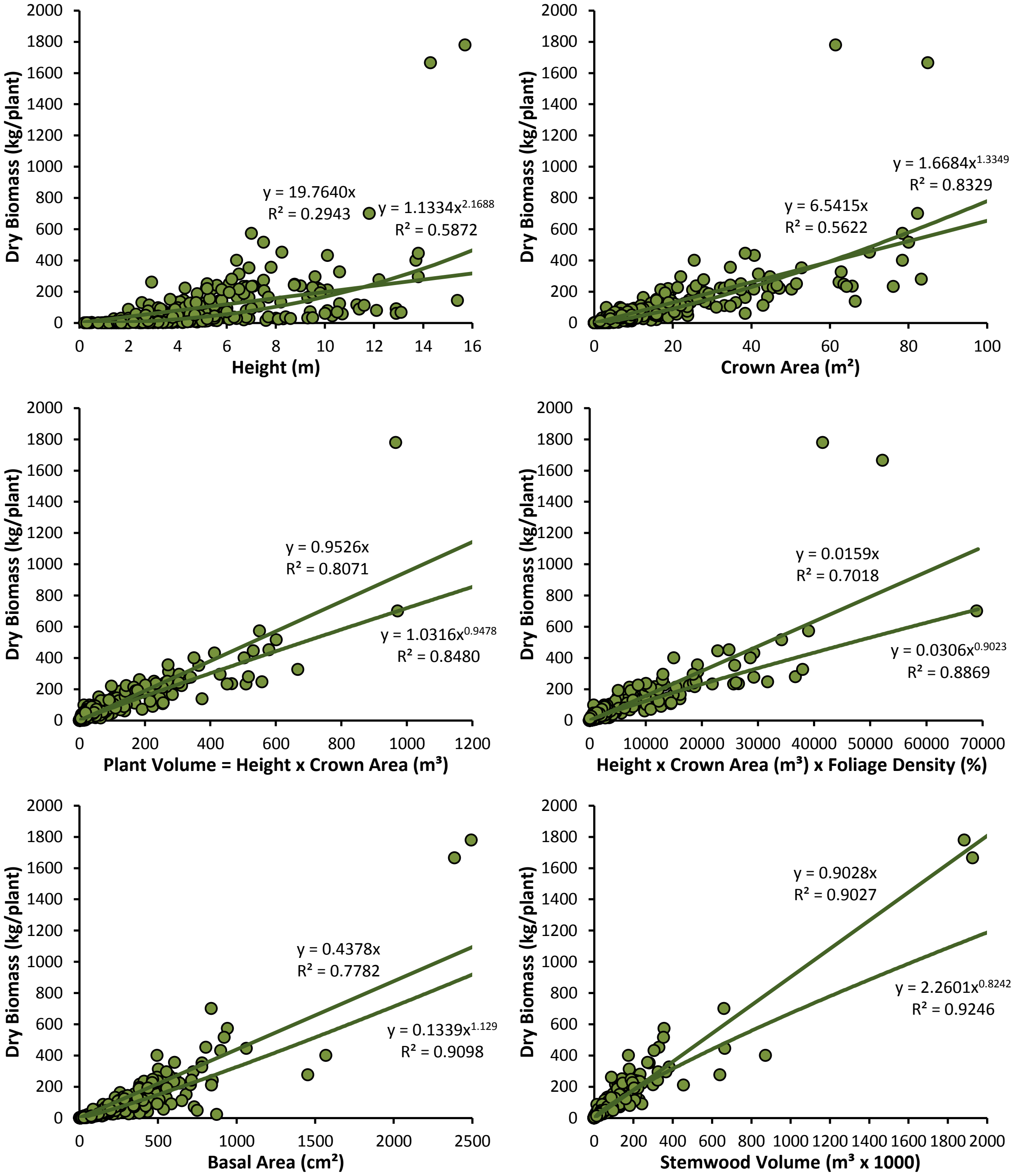


Figure 5. Basic allometric relationships between some simple plant measurements and individual plant dry biomass.

Table 4. Improvements in allometric model fit from baseline Stemwood Volume and Basal Area models by the stepwise addition of significant variables.

Predictors of Ln(Plant Biomass) Stepwise Models (n=508)	Model Fit (r^2)	Improvement	AICc
Stemwood Volume			
Ln(Stemwood Volume)	0.9460	+94.6%	419.2
+Ln(Crown Area)	0.9650	+1.9%	189.0
+Ln(Height)	0.9682	+0.3%	140.6
Basal Area			
Ln(Basal Area)	0.9136	+91.4%	668.6
+Ln(Crown Area x Height)	0.9580	+4.4%	286.1
+Ln(Height)	0.9593	+0.1%	270.6
+Ln(Crown Area)	0.9596	+0.03%	268.7

Table 5. The best single variable and multivariate allometric models for predicting above-ground plant biomass from simple plant measurements.

Single and Multivariate Models of Above-ground Plant Biomass	Model Fit	
Plant Dry Biomass, B_{ag} (kg/plant)	r^2	**AICc**
Single Parameter Models (n=535)		
Stemwood Volume, SV (m^3 x1000)	0.9460	419.2
$Ln(B_{ag}+1) = 0.9161xLn(SV+1) + 0.5444$		
Basal Area, BA (cm^2)	0.9136	668.6
$Ln(B_{ag}+1) = 1.0259xLn(BA+1) - 1.4418$		
Plant Volume, PV (m^3) = Height (m) x Crown Area (m^2)	0.8814	840.1
$Ln(B_{ag}+1) = 0.9714xLn(PV+1)$		
Crown Area, CA (m^2)	0.8513	959.2
$Ln(B_{ag}+1) = 1.5050xLn(CA+1)$		
Foliage Volume, FV (m^3) = Plant Volume (m^3) x Foliage Density (%)	0.8749	838.0
$Ln(B_{ag}+1) = 0.8068xLn(FV+1) - 2.6622$		
Height, H (m)	0.5829	1512.9
$Ln(B_{ag}+1) = 2.5543xLn(H+1) - 0.9193$		
Recommended Multivariate Models (n=535)		
Stemwood Volume, SV + Crown Area, CA	0.9650	189.0
$Ln(B_{ag}+1) = 0.6626xLn(SV+1) + 0.4757xLn(CA+1) + 0.2566$		
Where, SV = Stemwood Volume (m^3 x1000), CA = Crown Area (m^2).		
Basal Area, BA + Plant Volume, PV	0.9580	286.1
$Ln(B_{ag}+1) = 0.6151xLn(BA+1) + 0.4605xLn(PV+1) - 1.0790$		
Where, BA = Basal Area (cm^2), PV = Plant Volume (m^3) = Height (m) x Crown Area		
Old Man Saltbush Model (Hobbs *et al.* 2010, n=125)		
Plant Volume, PV = Height (m) x Elliptical Crown Area (m^2)	0.8203	643.3
$B_{ag} = 2.6531xPV$		

Model Robustness

Many allometric models are developed for species or site specific use and have limited value at new locations or species. This project's intent was always to develop a generic model with wide applicability to new sites and species in the agricultural regions of southern Australia. The only way to ensure that any model developed can be used in other situations is to validate the model using independently collected data.

The Stemwood Volume model is the leading single variable model approach and independent data was sought to evaluate the robustness of this approach. Access was provided to a destructive sampling database compiled for DOTE by CSIRO and partners (Paul *et al.* 2012, 2013b) for a wide range plant species across Australia. The dataset contains measurements of key physical plant attributes and destructive sampling (e.g. plant height, stem diameters, dry biomass) for 121 tree and shrub species. The database also includes a nominal lifeform by species group classification (by CSIRO) for clusters of allied data (e.g. Tree or Shrub by Eucalypts, Acacias, Melaleucas, Casuarinas, Other Species). Plant records were divided into Tropical and Temperate Species groups, and eucalypt species classified into Tree, Mallee and Mallet lifeform types (DEWNR). The Tropical Species group has been omitted from this comparison as they are unrepresentative species for southern Australia.

For 2,382 trees and shrubs (≥1m tall; 99 species) with both height and stem diameter measurements stemwood volume of each plant was calculated using the same methodology described earlier in this report. The single parameter "Stemwood Volume" model was then used to predict the dry biomass of each plant. Due to non-normal distributions of data it was transformed using natural logarithms for this analysis.

The modelled versus observed data has been plotted for each lifeform by species groups and linear regression analysis used to evaluate the reliability (variance explained, goodness of fit) of the Stemwood Volume model and to identify any plant group differences (regression slope) from the generic DEWNR model (Figure 6). Results of this analysis shows that Stemwood Volume approach provides a reliable predictor (i.e. model fit) of plant dry biomass but it also identifies that that's some lifeform by species groups diverge (i.e. linear adjustment factor) from the generic approach (see Table 6). This table also includes a summary of differences observed for each Lifeform groupings within the DEWNR destructive dataset.

Generally, the DEWNR stemwood volume model:

- over-predicts for faster growing tree species with lower wood density values and few side branches
- under-predicts for some smaller shrubby species and mallees and with many side branches that adds to the plants weight beyond its central stem
- matches strongly for mallee and tree species commonly used in medium to lower rain regions of southern Australia.

Note that DEWNR data has a large proportion of eucalypt mallee-form records and the DOTE/CSIRO data is dominated by eucalypt tree-form records. The combined dataset is also dominated by tree records (81%) and, notably, eucalypt tree-form records (42%) are the largest component of this dataset. Differences between some lifeform and species groups are apparent from this analysis and the indicative adjustment factors from linear regressions listed in Table 6 may allow users to improve the accuracy of prediction from the DEWNR Stemwood Volume model for some groups of plants.

In practical situations (and even among professional scientists and technicians) observers can be very inconsistent in their classification of lifeforms and these subjective evaluations can sometimes lead to significant differences in predicted values. Confusion can result from interpretations of current form versus mature form, fuzzy boundaries along a physical continuum or often from taxonomic generalisations used for classification. To avoid subjective classifications the DEWNR modelling approach focuses on physical measurements to distinguish between architectural differences that influence plant biomass. Therefore it is recommend the use of the Stemwood Volume + Crown Area model (Table 5) for the most reliable results across different observers.

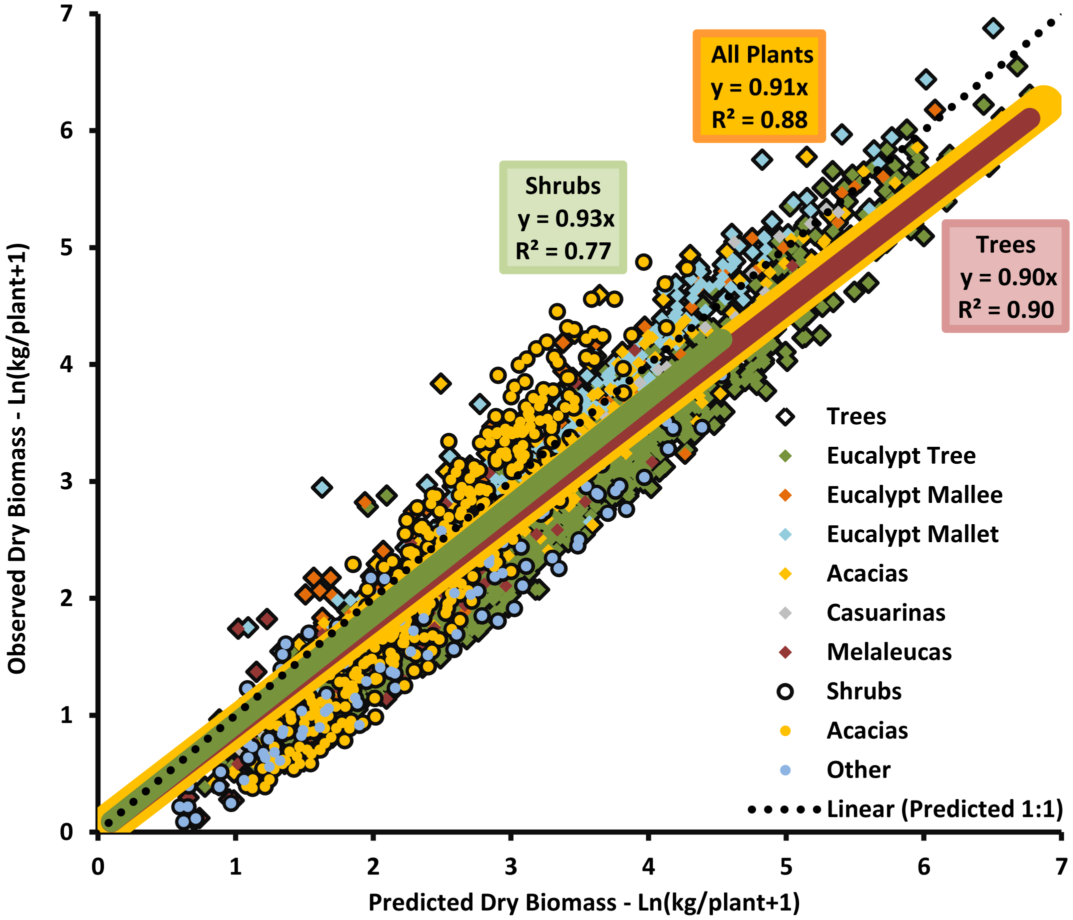


Figure 6. **Independently observed (DOTE/CSIRO data) versus predicted (DEWNR Stemwood Volume model) of above-ground dry plant biomass for southern Australian plant species.**

Table 6. **An evaluation of the robustness of DEWNR Stemwood Volume model by lifeform and species groupings using DEWNR and independently collected DOTE/CSIRO destructive data.**

Lifeform /Species Group	DEWNR			DOTE/CSIRO			Combined		
	Obs. (n)	Model Fit	Adj.* Factor	Obs. (n)	Model Fit	Adj.* Factor	Obs. (n)	Model Fit	Adj.* Factor
All plants	535	95%	1.00	2382	88%	0.91	2917	89%	0.92
Tree Form	478	95%	0.98	1882	90%	0.90	2360	91%	0.92
Eucalypt Tree	116	96%	0.91	1108	92%	0.86	1224	93%	0.86
Eucalypt Mallee	270	97%	1.03	130	88%	0.98	400	95%	1.01
Eucalypt Mallet	0	-	-	251	95%	1.02	251	95%	1.02
Acacia	54	91%	0.87	284	93%	0.94	338	94%	0.94
Casuarina	13	93%	0.96	38	97%	0.96	51	97%	0.96
Melaleuca	22	79%	0.96	71	83%	0.91	93	88%	0.90
Shrub Form	57	89%	1.06	499	77%	0.93	556	78%	0.95
Acacia	26	83%	1.12	387	77%	0.97	413	78%	0.98
Other	31	93%	0.99	112	90%	0.78	143	87%	0.83

* Adjustment factor is the multiplier (regression slope) to be applied to the generic Stemwood Volume model for each lifeform or species group.

BELOW-GROUND (ROOT) BIOMASS

The Moorlands Case Study, in partnership with CSIRO researchers, provided a rare opportunity to investigate relationships between above-ground biometrics/biomass and below-ground (root) biomass. The methodology and design of destructive sampling and resulting data is outlined in Appendix F - Improving National Carbon Accounting Models: Moorlands Case Study and in more detail by Paul *et al.* (2012).

Allometric relationships between simple measurements of height, crown area, stem basal area, stemwood volumes, plant volume, above-ground biomass and observations of root dry biomass were plotted, explored visually and tested using linear and non-linear regressions (see Figure 7). Stepwise multivariate regression modelling methods were used to identify clusters of biometric parameters that significantly improved the fit of models over any single variable model.

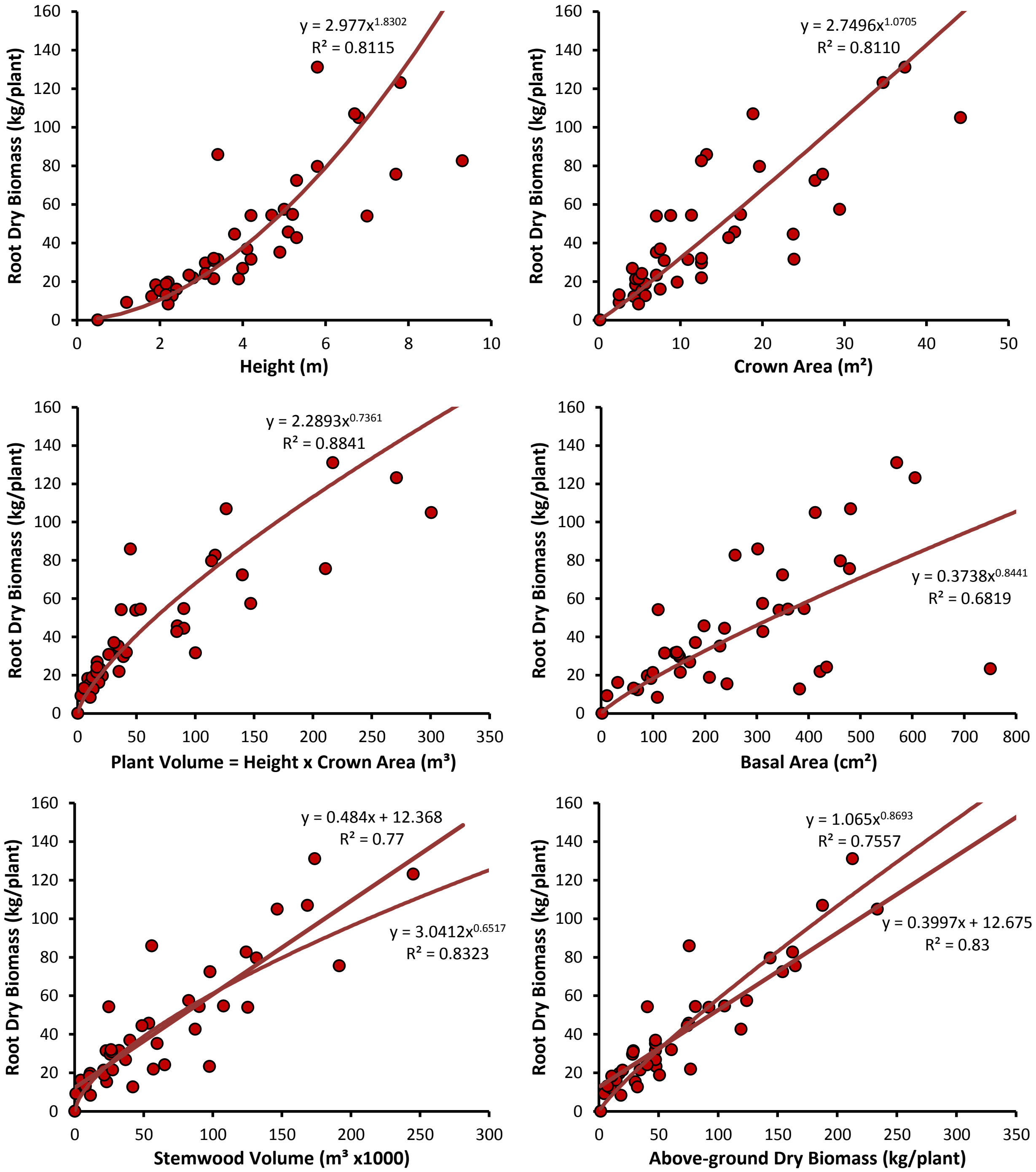


Figure 7. Simple allometric relationships between individual plant measurements, above-ground plant dry biomass and root dry biomass.

For linear regressions and multivariate stepwise modelling approach, any variables that were not normally distributed were transformed using natural logarithms prior to analysis. From simple regression analysis Plant Volume (i.e. Height x Crown Area) was the strongest single predictor of root biomass (see Figure 7 & Table 7, r^2=0.86). Height, Basal Area, Crown Area and Stemwood Volume are also strong predictors of root biomass (r^2=0.57 - 0.77). Results show that root biomass is also strongly correlated to above-ground biomass (r^2=0.82).

Constant Root to Shoot Ratios of biomass is often used to estimate below-ground biomass from above-ground surveys (Paul *et al.* 2012), however, DEWNR data indicates that Root to Shoot Ratios typically decrease with increasing plant size (i.e. non-linear response curve, Figure 7). These ratios can change across species and plants as they mature. Multivariate stepwise models were also explored and best model (i.e. Plant Volume + Basal Area, Table 7) provides around +2% improvement in predictions above any single variable model (e.g. Plant Volume).

Table 7. The best single variable and recommended multivariate allometric models for predicting below-ground (root) biomass from simple plant measurements and above-ground biomass.

Single and Multivariate Models of Below-ground (Root) Biomass	Model Fit	
Root Dry Biomass, B_{root} (kg/plant)	**r^2**	**AICc**
Single Parameter Models (n=41)		
Plant Volume, PV (m^3) = Height (m) x Crown Area (m^2)	0.8555	32.41
$Ln(B_{root}+1) = 0.6724xLn(PV+1) + 1.0722$		
Above-ground Dry Biomass, B_{ag} (kg/plant)	0.8194	41.57
$Ln(B_{root}+1) = 0.7426xLn(B+1) + 0.6073$		
Height, H (m)	0.8191	41.64
$Ln(B_{root}+1) = 2.2488xLn(H+1)$		
Stemwood Volume, SV (m^3 x1000)	0.7583	53.51
$Ln(B_{root}+1) = 0.6272xLn(SV+1) + 1.2177$		
Crown Area, CA (m^2)	0.7510	54.73
$Ln(B_{root}+1) = 1.0177xLn(CA+1) + 1.0605$		
Basal Area, BA (cm^2)	0.4321	68.64
$Ln(B_{root}+1) = 0.6697xLn(BA+1)$		
Recommended Multivariate Model (n=41)		
Height, H (m) + Crown Area, CA (m^2)	0.8847	25.62
$Ln(B_{root}+1) = 1.4783xLn(H+1) + 0.4985xLn(CA+1)$		

4. CARBON SEQUESTRATION IN REVEGETATION AND REMNANTS

SURVEYS OF ABOVE-GROUND BIOMASS

Over the last 10 years DEWNR SMK staff have been involved in several projects to evaluate the productivity of plantations of agroforestry and revegetation (e.g. Hobbs & Bennell 2005; Hobbs *et al.* 2006, 2009a, 2010; Neumann *et al.* 2011). These projects had previously focussed on the Upper South East and Murray-Darling Basin regions due to their greatest potential for woody crop development (Hobbs *et al.* 2009a). In the past 4 years this work has expanded to include a greater representation of mixed species environmental plantings and other agricultural NRM Regions of the state, as interest in carbon sequestration from agroforestry and reforestation has increased. New surveys have been strategically conducted in the Northern & Yorke, Eyre Peninsula, Mount Lofty Ranges and Kangaroo Island NRM Regions, and additional "gap-filling" surveys conducted in the SA Murray-Darling Basin and South East NRM Regions (supported by the State NRM Program and Future Farm Industries CRC activities). Additionally, limited surveys of carbon sequestration in remnant vegetation have also been conducted to allow some comparisons of sequestration between native species revegetation and extant native vegetation.

Revegetation sites of known age were chosen to represent 2 main planting designs: 1) Woodlots (mainly monocultures); or 2) Environmental Plantings (mainly mixed species) to match with classifications used in DOTE's NCAT/RMT models. A few sites surveyed overlap in this classification system. For example, some sites may have been intended by the landholder as woodlot of local native species for firewood harvest but effectively represent and an environmental planting, or when monocultures of species that are not classically used agroforestry were planted to provide an environmental benefit. Each site was nominated to these 2 classes but where sites met the criteria of both systems they were noted and their dominant purpose used in the classification. Surveys focussed on block planting designs (i.e. >4 row plantations) with only a few windbreak sites included in DEWNR datasets.

Two hundred and sixty-four revegetation sites of known age were surveyed to assess plant growth and carbon sequestration of Kyoto-complaint species (i.e. >2m height at maturity) over a wide range of environmental conditions in the agricultural zone of South Australia (Table 8, Figure 8). A further 37 remnant sites were also surveyed, predominantly from the Adelaide & Mt Lofty Ranges (18) and Northern & Yorke (14) NRM Regions, with some additional surveys in the SA Murray-Darling Basin (4) and South East (1) NRM Regions. The approximate age of dominant plants (time since catastrophic disturbance, e.g. fire) of remnant vegetation sites was estimated using average age of largest cohort (largest 17% of individuals) at each site, and a relationship between basal area/rain and age determined from known age plants (e.g. Age[yrs]=11.776xBasalArea[cm^2]/Rainfall[mm/yr] + 12.254; r^2=0.24).

The average age of all revegetation sites was 22 years (n=264; range 3 to 131 years) with average of woodlots being 26 years (n=132; range 5 to 131 years) and environmental plantings averaging 17 years (n=132, range 3 to 36 years). Estimated average age of remnant sites was 82 years (n=37; range 13 to 225 years). Monoculture plantations represent 58% of surveyed revegetation sites.

SURVEY METHODS

Productivity assessment protocols for the DEWNR Rapid Survey method varied according to species mixes (see Table 9). These were based on 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 percentage 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%).

Exceptions to this protocol applied to DEWNR field trials (8 species blocks; average 249 individuals per block) and detailed surveys located at Moorlands (e.g. Block 1991, Block 1996, Windbreak 1996) where all individual at each site were measured (see Appendix F - Improving National Carbon Accounting Models: Moorlands Case Study). At 18 of the mixed species remnant sites, on some Northern Mount Lofty to Yorke Peninsula sites, only 36 individuals were measured. On remnant sites (i.e. without rows) 6 transects replaced row segments and 6 or 10 individuals were measured along 5m wide swath following a compass bearing at each transect.

A total of 15,045 individual plants have been measured from revegetation sites representing 143 species with 1,633 individual remnant plants measured representing 49 species. Distance to neighbouring plants (>2m high) for each individual permitted calculation of the area occupied for each plant. Where individuals were located on the edge of stand of vegetation the effective buffer edge of the stand was consistently nominated as 5 metres. The plant density (plants/ha) was determined from the number of individuals divided by sum of areas occupied by individual plants. The average observed plant density of revegetation sites in this study was 894 plants/ha of Kyoto-compliant species (i.e. >2m tall at maturity). Woodlots had an average 714 plants/ha (range 95 to 2205), Environmental Plantings averaged 1074 plants/ha (range 159 to 8575) and Remnants averaged of 669 plants/ha (range 35 to 1991). The proportion of trees versus shrubs (i.e. "Proportion Trees", Paul *et al.* 2012) was also calculated for each survey site based on counts of individuals in each lifeform class. The observed average proportion of trees was 89% for all revegetation, 83% in mixed species environmental plantings and 89% for remnant vegetation.

Table 8. Total number of revegetation and remnant vegetation sites surveyed for this study, stratified by NRM Region and rainfall zone.

	Surveys of Revegetation Sites					
	Rainfall Zone (mm/yr)					
NRM Region	**250-350**	**351-450**	**451-550**	**551-650**	**>650**	**Total**
Adelaide & Mt Lofty Ranges (AMLR)	-	1	6	5	3	15
Eyre Peninsula (EP)	6	5	1	-	-	12
Kangaroo Island (KI)	-	-	3	2	2	7
Northern & Yorke (NY)	6	33	15	3	-	57
SA Murray Darling Basin (SAMDB)	36	65	17	9	-	127
South East (SE)	-	4	37	5	-	46
Total	**48**	**108**	**79**	**24**	**5**	**264**
	Surveys of Remnant Vegetation Sites					
	Rainfall Zone (mm/yr)					
NRM Region	**250-350**	**351-450**	**451-550**	**551-650**	**>650**	**Total**
Adelaide & Mt Lofty Ranges (AMLR)	-	2	4	8	4	18
Northern & Yorke (NY)	4	4	5	1	-	14
SA Murray Darling Basin (SAMDB)	1	1	2	-	-	4
South East (SE)	-	-	-	1	-	1
Total	**5**	**7**	**11**	**10**	**4**	**37**

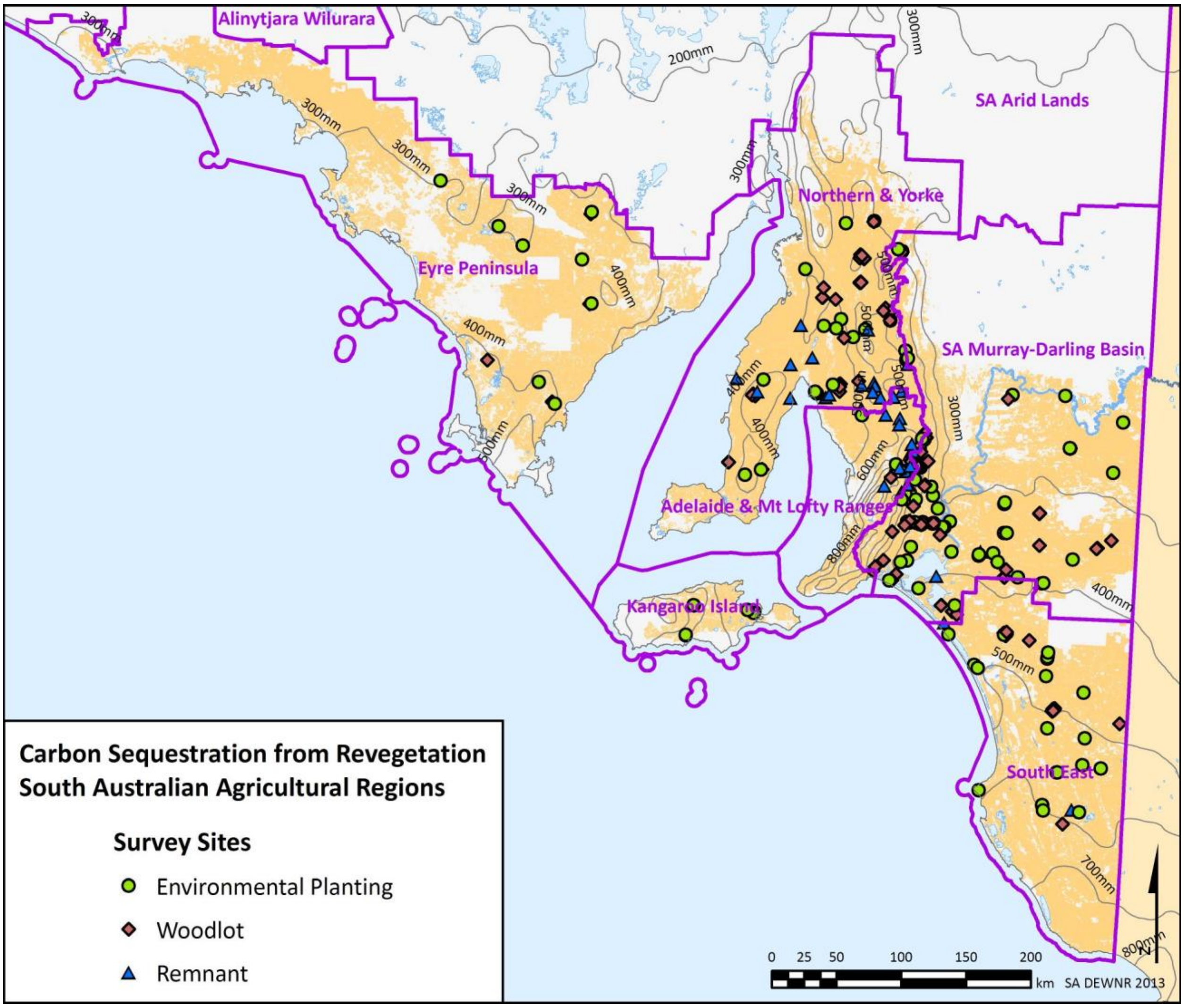


Figure 8. Carbon Sequestration from Revegetation: SA Agricultural Regions project survey sites.

Table 9. Generalised summary of measurement protocols used in 301 surveys of carbon sequestration in the agricultural regions of South Australia.

Site Type	Block Size	Total Observations	Design
Single species block	>4 rows; >110m long	36 (6x6 plant segments)	6 segments randomly located within inside rows
Mixed species block	>4 rows; >110m long	60 (6x10 plant segments)	6 segments randomly located within inside rows

Individual plant measurements were converted to a consistent set of biometrics to allow prediction of biomass and carbon content of individual plants (see section 3. Carbon Assessment Methods). Basal and intermediate stem area (outer bark) at each measurement height was calculated using circumference measurements of each stem, and the sum of individual stem areas calculated for multi-stemmed species (i.e. identical results to quadratic mean of diameter method). 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 - cylindrical volume; 2. mid-section - Smalian's frustrum of a paraboloid volume, and 3. upper section - paraboloid volume).

The above-ground dry biomass of each measured individual was then estimated using the generic DEWNR Stemwood Volume model (see Table 5) and the standing above-ground biomass per hectare determined from sum of estimated dry biomass of all individuals trees and tall shrubs divided by the sum of physical space occupied by all individuals. The estimated total standing biomass (dry matter t/ha) at each site was then converted to an average annual accumulation rate (dry matter t/ha/year) using the known age of the each revegetation site (or estimated age of dominant plants in remnant vegetation). To convert dry biomass to tonnes of elemental carbon (C t/ha) a generic conversion factor of 0.496 was applied (Stein & Tobiasen 2007). Elemental carbon was converted to carbon dioxide equivalents (CO_2-e t/ha) using a conversion factor of 3.67 (based on the atomic weights of C and O). Table 10 provides summary data for DEWNR sequestration surveys in woodlots, environmental plantings and remnant vegetation in South Australia. More detailed site survey data (e.g. species information, sequestration rates and environmental data) can be found in Appendix D - Productivity and Carbon Sequestration Studies.

SPATIAL INFORMATION

Each survey site was accurately located using a Global Positioning System (GPS) to allow spatial data from other sources to be combined with survey data to evaluate the influence of environmental conditions on planting designs and sequestration rates. Core drivers to revegetation design and productivity (water availability, climate and soil properties) underpin the choice of spatial data used in this study. Expert soil scientist opinion and recommendations (James Hall, pers. comm.) were used to identify a subset of soil factors most likely to influence plant growth for this study (see below).

The DOTE's National Carbon Accounting Toolbox (NCAT) and Reforestation Modelling Tool (RMT) is underpinned by a spatial climate and soil model (Forest Productivity Index, DCCEE 2009) to predict carbon sequestration rates and Maximum Above-ground Biomass across Australia. Previous research in South Australia (Hobbs *et al.* 2006, Hobbs *et al.* 2010) has identified that the BiosEquil model (Raupach *et al.* 2001) can also provide a useful indicator of revegetation growth in South Australian landscapes. Spatial data from these externally-sourced climate and soil models (FPI, BiosEquil) has been included in this study.

Spatial environmental data used in this study included:

- DEWNR surveys of above-ground plant dry biomass (GPS located)
- Average annual rainfall (CSIRO Land & Water 2001)
- Average annual potential evaporation (CSIRO Land & Water 2001)
- Soil data (Hall *et al.* 2009) including:
  - Soil classification groups and sub-groups
  - Surface soil texture (surface clay content)
  - Subsurface soil texture (subsurface clay content)
  - Inherent fertility (clay index of soil profile)
  - Water-holding capacity
  - Depth to rock
  - Depth to hardpan
  - Dryland agriculture potential (root zone depth, Class C - hardy perennials crops, e.g. vines, olives)
- NCAT Maximum Above-ground Biomass (DCCEE 2009)
- Forest Productivity Index (FPI, DCCEE 2009)
- BiosEquil (BE) model values (Raupach *et al.* 2001, Hobbs *et al.* 2006)

Soil mapping in South Australia is currently represented by polygons of soil-landscape map units. Each polygon can contain multiple landscape elements and soil types when the size of each component is lower than the spatial scale of original mapping. The estimated areal proportion of each component within the polygon is also documented. Soil attributes (e.g. depth, clay content) within components are described using semi-quantitative classes (Hall *et al.* 2009).

To increase analytical power the class data for each attribute has been converted into a continuous variable using the nominal mid-point values of each attribute within a class or an assigned nominal peak value (James Hall, pers. comm.). A summary of these soil classes and nominal values can be found in Appendix E (Table 49).

For each polygon the area-weighted average attribute value was calculated from the proportion of each component and its nominal attribute value within each polygon. Soil-landscape polygons were then converted to 1 hectare resolution raster coverages for each soil attribute for spatial data consistency with raster coverages representing climate and growth models. The resulting soil spatial data contains some local inaccuracies in attributes due to rescaling, but is on average, consistent with the original mapping.

For each DEWNR survey location the corresponding climate, soil attribute and externally-sourced productivity model data were extracted and assimilated with productivity survey data.

SURVEY ESTIMATES OF CARBON SEQUESTRATION RATES

Total above-ground plant biomass and carbon content of 264 revegetation sites (132 woodlots, 132 mixed species) of known age and 37 remnant vegetation sites in the agricultural regions of South Australia were surveyed (Figure 8). Summaries of site data and observed productivity rates for woodlots, environmental plantings and remnants are presented in Table 10. The average carbon sequestration rate of all revegetation sites was 9.5 tonnes of carbon dioxide equivalents per hectare per year (CO_2-e t/ha/yr; mean annual rainfall 429mm/yr), 11.4 CO_2-e t/ha/yr in woodlots (441mm/yr) and 7.6 CO_2-e t/ha/yr in environmental plantings (418mm/yr). However, mean annual rainfall and plant density (plants/ha) have a significant influence on growth rates (Figure 10).

Carbon stock from remnant vegetation survey sites was observed to be around 428 CO_2-e t/ha (515mm/yr). The average plant density within all surveyed revegetation sites was 894 plants/ha (at 22 years), 714 plants/ha for woodlot plantings (at 26 years), 1074 plants/ha for environmental plantings (at 17 years) and 669 plants/ha in remnant vegetation.

The average observed carbon sequestration rates of woodlots measured in this study exceeded both environmental plantings and remnant vegetation (approx. +50 to +100%) despite woodlots having a lower (-34%) plant density than environmental plantings and similar density (+7%) to remnant vegetation (Table 10). The youngest woodlot plantings produced outstanding carbon sequestration rates, around twice as much biomass of environmental plantings of similar age, soil and rainfall conditions. Carbon sequestration rates of environmental plantings are higher than estimates from remnant vegetation. This suggests that water and nutrient stores resulting from prior agricultural land uses has created better growing condition for revegetation at these sites, especially during the early years of growth. The presence of additional nutrients at revegetation sites make it highly likely that revegetation sites will ultimately store greater plant biomass and carbon stock than remnant vegetation under the same climatic conditions.

More detailed data from these survey sites, including key environmental characteristics, species composition, biomass production, carbon stock and sequestration rates can be found in Appendix D - Productivity and Carbon Sequestration Studies (Table 47, Table 48).

Table 10. Summary of average annual rainfall and spatial growth model indices, and observed plant attributes, biomass and carbon sequestration estimates from woodlots, environmental plantings and remnant vegetation in the agricultural regions of SA.

	Rain (mm/yr)	NCAT – Max. Dry Matter (t/ha)	NCAT Forest Productivity Index	Bios Equil (t C/ha/yr)	Age (years)	Plant Density (plants/ha)	Height (m)	Stem Volume MAI (m^3/ha/yr)	Dry Biomass (t/ha/yr)	Carbon (t/ha/yr)	CO_2e (t/ha/yr)	Dry Biomass (t/ha)	Carbon (t/ha)	CO_2e (t/ha)
Revegetation (n=264)	**429**	**74**	**5.2**	**1.9**	**22**	**894**	**7.9**	**4.6**	**5.2**	**2.6**	**9.5**	**89**	**25**	**91**
Env. plantings (n=132)	418	70	5.0	1.9	17	1074	5.6	3.6	4.1	2.1	7.6	65	128	471
Woodlots (n=132)	441	77	5.4	1.9	26	714	10.1	5.6	6.3	3.1	11.4	112	25	91
Remnant veg. (n=37)	**515**	**89**	**5.9**	**2.3**	**82***	**669**	**8.7**	**3.1**	**3.2**	**1.6**	**5.8**	**179**	**117**	**428**

* Age estimated using basal diameters of ten largest trees in sample

5. CARBON SEQUESTRATION MODELS

PREVIOUS STUDIES

Prior research undertaken by DEWNR SMK staff resulted in the construction of preliminary models of carbon sequestration rates from revegetation in the low to medium rainfall regions (250-650mm/yr) of South Australia (Hobbs *et al.* 2006, Hobbs *et al.* 2009b, Hobbs *et al.* 2010). These models have been primarily based on data and analyses from the Upper South East and Murray-Darling Basin regions, and correlations with indices of growth derived from climate and soil factors (i.e. BiosEquil model, Raupach *et al.* 2001). In recent years, new surveys in the Northern & Yorke, Eyre Peninsula, Adelaide & Mount Lofty Ranges and Kangaroo Island NRM Regions, and additional "gap-filling" surveys in the SA Murray-Darling Basin and South East NRM Regions has greatly increased the representativeness of revegetation survey data for the dryland agricultural regions of the state.

The increased quality and spatial extent of revegetation survey data, and greatly expanded range of spatial environmental data (e.g. additional climate and soils), has also permitted more detailed analyses to be undertaken to determine drivers and interactions that influence carbon sequestration rates in revegetation.

REVEGETATION TYPES

In the past, DEWNR carbon sequestration models have been represented by 2 broad revegetation classes (based on species selections and designs):

1. **Woodlots -** Blocks containing monocultures of typical woodlot species, including Sugar Gum (*Eucalyptus cladocalyx*), River Red Gum (*E. camaldulensis*), and SA Blue Gum (*E. leucoxylon*).
2. **Environmental Plantings -** Blocks containing predominately mixtures of native species for biodiverse/habitat plantings intended for environmental services.

These classes persist as an appropriate rudimentary grouping for revegetation types. However, the proportion of individual trees to shrubs (i.e. "proportion trees") within a revegetation plant community does influence plant competition and site productivity. Future versions of the DOTE Reforestation Modelling Tool (RMT) will include "Proportion Trees" classes (i.e. "Tree dominated >= 75% trees", "Mixed Strata < 75% trees") within Mixed Species Environmental Planting models (Paul *et al.* 2012). SA survey data also utilised the lifeform classification of tree or shrub for each individual plant surveyed, but also included a finer classification of the tree group into eucalypt trees, non-eucalypt trees and eucalypt mallees.

PLANT DENSITY

The RMT (DCCEE 2011) currently utilises 3 plant density classes (i.e. "High" >= 1,200 stems/ha, "Medium" ~ 1,000 stems/ha and "Low" <= 800 stems/ha) to estimate carbon sequestration from Mixed Species Environmental Plantings. Generally, these classes represent different plant densities in response to decreasing rainfall and increasing drought stress. This trend of decreasing plant density as growing conditions are harsher is also reflected in observations made from SA revegetation surveys. Due to natural attrition within revegetation sites (e.g. competition, senescence, droughts, limited recruitment) the number of plants per hectare also decreases over time. Preliminary DEWNR models of carbon sequestration (Hobbs *et al.* 2010) used fixed plant density of 800 plants/ha for woodlots and 1400 plants/ha for environmental plantings based on average observed plant densities from revegetation surveys. However, observed plant densities are typically variable depending on the purpose of the revegetation, establishment method, mix of species or lifeforms, climate, landscapes and soils.

The interactions between plant density, proportion of trees, age, climate and soil variables were explored using survey data from 264 revegetation sites. Forward-stepwise multiple linear regression modelling was used to identify the best predictors of local plant density (Table 11). Further exploration of the model revealed a further interaction between soil classifications (based on clay content of the soil profile) and plant density. The best local plant density models are presented in Table 12.

Table 11. Improvements in local plant density model fit by the stepwise addition of significant variables and the inclusion of a soil interaction.

Predictors of Ln(Plant Density) Stepwise Models	Model Fit (r^2)	Improve-ment	AICc
Climate plus Soils			
Ln(Annual Pot. Evaporation)	0.1330	+13.3%	574.4
+Proportion Tree	0.1802	+4.7%	561.7
+Ln(Age)	0.2107	+3.1%	553.7
+Ln(Annual Rainfall)	0.2322	+2.2%	548.5
x Clay Index of Soil Profile	0.2463	+1.4%	544.8

Table 12. Models for predicting average local plant stocking rate using planting design, age, climate and soil parameters.

Models of Local Plant Density	Model Fit	
Plant Density, pd (plants/ha)	r^2	AICc
Climate Model (n=264)	0.2322	548.5
Ln(pd+1) = -1.9914xLn(Evap+1) - 0.7235xPropTree - 0.27013xLn(Age+1) + 0.6448xLn(Rain+1)) + 18.2928		
Climate plus Soil Model (n=264)	0.2463	544.8
Ln(pd+1) = (-1.9914xLn(Evap+1) - 0.7235xPropTree - 0.2701xLn(Age+1) + 0.6448xLn(Rain+1)) + 18.2928) x (0.0007457xClayIndex) + 0.9535)		
where, Rain = average annual rainfall (mm/yr) Evap = average annual potential evaporation (mm/yr) Age = age of revegetation site (years) PropTree = proportion of trees (number of tree lifeforms/number of all plants at a site) ClayIndex = clay index of soil profile (~inherent fertility, Hall *et al.* 2009)		

ABOVE-GROUND BIOMASS PRODUCTION AND CARBON SEQUESTRATION RATES

National carbon accounting systems, models and tools currently used by the DOTE are based on a primary spatial climate/soil model (Forest Productivity Index, FPI) to evaluate the productive potential of all lands across Australia. This FPI model underpins the FullCAM model implemented through the National Carbon Accounting Toolbox and the CFI Reforestation Modelling Tool. Previous DEWNR research has indicated that other growth models (e.g. BiosEquil or empirical climate-growth relationships) can better represent carbon sequestration rates in South Australia (Hobbs *et al.* 2010).

Since 2010 the number of revegetation sites measured and assessed by DEWNR staff for carbon sequestration studies has greatly increased from 94 to 264 sites, and now covers a much wider range of environmental conditions and planting designs. With this new information the relationships between observed South Australian growth rates and the DOTE Forest Productivity Index (FPI), BiosEquil model and empirical climate/soil data have been reanalysed. Table 13 provides a summary of that renewed analysis. It shows that the FPI used by DOTE modelling approaches (including FullCAM, NCAT, RMT) is the poorest predictor of carbon sequestration rates from revegetation in South Australia. As a primary predictor of revegetation growth the FPI is 3.5 times less reliable than rainfall only data, and 3 times less reliable than the BiosEquil model. Even when growth rate influencing variables (i.e. age, plant density, proportion of trees) are included in the analysis, the BiosEquil and FPI models are 13 to 22% less reliable than models based on rainfall, potential evaporation and soils.

Due to the unreliability of the DOTE FPI to predict growth and carbon sequestration rates in South Australia revegetation, and the decreased efficiency of the BiosEquil model, both the FPI and BiosEquil based models have been abandoned as a methodology to represent growth rates in the agricultural regions of South Australia. New DEWNR productivity models, based on climate/soil relationships have been adopted and developed further to represent plant growth and carbon sequestration rates from revegetation in the state.

The DEWNR growth rate models have been constructed in 2 forms using: 1) "Climate" data, where reliable soil data is not available; and 2) "Climate plus Soil" data, where reliable soil data is present. All plant growth and spatial climate/soil variables were inspected and non-normally distributed variables were transformed using natural-logarithms. Multiple linear regression and forward-stepwise regression techniques were used to identify the best predictors of productivity rates (Table 14). Several iterations of the multiple linear regression modelling process were explored to identify any potential issues that would influence the robustness of resulting models. The resulting "Climate" and "Climate plus Soils" above-ground biomass productivity models and carbon conversion factors are presented in Table 15.

PRELIMINARY MODELS OF CARBON STOCKS IN REMNANT VEGETATION

Following a similar methodology used to develop DEWNR models of carbon sequestration from revegetation, preliminary models of above-ground biomass and carbon stock held in remnant vegetation have been developed (Table 1). A strong relationship exists between remnant above-ground biomass and rainfall (r^2=0.54), with significant improvements if height and plant density data is available (r^2=0.75). However, when on-site plant data is absent, soil profile texture data can be used to marginally improve model fit (r^2=0.59). Due to the limited number of surveys conducted in remnant sites for this study (n=37) caution should be exercised in the use of these preliminary models for state-wide estimates. Additional remnant vegetation data should be sourced to further test and validate these models.

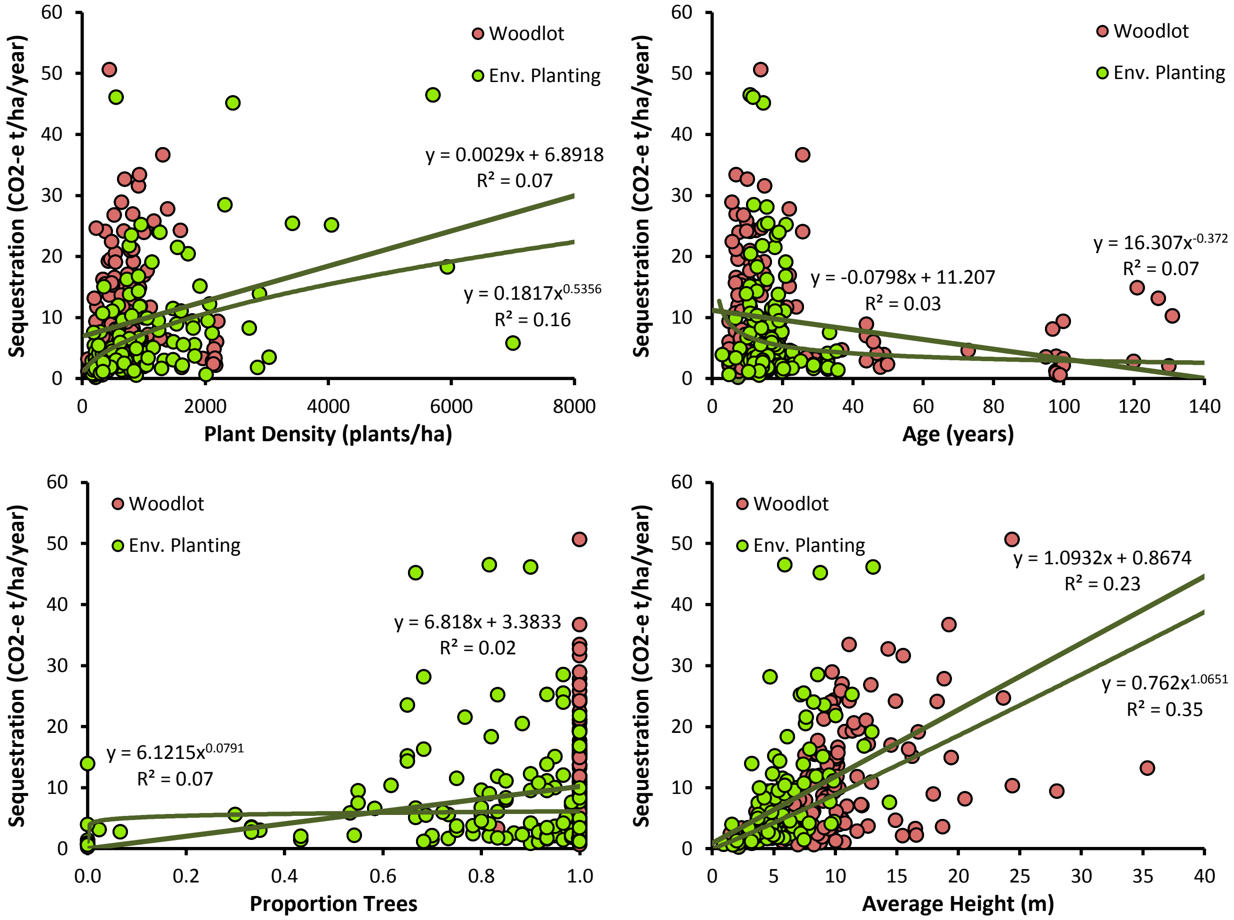


Figure 9. Relationships between carbon sequestration rates of revegetation (woodlots & environmental plantings) and planting design, age or height in agricultural regions of South Australia.

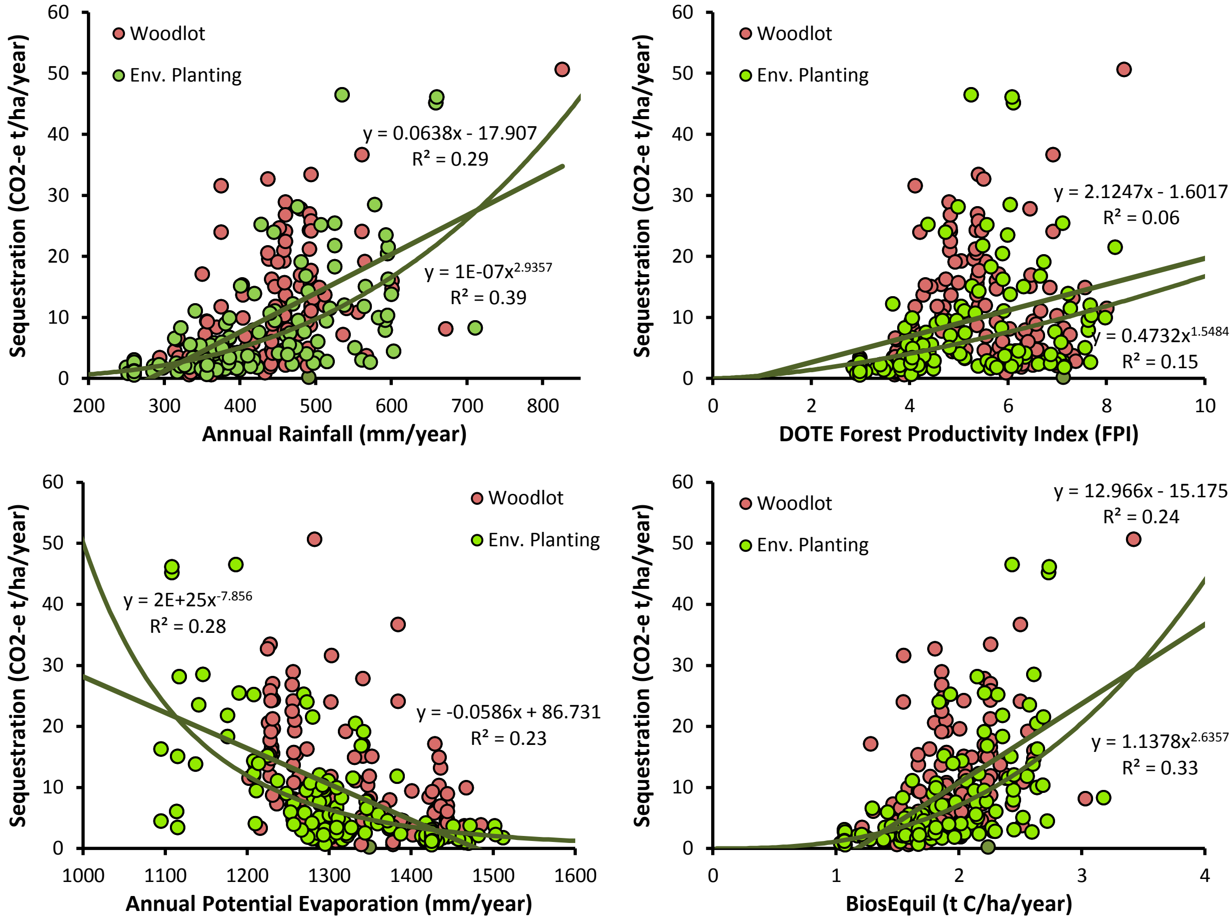


Figure 10. Relationships between carbon sequestration rates of revegetation (woodlots & environmental plantings) and environmental conditions or current national carbon models in agricultural regions of South Australia.

Table 13. Comparisons of relationships between above-ground biomass production in revegetation sites and DOTE FPI, BiosEquil and DEWNR Climate plus Soil models (rainfall primary predictor), including the influence of additional predictor variables on primary predictors.

Models of Above-ground Biomass Productivity Rate	Primary Predictor by Model Fit (r^2; n=264)		
Predictors	FPI	BiosEquil	Rainfall
Baseline	0.1120	0.3315	0.3914
+ Age	0.2245	0.3971	0.4621
+ Plant Density	0.2950	0.4256	0.4919
+ Proportion Trees	0.3767	0.4698	0.5321
+ Pot. Evaporation	-	-	0.5442
+ Soils	-	-	0.5967

Table 14. Improvements in carbon sequestration model fit from baseline Climate and Climate plus Soils models by the stepwise addition of significant variables.

Predictors of Ln(Carbon Sequestration Rate) Stepwise Models	Model Fit (r^2)	Improve-ment	AICc
Climate			
Ln(Annual Rainfall)	0.3914	+39.1%	467.0
+Ln(Age)	0.4621	+7.1%	436.5
+Ln(Plant Density)	0.4919	+3.0%	423.5
+Ln(Shrub Density)	0.5260	+3.4%	407.3
+Ln(Annual Pot. Evaporation)	0.5424	+1.6%	400.1
Climate plus Soils			
Ln(Annual Rainfall)	0.3914	+39.1%	467.0
+Ln(Age)	0.4621	+7.1%	436.5
+Depth to Rock	0.5060	+4.4%	416.1
+Ln(Plant Density)	0.5291	+2.3%	405.6
+Ln(Shrub Density)	0.5649	+3.6%	386.8
+Clay Index of Soil Profile	0.5825	+1.8%	378.0
+Ln(Surface Clay Content)	0.5916	+0.9%	374.4
+Ln(Annual Pot. Evaporation)	0.5967	+0.5%	373.2

Table 15. Models for predicting above-ground biomass productivity and carbon sequestration rates using planting design, age, climate and soil parameters.

Models of Above-ground Biomass Productivity	Model Fit	
Above-ground Biomass Production Rate, P_{ag} (t/ha/yr)	**r^2**	**AICc**
Climate Model (n=264)	0.5424	400.1
$Ln(P_{ag}+1) = 1.7401*Ln(Rain+1) - 0.1601*Ln(Age+1) + 0.2555*Ln(Plants+1) - 0.06051*Ln(Shrubs+1) - 1.4020*Ln(Evap+1)$		
Climate plus Soil Model (n=264)	0.5967	373.2
$Ln(P_{ag}+1) = 1.8371*Ln(Rain+1) - 0.09543*Ln(Age+1) + 0.003784*SoilDepth + 0.2772*Ln(Plants+1) - 0.06623*Ln(Shrubs+1) - 0.009872*ClayIndex + 0.2237*Ln(SurfClay+1) - 1.6105*Ln(Evap+1)$		
where, Rain = average annual rainfall (mm/yr) Evap = average annual potential evaporation (mm/yr) Age = age of revegetation site (years) Plants = plant density (plants/ha) Shrubs = shrub density (shrubs/ha) SoilDepth = average depth of soil (cm), if depth greater than 200cm then depth=200cm SurfClay = soil surface clay content (%), if content >45% then content=45% ClayIndex = clay index of soil profile (~inherent fertility, Hall *et al.* 2009)		
Biomass to Carbon Conversion Factors		
Elemental Carbon (C) = Plant Biomass * 0.496 Carbon Dioxide equivalent (CO_2-e) = Elemental Carbon * 3.67 Carbon Dioxide equivalent (CO_2-e) = Plant Biomass * 0.496 * 3.67		

Table 16. Preliminary models for predicting above-ground biomass and carbon stocks in remnant vegetation.

Preliminary Models of Above-ground Biomass in Remnant Vegetation	Model Fit	
Remnant Above-ground Biomass, $B_{rem\ ag}$ (t/ha)	**r^2**	**AICc**
Climate Model (n=37)	0.5433	78.9
$Ln(B_{rem\ ag}+1) = 2.7217xLn(Rain+1) – 12.1433$		
Climate, Height plus Plant Density Model (n=37)	0.7451	62.6
$Ln(B_{rem\ ag}+1) = 1.0328xLn(Rain+1) + 0.4817xLn(Plants+1) + 0.1545*Ln(Height+1) – 5.8425$		
Climate plus Soil Model (n=37)	0.5906	77.4
$Ln(B_{rem\ ag}+1) = 2.8169xLn(Rain+1) – 0.01287xClayIndex – 11.9387$		
where, Rain = average annual rainfall (mm/yr) Plants = plant density (plants/ha) Height = average height of plants (m) ClayIndex = clay index of soil profile (~inherent fertility, Hall *et al.* 2009)		
Biomass to Carbon Conversion Factors		
Elemental Carbon (C) = Plant Biomass * 0.496 Carbon Dioxide equivalent (CO_2-e) = Elemental Carbon * 3.67 Carbon Dioxide equivalent (CO_2-e) = Plant Biomass * 0.496 * 3.67		

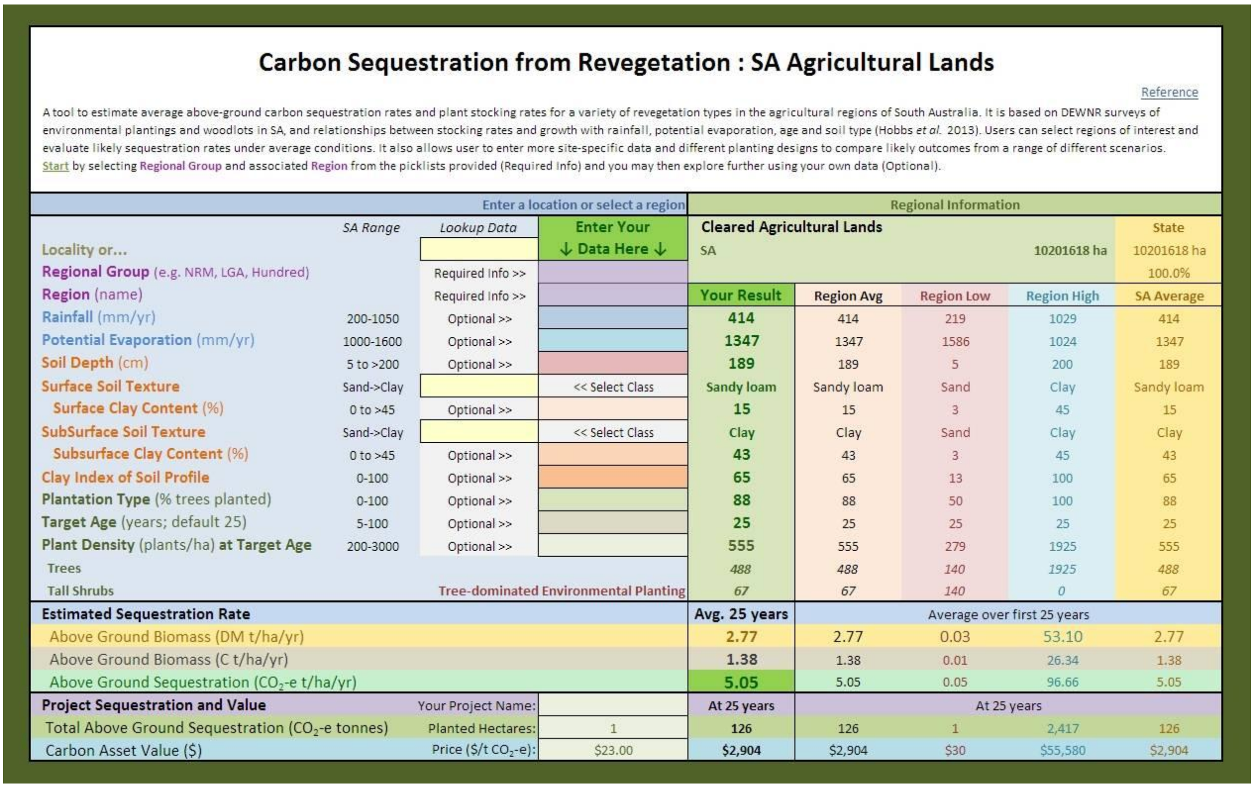
DEWNR CARBON SEQUESTRATION FROM REVEGETATION ESTIMATOR TOOL

To enable greater access to the predictive models developed by DEWNR research to landholders, natural resource managers, regional planners, scientists and policy staff a Microsoft Excel tool, embedded with the same models used to estimate regional carbon sequestration rates from revegetation, has been created (Table 15). The user interface and dynamic outputs allow individuals to explore the impact of choices using different locations, planting designs, climatic zones, soil types and ages on carbon sequestration rates (Figure 11). Regional and local environmental parameters that drive carbon sequestration rates have been preloaded into this tool for most environmental or administrative regions of South Australia (e.g. NRM Regions, rainfall zones, local government areas, cropping districts, administrative Hundreds, IBRA subregions & Trees For Life zones) and are available via simple drop-down choices. Average regional conditions can be further modified by the user to evaluate local site conditions. While this tool has been designed and calibrated for local South Australian conditions, and produces a reliable guide to carbon sequestration rates in the State, is not an official CFI methodology.

Outputs of the tool include (see Figure 11):

- average expected local plant density based on regional or site-specific conditions
- estimated average sequestration rate of above-ground biomass, elemental carbon and CO_2-e (t/ha/year)
- estimated carbon stock at a user defined-age (CO_2-e t/ha)
- estimated carbon stock value at a user defined-age and price ($/ha)

Additional outputs and plots show changes in average local plant density, carbon sequestration rates, carbon stock and asset values over time (Figure 12, Figure 13). The expected impact of 4 climate change scenarios (i.e. S0 Baseline – current conditions, S1 Mild warming and drying, S2 Moderate warming and drying, S3 Severe warming and drying) are also calculated and plotted.



Carbon Sequestration from Revegetation : SA Agricultural Lands

Reference

A tool to estimate average above-ground carbon sequestration rates and plant stocking rates for a variety of revegetation types in the agricultural regions of South Australia. It is based on DEWNR surveys of environmental plantings and woodlots in SA, and relationships between stocking rates and growth with rainfall, potential evaporation, age and soil type (Hobbs *et al.* 2013). Users can select regions of interest and evaluate likely sequestration rates under average conditions. It also allows user to enter more site-specific data and different planting designs to compare likely outcomes from a range of different scenarios.
Start by selecting Regional Group and associated Region from the picklists provided (Required Info) and you may then explore further using your own data (Optional).

	SA Range	Lookup Data	Enter a location or select a region: Enter Your ↓ Data Here ↓	Regional Information: Cleared Agricultural Lands				State
Locality or...				SA			10201618 ha	10201618 ha
Regional Group (e.g. NRM, LGA, Hundred)		Required Info >>						100.0%
Region (name)		Required Info >>		Your Result	Region Avg	Region Low	Region High	SA Average
Rainfall (mm/yr)	200-1050	Optional >>		414	414	219	1029	414
Potential Evaporation (mm/yr)	1000-1600	Optional >>		1347	1347	1586	1024	1347
Soil Depth (cm)	5 to >200	Optional >>		189	189	5	200	189
Surface Soil Texture	Sand->Clay		<< Select Class	Sandy loam	Sandy loam	Sand	Clay	Sandy loam
Surface Clay Content (%)	0 to >45	Optional >>		15	15	3	45	15
SubSurface Soil Texture	Sand->Clay		<< Select Class	Clay	Clay	Sand	Clay	Clay
Subsurface Clay Content (%)	0 to >45	Optional >>		43	43	3	45	43
Clay Index of Soil Profile	0-100	Optional >>		65	65	13	100	65
Plantation Type (% trees planted)	0-100	Optional >>		88	88	50	100	88
Target Age (years; default 25)	5-100	Optional >>		25	25	25	25	25
Plant Density (plants/ha) at Target Age	200-3000	Optional >>		555	555	279	1925	555
Trees				488	488	140	1925	488
Tall Shrubs			Tree-dominated Environmental Planting	67	67	140	0	67

Estimated Sequestration Rate	Avg. 25 years	Average over first 25 years			
Above Ground Biomass (DM t/ha/yr)	2.77	2.77	0.03	53.10	2.77
Above Ground Biomass (C t/ha/yr)	1.38	1.38	0.01	26.34	1.38
Above Ground Sequestration (CO_2-e t/ha/yr)	5.05	5.05	0.05	96.66	5.05

Project Sequestration and Value			At 25 years	At 25 years			
	Your Project Name:						
Total Above Ground Sequestration (CO_2-e tonnes)	Planted Hectares:	1	126	126	1	2,417	126
Carbon Asset Value ($)	Price ($/t CO_2-e):	$23.00	$2,904	$2,904	$30	$55,580	$2,904

Figure 11. Main screen of the "DEWNR Carbon Sequestration from Revegetation Estimator" tool.

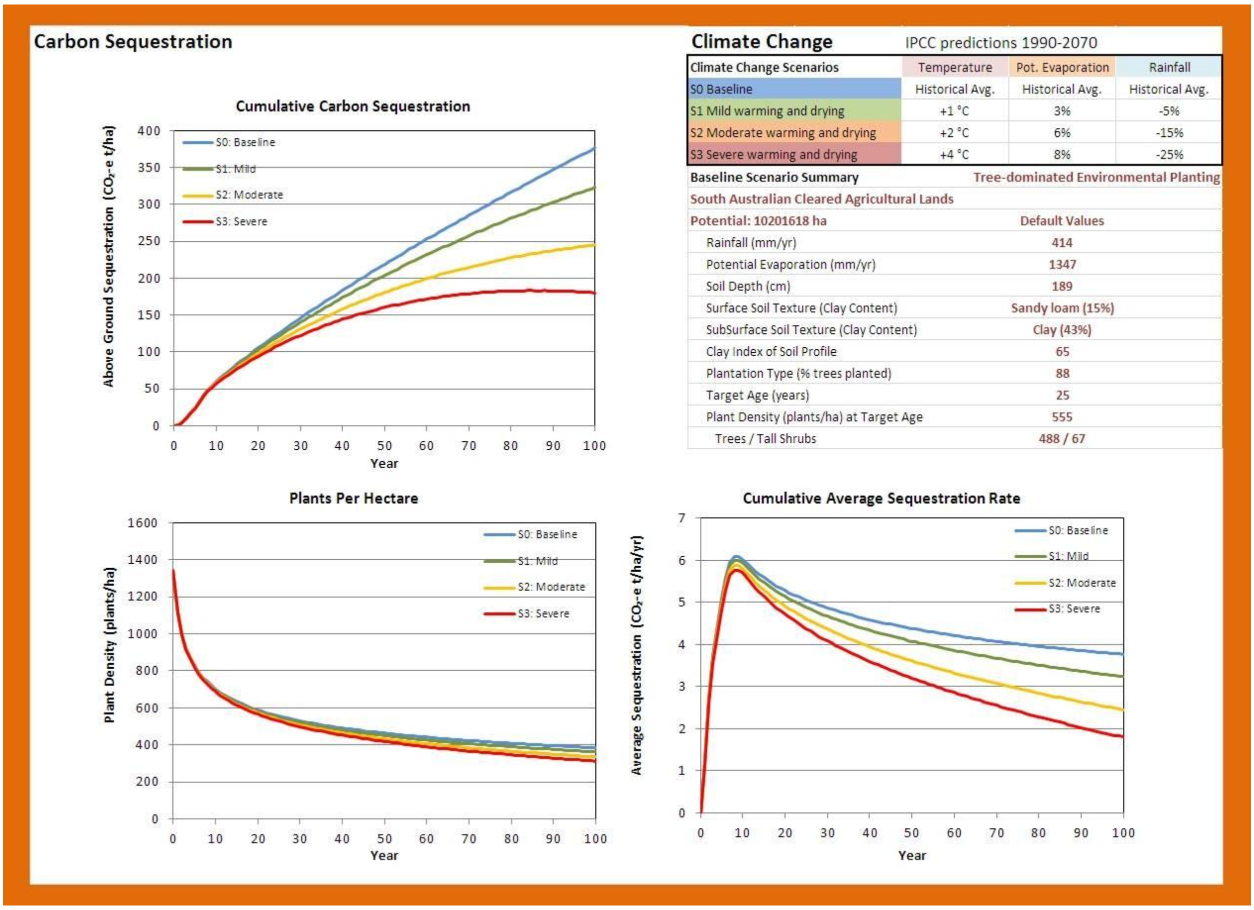


Figure 12. Changes in revegetation carbon sequestration rates over time and under different climate scenarios using the "DEWNR Carbon Sequestration from Revegetation Estimator" tool.

Figure 13. Changes in revegetation carbon asset values over time and under different climate scenarios using the "DEWNR Carbon Sequestration from Revegetation Estimator" tool.

CLIMATE CHANGE AND CARBON SEQUESTRATION RATES

Several relationships between climate variables and carbon sequestration rates (and average plant density) were identified during the development of DEWNR carbon sequestration models. The quantification of these relationships now allows the exploration of the average potential impact of changes in climate on future carbon sequestration rates from revegetation.

There are many potential climate change scenarios that could be explored here. To maintain consistency with other climate change research conducted in South Australia by CSIRO and the University of Adelaide (Crossman *et al.* 2010) this study has explored the same 4 representative climate scenarios used within their "*Landscape Futures Analysis*" research (Table 17). Representative estimates of potential evaporation rates for the 4 climate scenarios have been included for consistency with the DEWNR modelling approach. These estimates are based on previous studies of the likely impact of climate change on crop productivity (Hayman *et al.* 2011) and water resources (Gibbs *et al.* 2011) in South Australia. Potential atmospheric carbon dioxide fertilization effects have not been included in these analyses or models.

These 4 climate change scenarios, regional average environmental conditions (i.e. climates, soils) and calculation/plotting functions within the DEWNR Carbon Sequestration from Revegetation Estimator Tool (i.e. MS Excel Spreadsheet model) were used to provide representative outputs for each non-arid Natural Resource Management region of South Australia (Figure 14).

Relative to the 100 year estimate of carbon sequestration under current climatic conditions (i.e. "*Baseline*") the "*Mild warming and drying*" scenario has the greatest impact in the SA Murray-Darling Basin (-19%) NRM Region. Other NRM Regions are less affected but also reduced by around -13%. As climatic conditions further degrade (i.e "*Moderate warming and drying*") carbon sequestration is reduced by between -47% to -27% (average -35%). Under the most extreme

Table 17. Climate change scenarios used to explore the influence of increases in temperature and potential evaporation, and decreases in annual rainfall, on carbon sequestration rates from revegetation.

Climate Change Scenario	Rate of Change 1990 - 2070		
	Temp.	Potential Evap.	Rainfall
S0 Baseline	Historic	Historic	Historic
S1 Mild warming & drying	+1 °C	+3%	-5%
S2 Moderate warming &	+2 °C	+6%	-15%
S3 Severe warming & drying	+4 °C	+8%	-25%

scenario (i.e. "*Severe warming and drying*") carbon sequestration can be reduced by around -52% with the strongest influences in the SA Murray-Darling Basin, Eyre Peninsula and Northern & Yorke NRM Regions. As anticipated, the effect of increasing severity of climate change is relatively greatest in the lower rainfall regions, but the scale of change (absolute tonnes of CO_2-e) is highest in higher rainfall regions.

There is no doubt increasing warming and drying of our climate will reduce the average gross primary productivity of both revegetation and agricultural crops in the future. The high likelihood of change will influence farming and revegetation practices into the future (Booth & Williams 2012). Due to the long-term intent and nature of revegetation activities, plans for targeted revegetation should include considerations of planting design and species choices that match future climatic conditions and future needs of biodiversity, environmental services, economics and resilience for sustainability outcomes across South Australia.

IMPROVING NATIONAL CARBON ACCOUNTING MODELS

In 2011, DOTE recognised that FullCAM and RMT model estimates of carbon stocks in environmental plantings and mallee plantings were generally biased towards underestimating carbon stocks, and that new research was required to address this issue. DOTE engaged CSIRO, DEWNR and others (Paul *et al.* 2012) to undertake surveys and research to improve carbon assessment methods in revegetation and recalibrate FullCAM biomass accumulation models for environmental plantings and mallee plantings across Australia. This work involved collating existing biometric and productivity data from prior studies in Australia, undertaking detailed measurements and destructive sampling from several new sites, and recalibrating FullCAM models from these combined datasets.

In South Australia, 2 sites (1 mallee, 1 environmental planting) were chosen at Moorlands (near Tailem Bend, SA) for detailed studies of spatial variation plant productivity, development of allometric models for above ground biomass, quantifying root to shoot biomass ratios, and assessing site productivity. Details of these studies can be found in Appendix F - Improving National Carbon Accounting Models: Moorlands Case Study and in Paul *et al.* (2012). Plant biometric and revegetation productivity data gathered from South Australian sites by DEWNR over the past decade, and information gathered from recent DEWNR/CSIRO studies at Moorlands, have been assimilated into national DOTE databases. This data has been used by CSIRO and DEWNR to improve biomass assessment methods and to recalibrate FullCAM models for environmental plantings and mallee plantings (Paul *et al.* 2012).

In February 2013, DOTE approved these new FullCAM calibrations for environmental plantings and mallee plantings (Paul *et al.* 2012), and their implementation in the next release of the RMT for carbon accounting in 2013/2014. This update will significantly improve DOTE's primary methodology (CFI RMT) for carbon accounting in Australia.

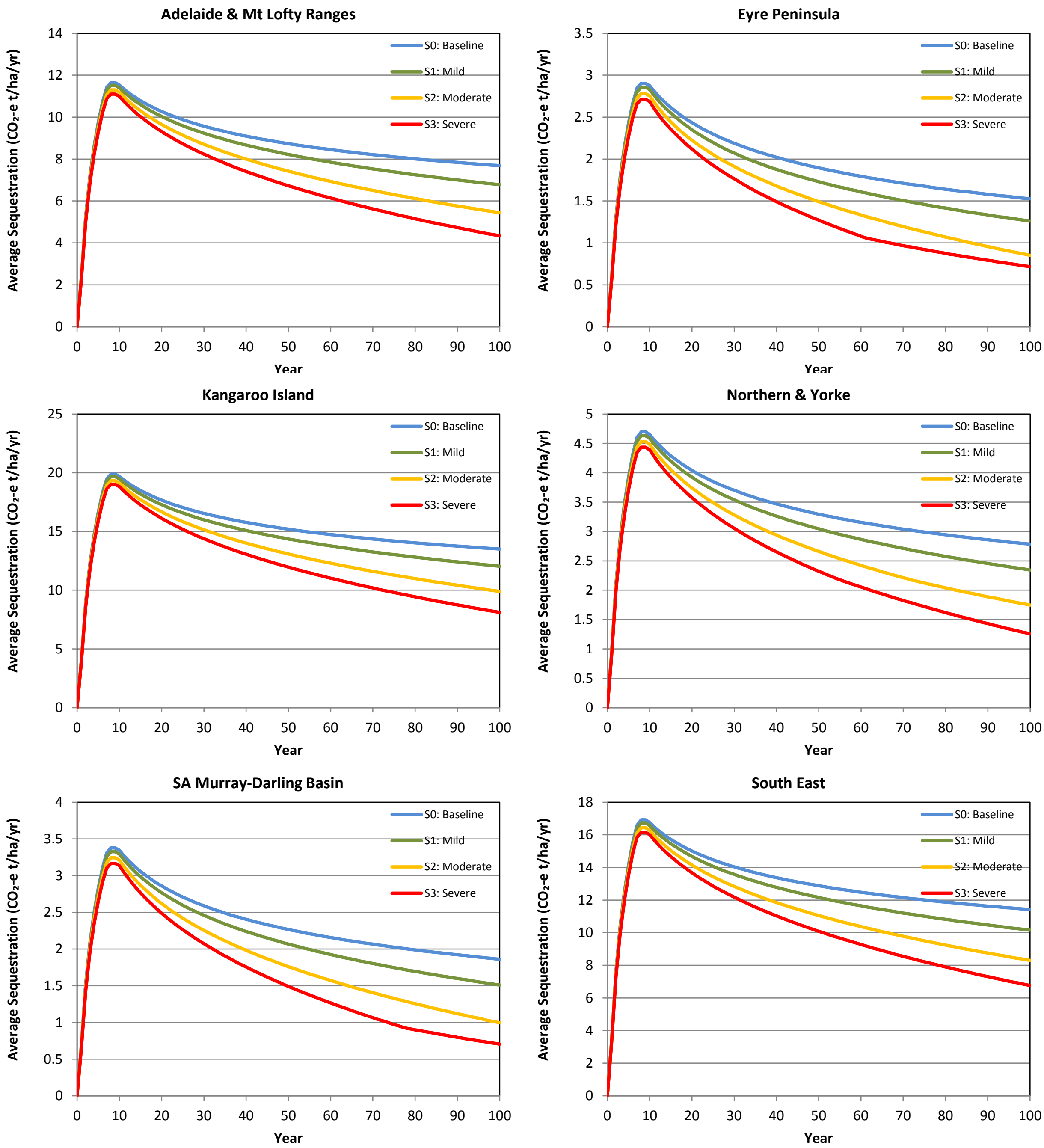


Figure 14. Estimated climate change influences on cumulative average carbon sequestration rates in environmental plantings (88% trees) by NRM Regions.

6. REGIONAL ESTIMATES OF CARBON SEQUESTRATION

CARBON SEQUESTRATION FROM REVEGETATION

The purpose, planting design, species selections, age and location of revegetation activities can be incredibly variable. The DEWNR carbon sequestration from revegetation models are adaptable to most of these choices and represent the typical local growth rates expected under current climatic conditions. While the survey data behind the models captured a wide range of planting designs, species blends, ages, climatic zones and soil types, these models should be considered most reliable for sites in the 250 to 650mm/year rainfall zone, between 10 to 40 years of age, with plant density values of 200 to 2000 plants per hectare, proportion of trees >65%, and on sandy to moderately clayey soils >60cm in depth.

Due to the large number of potential outputs, 3 representative revegetation scenarios (at 25 years) based on different proportions of trees have been generated:

1. **Woodlots** (100% trees)
2. **Tree Dominated Environmental Plantings** (88% trees, 12% medium to tall shrubs - typical SA)
3. **Mixed Strata Environmental Plantings** (50% trees, 50% medium to tall shrubs)

These groupings are consistent with current and proposed DOTE NCAT and RMT classifications. Past DEWNR surveys of revegetation sites across South Australian agricultural regions determined the average proportion of trees was between 83% (mixed species only) and 89% (all revegetation types). The "Tree Dominated Environmental Plantings" classification (88% trees) well represents the normal range of typical revegetation in South Australia.

The baseline predictions of average cumulative carbon sequestration rates for the 3 revegetation types have been generated for the interval 0 to 25 years of age. This convenient reporting interval (first 25 years) is close to the average age (22 years) of DEWNR surveyed revegetation sites. DEWNR survey data and models suggest that the average cumulative sequestration rate for the 0 to 100 years interval is approximately 75% of the 0 to 25 year interval rate.

Predictions of average carbon sequestration rates (i.e. first 25 years) for the 3 revegetation types were generated using Climate-only and Climate plus Soils models and data for every hectare of land within South Australia. Predictions of average local plant density preceded, and contributed later models of average biomass and carbon sequestration rates. In drier to more arid regions (i.e. annual rainfall <300mm/year, potential evaporation >1450mm/year) it was necessary to linearly rescale unreasonably low and negative predictions (due to unavailable model calibration data) from the most arid parts of the state (e.g. annual rainfall 106mm/year, potential evaporation 2106mm/year). In areas where reliable soil data is absent in the state, the predictions from the Climate-only model were merged with Climate plus Soils model to create a state-wide coverage of local plant density, and carbon sequestration rates (Figure 15). In areas where soil mapping data is unavailable (e.g. far-north & north-eastern regions) the model reliability is reduced by approximately 7%.

Summaries and maps presented in this report predominantly represent average sequestration rates for the first 25 years of typical South Australian "Tree Dominated Environmental Plantings" (i.e. 88% trees) under current climatic conditions (unless otherwise stated).

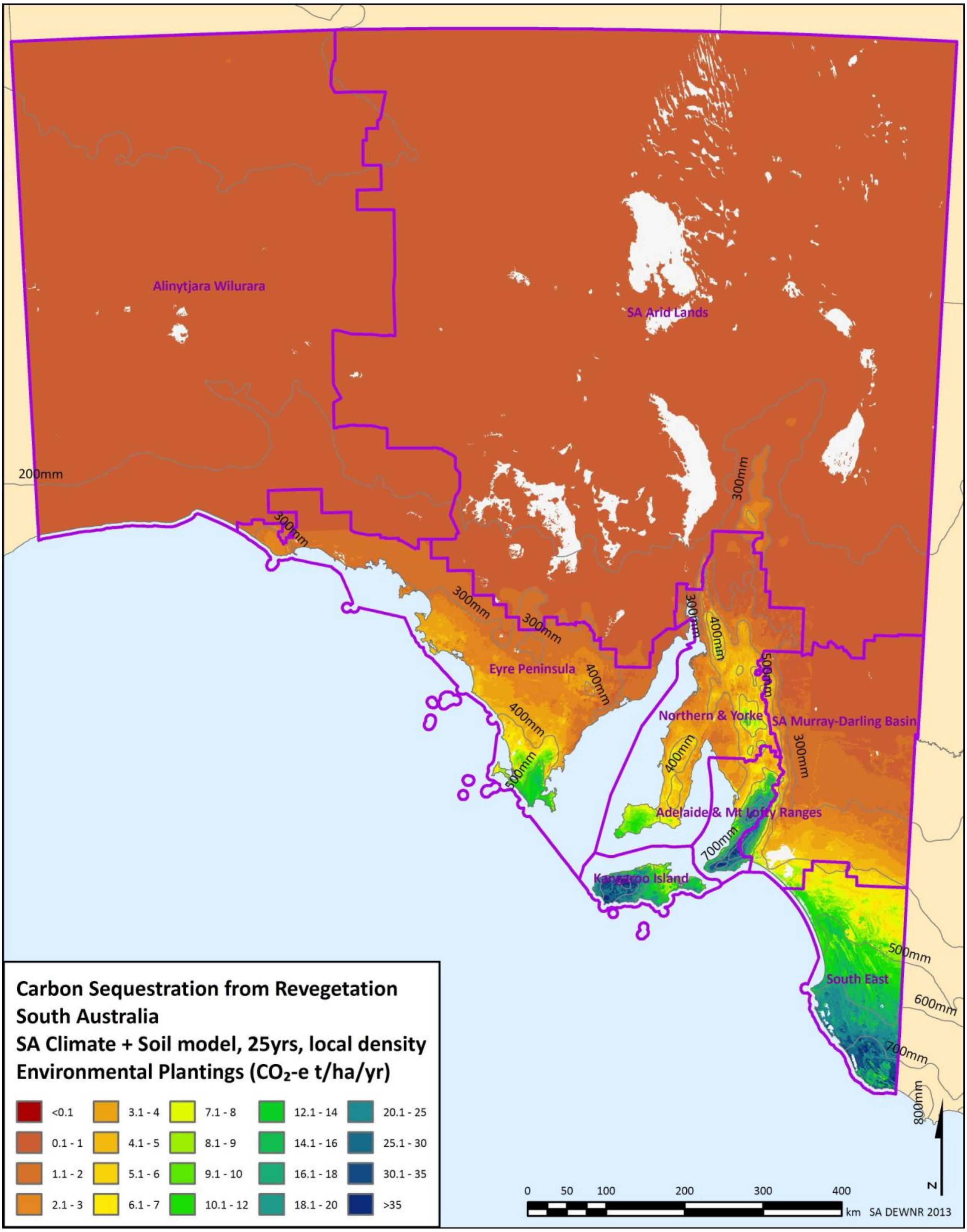


Figure 15. Predicted average annual carbon sequestration rates from Tree Dominated Environmental Plantings in South Australia.

REGIONAL ESTIMATES

Spatial predictions of carbon sequestration rates from revegetation (e.g. Woodlots, Tree Dominated Environmental Plantings, Mixed Strata Environmental Plantings) using DEWNR models have been restricted to cleared agricultural areas (see Figure 2) by masking out locations mapped by DEWNR 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.

The following sections report regional summaries of DEWNR carbon sequestration model predictions across the cleared agricultural lands of South Australia under current climatic conditions. DEWNR models are based on extensive surveys of mixed environmental plantings and woodlots within South Australia's agricultural districts. Most of the data presented here represents the average above-ground carbon sequestration rate (CO_2-e t/ha/year) using localised plant density (plants/ha; based on climate and soils) for 25 year old revegetation sites containing Kyoto-compliant species (i.e. >2m height trees, mallees & shrubs) and mapped at a 1 hectare scale.

Regional maps and tabulations of typical carbon sequestration rates by a series of different regional groupings are intended to provide natural resource managers, landholders, policy makers, scientists and carbon markets with a quick-look guide to anticipated sequestration rates from revegetation in regions of interest to each stakeholder.

Natural Resource Management Regions

There are over 10 million hectares of cleared agricultural lands in South Australia that are predominantly used for annual cropping and grazing (Table 18). These lands are predominantly found within the 250-650mm/year mean annual rainfall zone (9.4million ha, 92% of cleared lands). Due to significant differences in environmental conditions (Table 19, Table 20), plant density (Table 21, Figure 16) and planting designs (e.g. woodlots and environmental plantings), carbon sequestration rates from revegetation are highly variable across Natural Resource Management (NRM) regions (Table 22, Figure 17).

The carbon potential of each NRM Region is reliant on both the number of hectares of potential land and average productivity of that land. From cursory observations of available hectares (Table 18), the Eyre Peninsula and SA Murray-Darling Basin NRM Regions dominate (51% of cleared lands), but it should be noted that average rainfall is lower and average evaporation is higher in these NRM Regions than most other regions (Table 19).

To more reliably compare the carbon potential of each NRM Region an assimilation of data representing a target of 10% revegetation of available cleared agricultural (i.e. 10% utilisation) using woodlots and typical environmental plantings (i.e. 88%trees) was produced. These comparisons are based on a random allocation of 10% land available within a NRM Region, average carbon sequestration rates for the first 25 years, and an economic asset valuation based on a current CO_2-e price of $23/tonne (e.g. Woodlots - Table 23, Environmental Plantings - Table 24). Economic values presented in these tables only reflect the annual increment of carbon asset values based on current carbon market prices in Australia, and do not include any other investment considerations (e.g. no establishment, maintenance, investment, discount rates, compliance or opportunity costs).

Plots of carbon sequestration potential and annual incremental asset values at a target 10% revegetation by NRM Region and rainfall zones are presented in Figure 18, Figure 19 and Figure 20. Based on a uniform 10% adoption of revegetation by NRM Regions, considerable differences in carbon sequestration potential and values emerge. Key considerations from a review of this information includes:

- Adelaide & Mt Lofty Ranges, Eyre Peninsula, Northern & Yorke and SA Murray-Darling Basin NRM Regions have similar carbon potential with vastly different contributions from rainfall zones within regions
- Annual rainfall is a more limiting factor than available land in the Eyre Peninsula and SA Murray-Darling Basin NRM regions
- Adelaide & Mt Lofty Ranges, Kangaroo Island and South East NRM Regions have potential CFI restrictions due to higher proportion of lands in higher rainfall regions (e.g. >600mm/year restrictions in CFI program)
- South East NRM Region has 4 times more potential for carbon sequestration than any other NRM Region
- Typical Environmental Plantings sequester about 71% of the potential from Woodlots

Table 18. Area of agricultural land by NRM Region and rainfall zone in South Australia.

NRM Region*	Area of Agricultural Land (ha)							
	Rainfall Zone (mm/yr)							
	<250	250-350	351-450	451-550	551-650	651-750	>750	Total
AMLR		9,180	144,450	116,090	67,590	79,380	86,210	**502,900**
EP	250	1,962,810	655,000	112,740	10,280			**2,741,070**
KI			14,310	82,440	57,050	43,390	25,510	**222,690**
NY		418,700	1,103,580	519,000	35,340			**2,076,610**
SAMDB	100,650	1,476,190	711,120	118,840	31,130	24,510	30,720	**2,493,150**
SE			384,040	853,450	491,420	365,910	62,920	**2,157,730**
Total	**100,900**	**3,866,870**	**3,012,500**	**1,802,560**	**692,800**	**513,180**	**205,350**	**10,194,160**

* NRM Regions: Adelaide & Mt Lofty Ranges (AMLR); Eyre Peninsula (EP); Kangaroo Island (KI); Northern & Yorke (NY); SA Murray-Darling Basin (SAMDB); South East (SE).

Table 19. Potential evaporation rates of agricultural land by NRM Region and rainfall zone in South Australia.

NRM Region	Mean Annual Potential Evaporation (mm/yr)							
	Rainfall Zone (mm/yr)							
	<250	250-350	351-450	451-550	551-650	651-750	>750	Average
AMLR		1404	1398	1364	1258	1231	1195	**1310**
EP	1566	1476	1370	1257	1228			**1441**
KI			1131	1116	1107	1100	1090	**1108**
NY		1465	1391	1412	1390			**1411**
SAMDB	1464	1398	1312	1315	1248	1210	1192	**1366**
SE			1279	1215	1131	1071	1057	**1178**
Average	**1464**	**1445**	**1353**	**1286**	**1161**	**1105**	**1139**	**1347**

Table 20. Index of soil profile clay content of agricultural land by NRM Region and rainfall zone in South Australia.

NRM Region	Clay Index of Soil Profile*							
	Rainfall Zone (mm/yr)							
	<250	250-350	351-450	451-550	551-650	651-750	>750	Average
AMLR		68	84	83	73	71	71	**77**
EP	50	56	62	62	59			**58**
KI			77	69	67	61	58	**66**
NY		76	75	89	84			**79**
SAMDB	59	59	61	69	64	66	63	**60**
SE			46	57	74	75	67	**62**
Average	**54**	**65**	**67**	**72**	**70**	**68**	**65**	**67**

* Index of clay content or estimated inherent fertility of whole soil profile (0-50 Low, 50-70 Moderately Low, 70-90 Moderate, 90-100 High).

Table 21. Average plant density of revegetation (at 25 years of age) in agricultural land by NRM Region and rainfall zone in South Australia (DEWNR model).

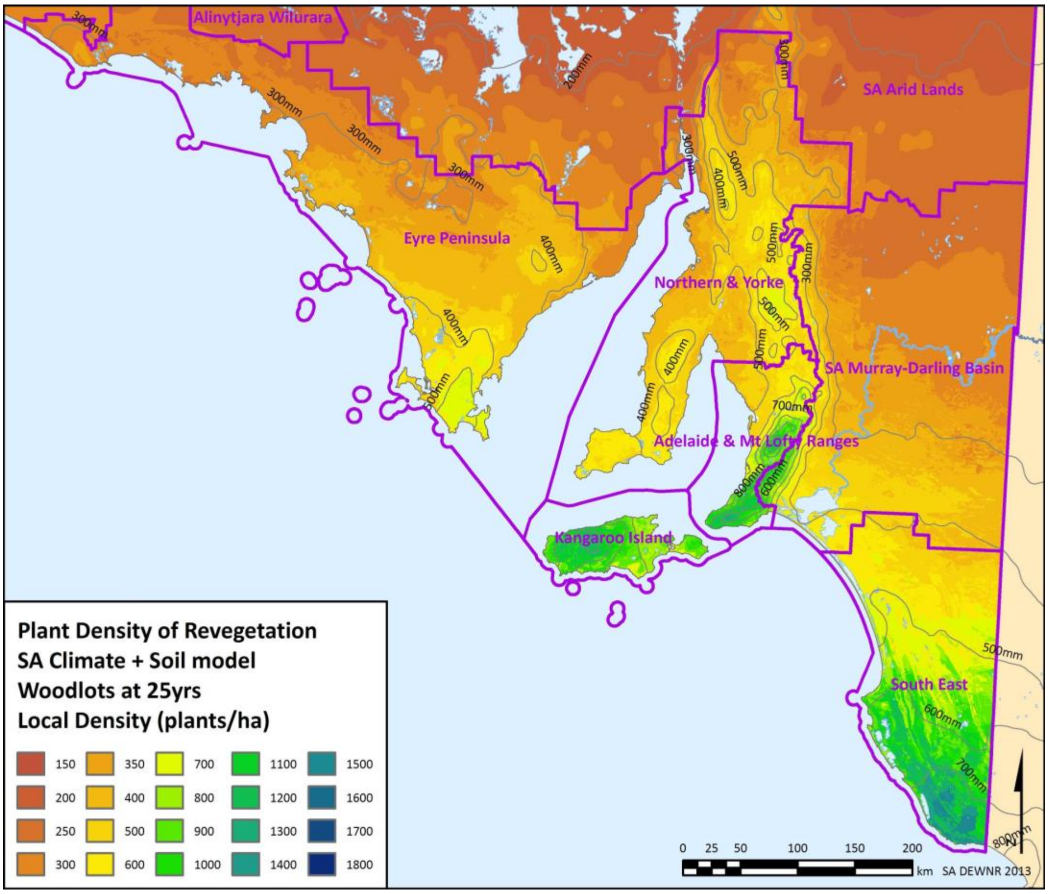
NRM Region	Reveg* Type % Trees	Mean Plant Density (plants/ha) at 25 years							
		Rainfall Zone (mm/yr)							
		<250	250-350	351-450	451-550	551-650	651-750	>750	Average
AMLR	W 100		422	505	605	787	896	1046	**719**
	EP 88		460	551	661	859	978	1142	**785**
	EP 50		607	729	874	1135	1290	1507	**1037**
EP	W 100	255	339	470	643	723			**384**
	EP 88	278	370	513	702	789			**419**
	EP 50	365	487	676	924	1038			**552**
KI	W 100			806	850	968	1053	1147	**951**
	EP 88			880	928	1056	1148	1251	**1038**
	EP 50			1162	1224	1393	1512	1647	**1368**
NY	W 100		392	492	576	654			**496**
	EP 88		428	537	629	714			**541**
	EP 50		566	710	833	945			**716**
SAMDB	W 100	300	371	507	609	750	897	988	**436**
	EP 88	327	405	553	664	818	979	1078	**476**
	EP 50	431	534	728	877	1078	1290	1420	**627**
SE	W 100			531	686	976	1205	1260	**829**
	EP 88			579	749	1065	1316	1375	**905**
	EP50			760	985	1407	1739	1813	**1193**
Average	**W 100**	**300**	**357**	**498**	**649**	**926**	**1130**	**1115**	**543**
	EP 88	**327**	**390**	**543**	**708**	**1011**	**1234**	**1217**	**592**
	EP 50	**431**	**514**	**716**	**934**	**1336**	**1629**	**1605**	**781**

* Woodlots (W 100), Tree Dominated Environmental Plantings (EP 88), Mixed Strata Environmental Plantings (EP 50).

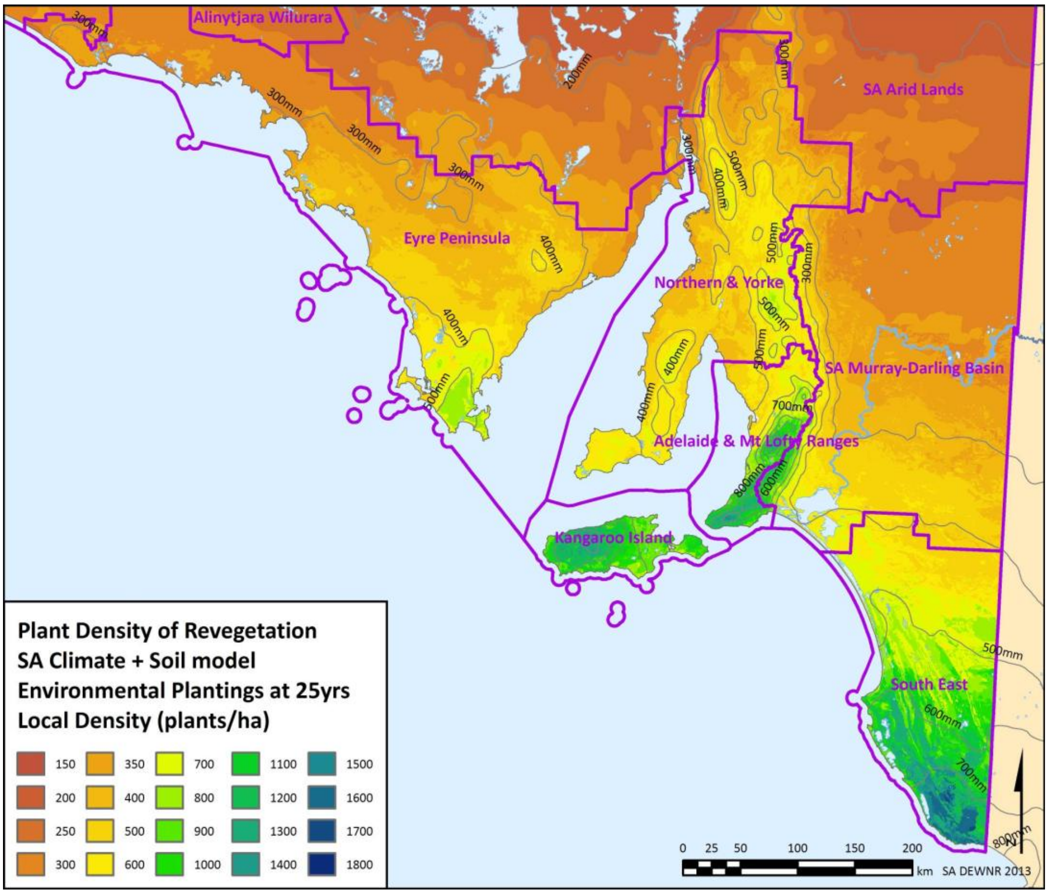
Table 22. Carbon sequestration rates from revegetation (first 25 years) in agricultural land by NRM Region and rainfall zone in South Australia (DEWNR model).

NRM Region	Reveg* Type % Trees	Mean Carbon Sequestration Rate (CO_2-e t/ha/yr) – first 25 years							
		Rainfall Zone (mm/yr)							
		<250	250-350	351-450	451-550	551-650	651-750	>750	Average
AMLR	W 100		4.09	5.20	8.44	16.85	24.33	36.59	**15.89**
	EP 88		2.81	3.64	6.05	12.24	17.70	26.55	**11.48**
	EP 50		2.65	3.45	5.78	11.75	17.02	25.55	**11.01**
EP	W 100	1.83	2.75	5.75	12.95	19.97			**3.95**
	EP 88	1.14	1.82	4.08	9.45	14.69			**2.72**
	EP 50	1.03	1.69	3.87	9.05	14.10			**2.56**
KI	W 100			12.18	14.94	23.32	35.53	49.23	**24.85**
	EP 88			8.71	10.74	16.87	25.80	35.71	**17.98**
	EP 50			8.35	10.30	16.21	24.81	34.37	**17.28**
NY	W 100		2.93	5.84	7.33	11.15			**5.72**
	EP 88		1.94	4.13	5.21	8.08			**4.02**
	EP 50		1.82	3.92	4.97	7.73			**3.82**
SAMDB	W 100	1.62	2.65	6.06	8.19	14.81	25.98	37.52	**4.66**
	EP 88	0.94	1.72	4.29	5.84	10.74	18.94	27.38	**3.21**
	EP 50	0.85	1.59	4.07	5.57	10.30	18.20	26.34	**3.04**
SE	W 100			9.15	14.43	24.09	33.84	40.74	**19.75**
	EP 88			6.66	10.53	17.44	24.34	29.33	**14.31**
	EP 50			6.36	10.09	16.76	23.42	28.22	**13.73**
Average	**W 100**	**1.62**	**2.74**	**6.30**	**11.52**	**22.18**	**32.14**	**39.57**	**8.86**
	EP 88	**0.94**	**1.79**	**4.48**	**8.34**	**16.06**	**23.18**	**28.67**	**6.31**
	EP 50	**0.85**	**1.67**	**4.25**	**7.99**	**15.44**	**22.30**	**27.59**	**6.03**

* Woodlots (W 100), Tree Dominated Environmental Plantings (EP 88), Mixed Strata Environmental Plantings (EP 50).

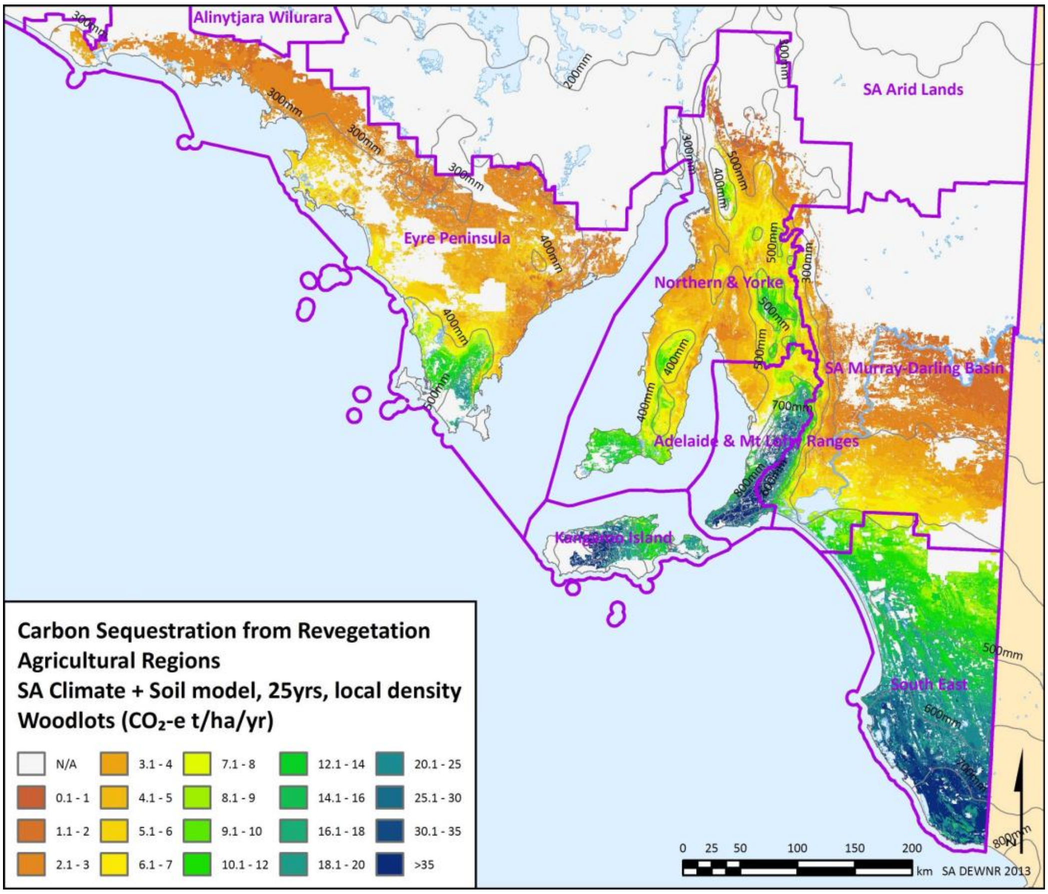


a)

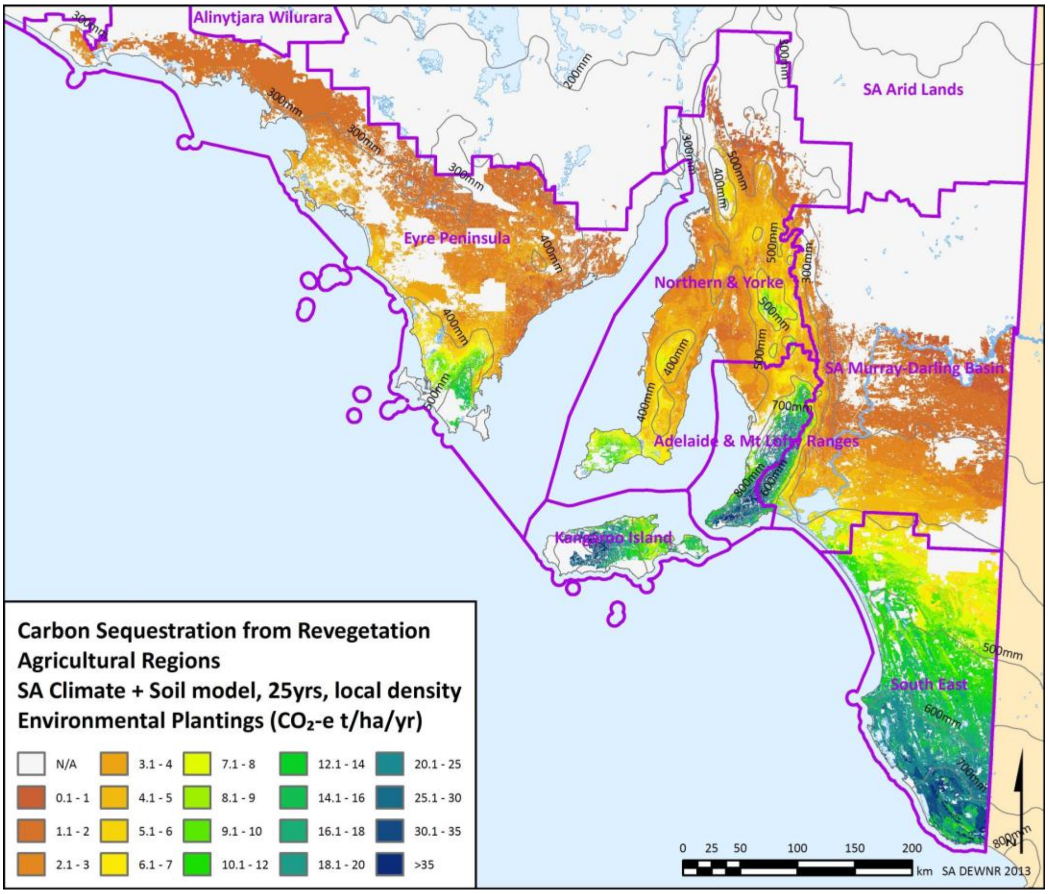


b)

Figure 16. Variations in local plant density (at 25 years of age) for a) Woodlots (100% trees) and b) Environmental Plantings (88% trees) resulting from differences in climate, soil and revegetation types in the agricultural region of South Australia.



a)



b)

Figure 17. Estimated average carbon sequestration rates (first 25 years) from a) Woodlots (100% trees) and b) Environmental Plantings (88% trees) using local plant density in the agricultural region of South Australia.

Table 23. Annual carbon sequestration potential crop and value from a 10% target Woodlot (100% trees) revegetation in agricultural land by NRM Region and rainfall zone in South Australia

NRM Region	Woodlots - Potential Sequestration^ (CO_2-e millions of t/yr) at 10% Utilisation							
	Rainfall Zone (mm/yr)							
	<250	250-350	351-450	451-550	551-650	651-750	>750	Total
AMLR		0.004	0.076	0.088	0.098	0.166	0.291	**0.724**
EP	0.0001	0.688	0.387	0.128	0.017			**1.220**
KI			0.018	0.119	0.118	0.138	0.117	**0.510**
NY		0.158	0.667	0.330	0.032			**1.188**
SAMDB	0.026	0.562	0.467	0.089	0.039	0.055	0.104	**1.341**
SE			0.358	1.159	1.126	1.191	0.250	**4.083**
Total	**0.026**	**1.414**	**1.974**	**1.912**	**1.431**	**1.551**	**0.761**	**9.065**
NRM Region	Woodlots - Potential Annual Value of Carbon# (millions $/yr) at 10% Utilisation							
	Rainfall Zone (mm/yr)							
	<250	250-350	351-450	451-550	551-650	651-750	>750	Total
AMLR		0.103	1.746	2.019	2.254	3.829	6.690	**16.641**
EP	0.001	15.832	8.900	2.937	0.391			**28.061**
KI			0.416	2.728	2.715	3.180	2.681	**11.721**
NY		3.643	15.349	7.598	0.729			**27.319**
SAMDB	0.589	12.917	10.749	2.036	0.903	1.266	2.381	**30.842**
SE			8.241	26.646	25.902	27.383	5.742	**93.914**
Total	**0.590**	**32.512**	**45.405**	**43.980**	**32.906**	**35.682**	**17.507**	**208.497**

^ Based on average of first 25 year sequestration rate. # Market CO_2-e price of $23/tonne.

Table 24. Annual carbon sequestration potential crop and value from a 10% target Environmental Plantings (88% trees) revegetation in agricultural land by NRM Region and rainfall zone in South Australia.

NRM Region	Environmental Plantings - Potential Sequestration^ (CO_2-e millions of t/yr) at 10% Utilisation							
	Rainfall Zone (mm/yr)							
	<250	250-350	351-450	451-550	551-650	651-750	>750	Total
AMLR		0.003	0.053	0.070	0.083	0.141	0.229	**0.578**
EP	0.00003	0.357	0.267	0.107	0.015			**0.746**
KI			0.012	0.089	0.096	0.112	0.091	**0.401**
NY		0.081	0.456	0.271	0.029			**0.836**
SAMDB	0.010	0.253	0.305	0.069	0.033	0.046	0.084	**0.802**
SE			0.256	0.899	0.857	0.891	0.185	**3.088**
Total	**0.010**	**0.694**	**1.349**	**1.505**	**1.114**	**1.190**	**0.589**	**6.450**
NRM Region	Environmental Plantings - Potential Annual Value of Carbon# (millions $/yr) at 10% Utilisation							
	Rainfall Zone (mm/yr)							
	<250	250-350	351-450	451-550	551-650	651-750	>750	Total
AMLR		0.060	1.209	1.616	1.907	3.234	5.269	**13.294**
EP	0.001	8.209	6.145	2.452	0.348			**17.154**
KI			0.286	2.039	2.215	2.576	2.100	**9.218**
NY		1.873	10.479	6.222	0.658			**19.232**
SAMDB	0.219	5.827	7.019	1.598	0.770	1.067	1.936	**18.436**
SE			5.880	20.681	19.722	20.498	4.245	**71.025**
Total	**0.219**	**15.969**	**31.019**	**34.608**	**25.619**	**27.374**	**13.551**	**148.359**

^ Based on average of first 25 year sequestration rate. # Market CO_2-e price of $23/tonne.

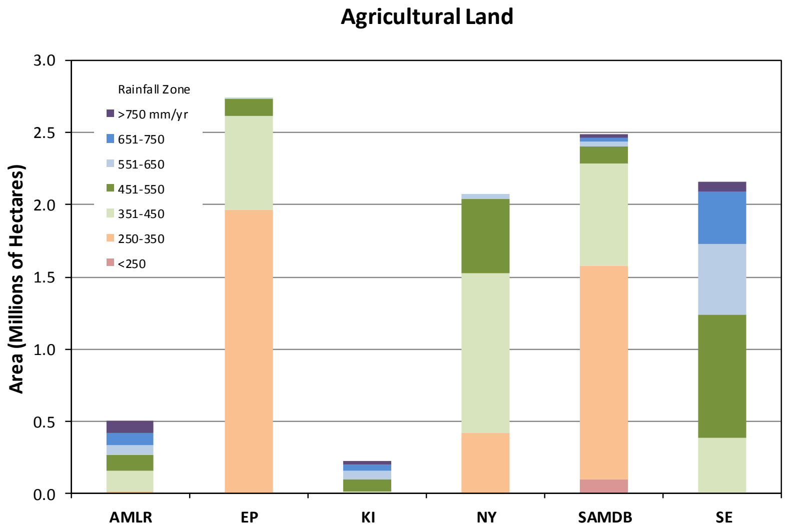


Figure 18. Agricultural land by NRM Regions and rainfall zones of South Australia.

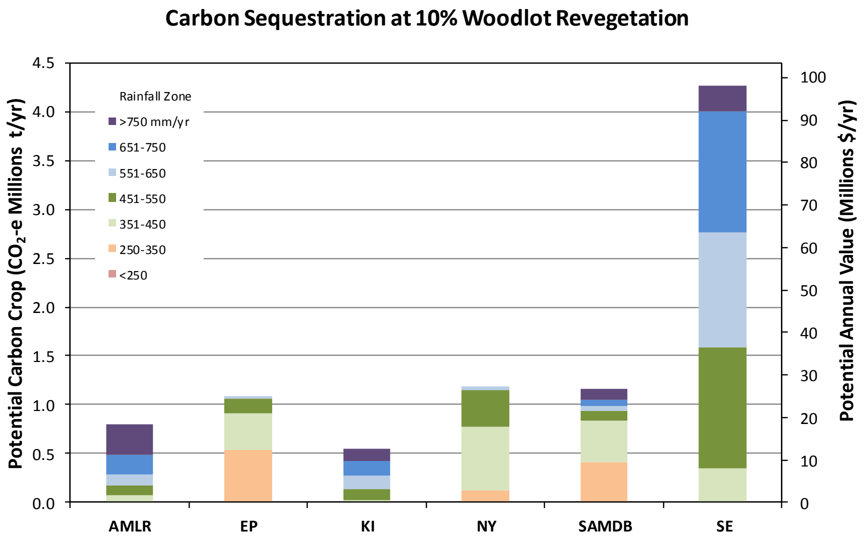


Figure 19. Potential annual carbon crop and annual value (at $23/t CO_2-e) based on 10% target utilisation of Woodlots (100%trees) revegetation on agricultural land by NRM Regions and rainfall zones.

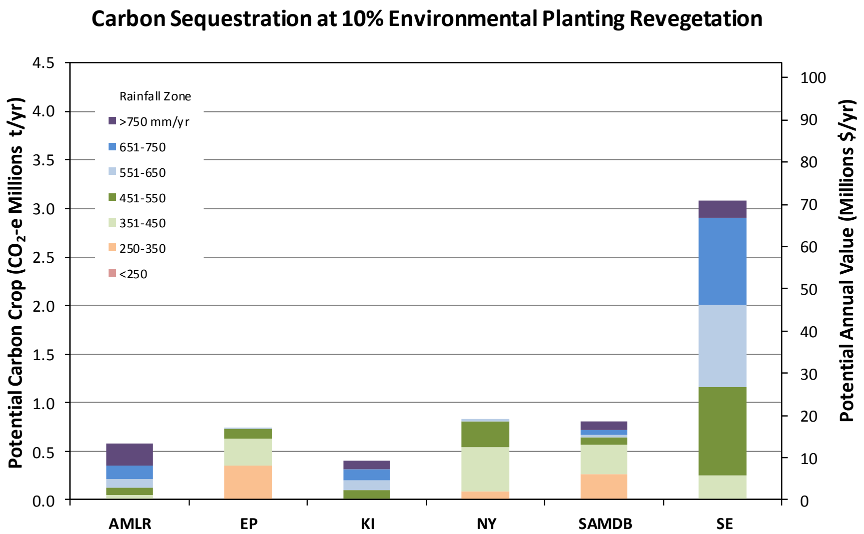


Figure 20. Potential annual carbon crop and annual value (at $23/t CO_2-e) based on 10% target utilisation of Environmental Plantings (88%trees) on agricultural land by NRM Regions and rainfall zones.

Adelaide and Mt Lofty Ranges NRM Region

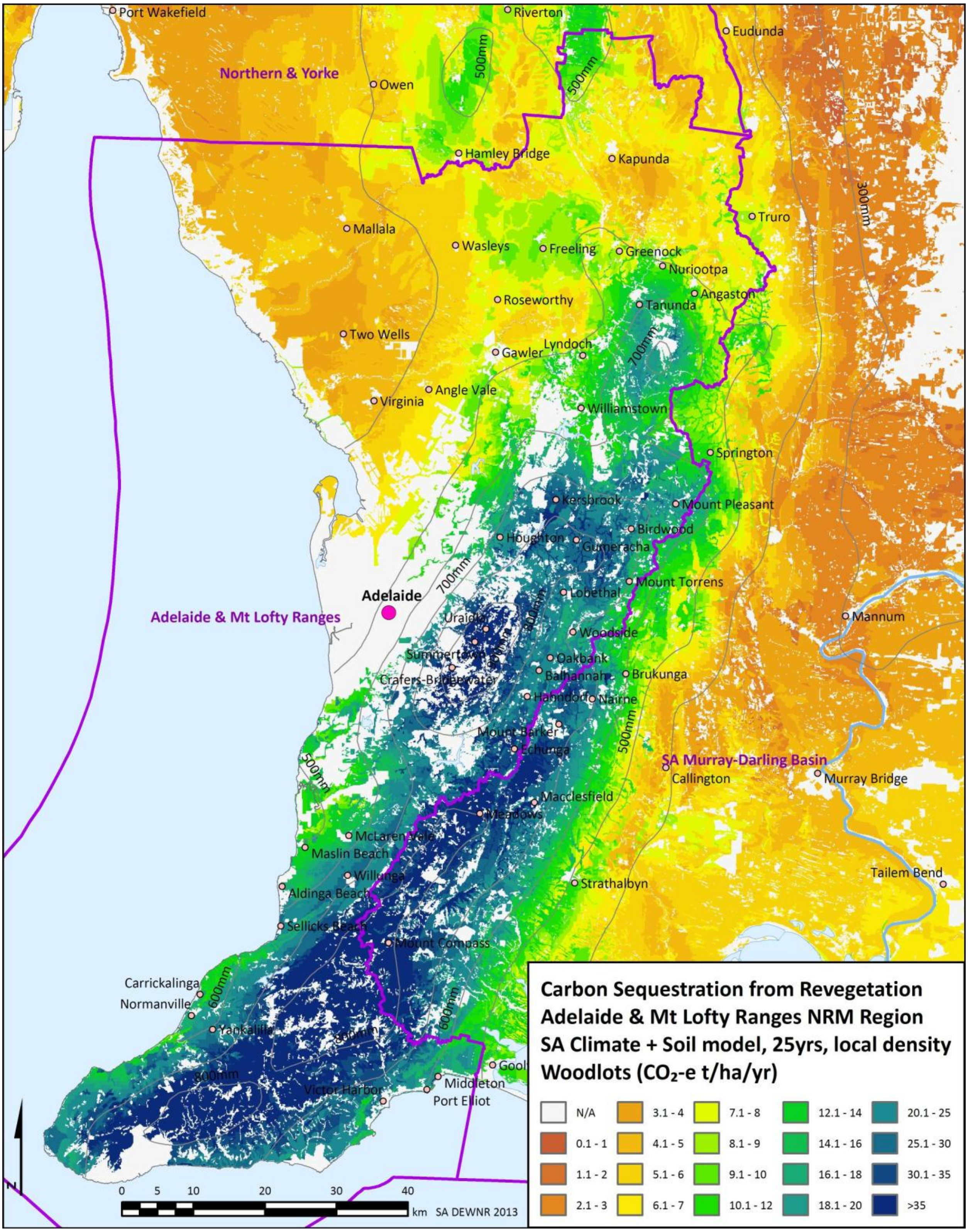


Figure 21. Estimated average carbon sequestration rates (first 25 years) from Woodlots in the Adelaide and Mt Lofty Ranges NRM Region.

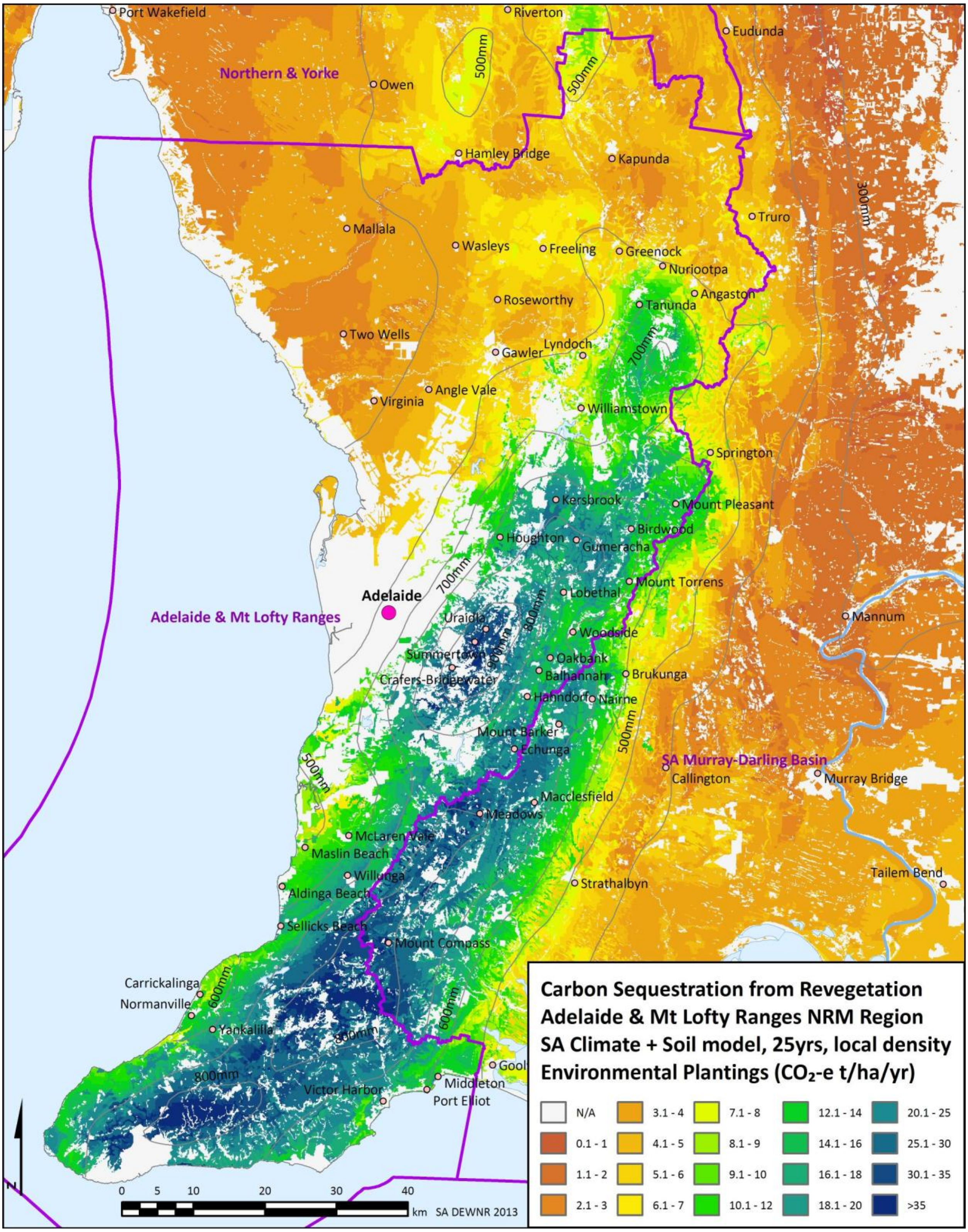


Figure 22. Estimated average carbon sequestration rates (first 25 years) from typical Environmental Plantings (88% trees) in the Adelaide and Mt Lofty Ranges NRM Region.

Eyre Peninsula NRM Region

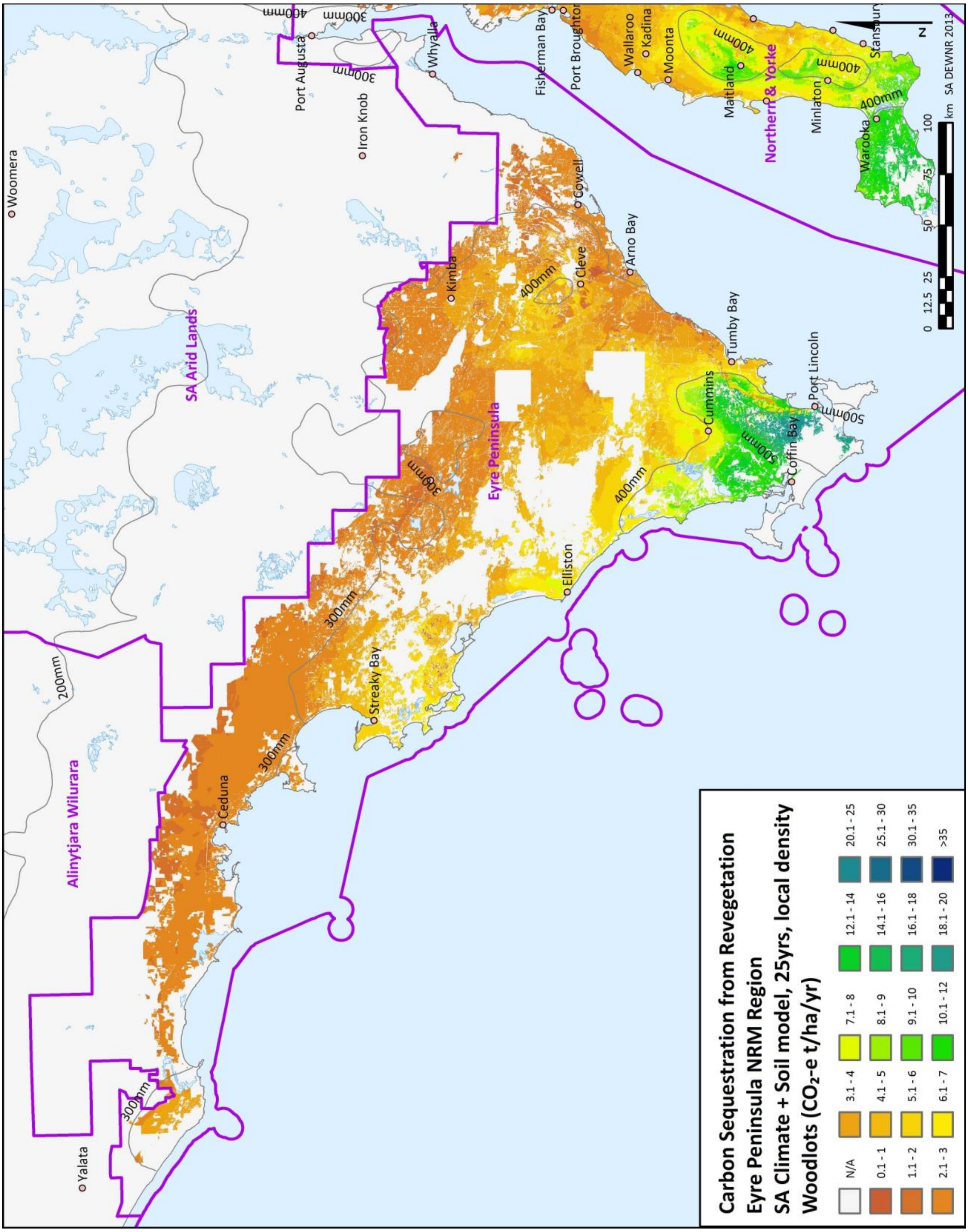


Figure 23. Estimated average carbon sequestration rates (first 25 years) from Woodlots in the Eyre Peninsula NRM Region.

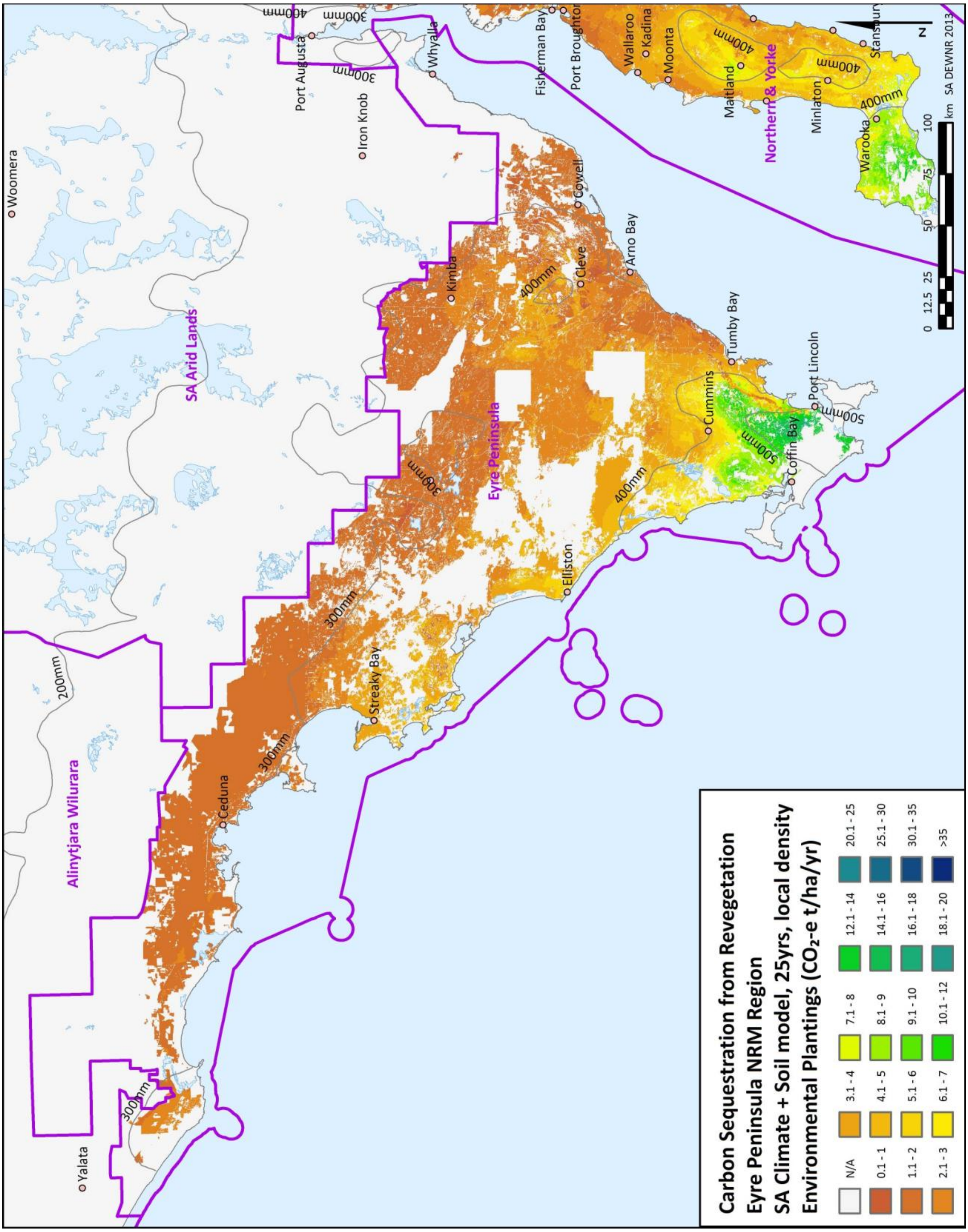


Figure 24. Estimated average carbon sequestration rates (first 25 years) from typical Environmental Plantings (88% trees) in the Eyre Peninsula NRM Region.

Northern and Yorke NRM Region

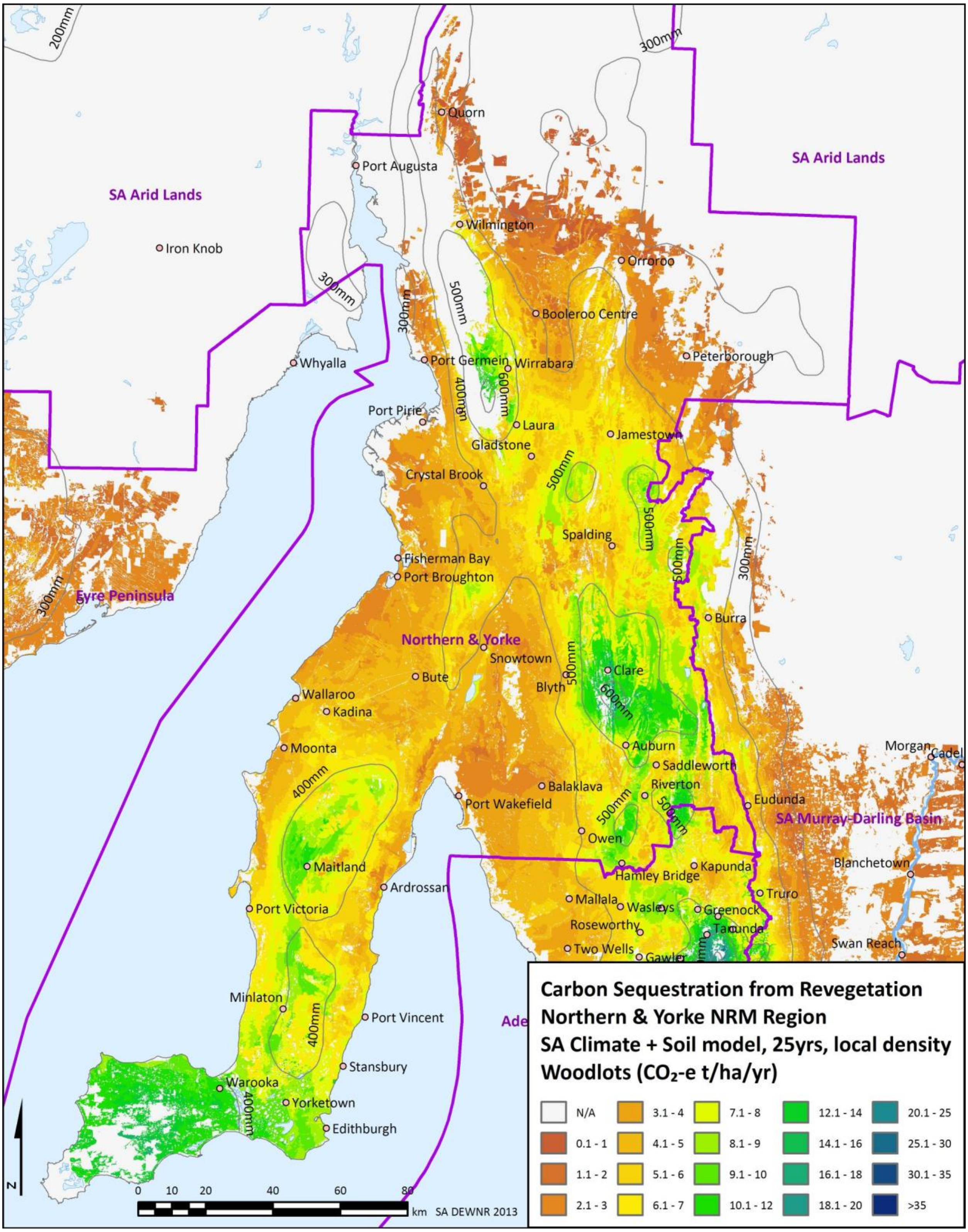


Figure 25. Estimated average carbon sequestration rates (first 25 years) from Woodlots in the Northern and Yorke NRM Region.

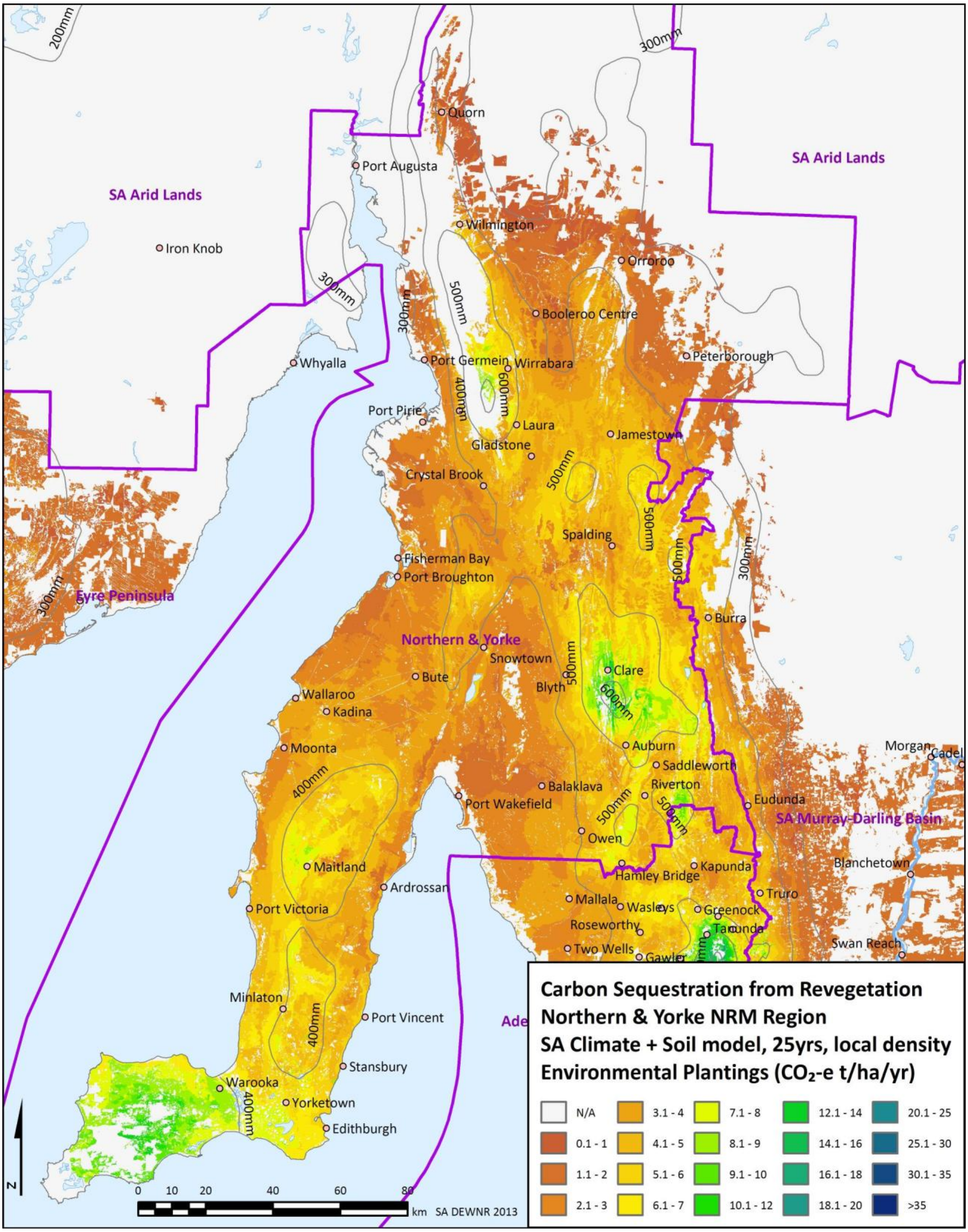


Figure 26. Estimated average carbon sequestration rates (first 25 years) from typical Environmental Plantings (88% trees) in the Northern and Yorke NRM Region.

SA Murray-Darling Basin NRM Region

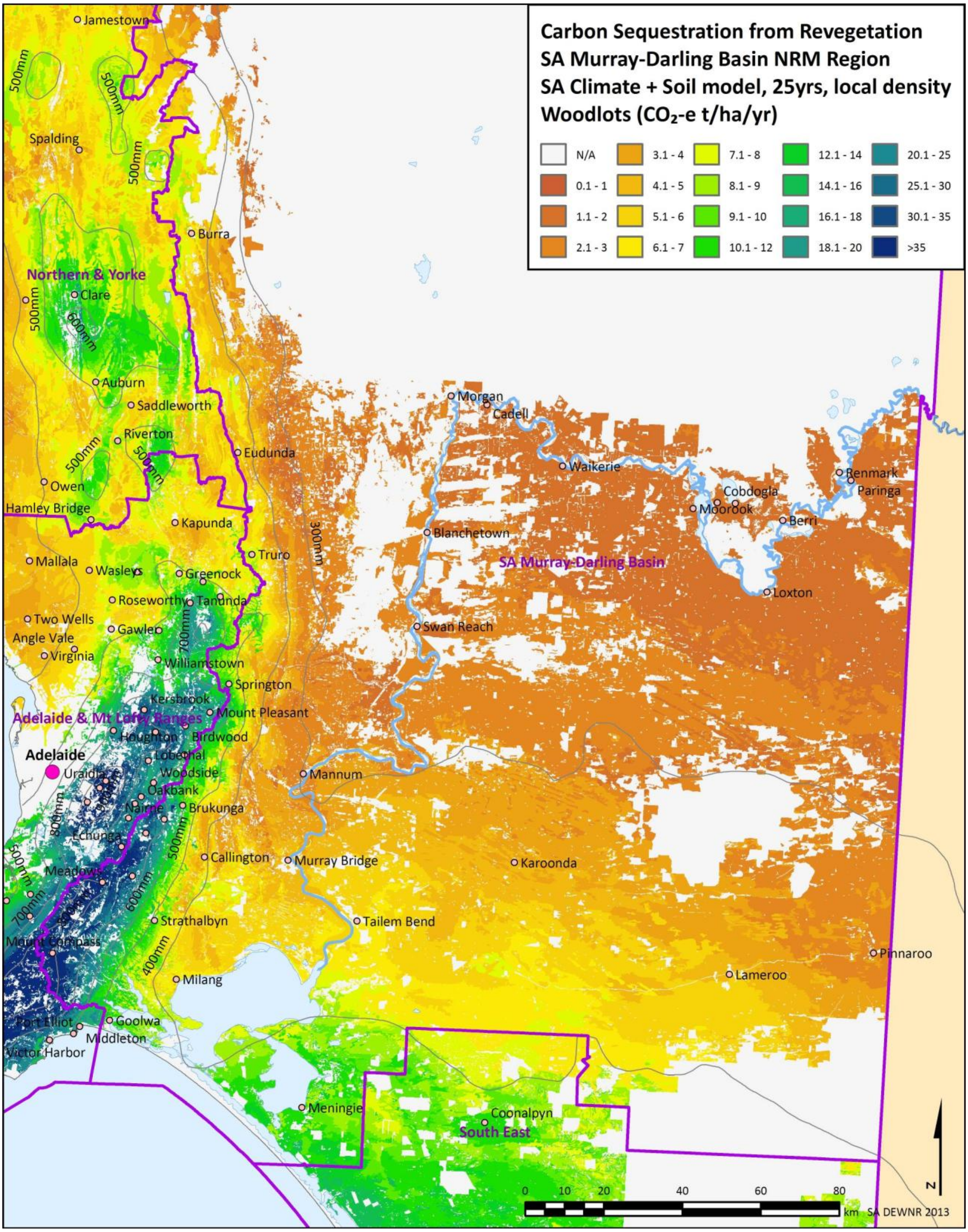


Figure 27. Estimated average carbon sequestration rates (first 25 years) from Woodlots in the SA Murray-Darling Basin NRM Region.

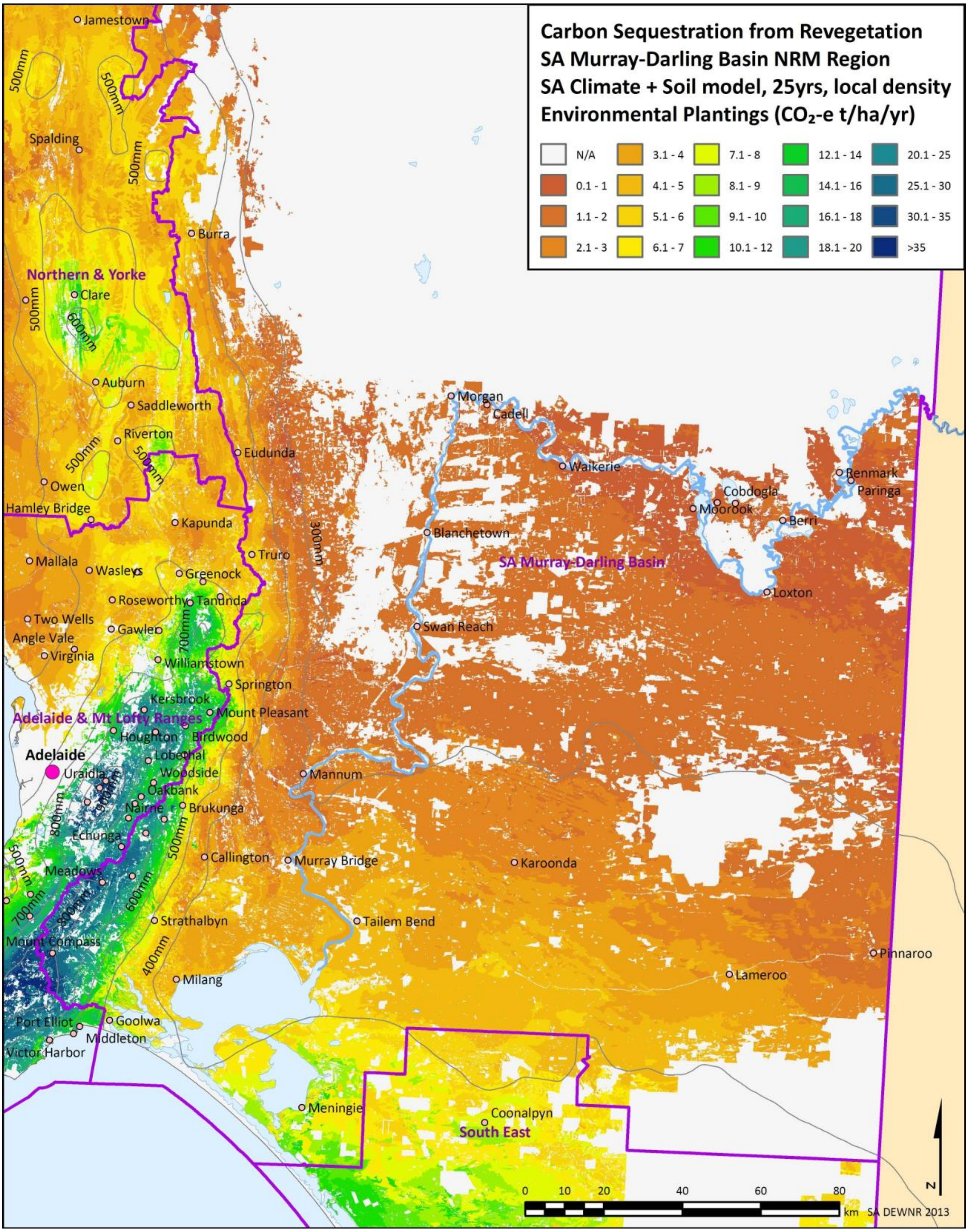


Figure 28. Estimated average carbon sequestration rates (first 25 years) from typical Environmental Plantings (88% trees) in the SA Murray-Darling Basin NRM Region.

South East NRM Region

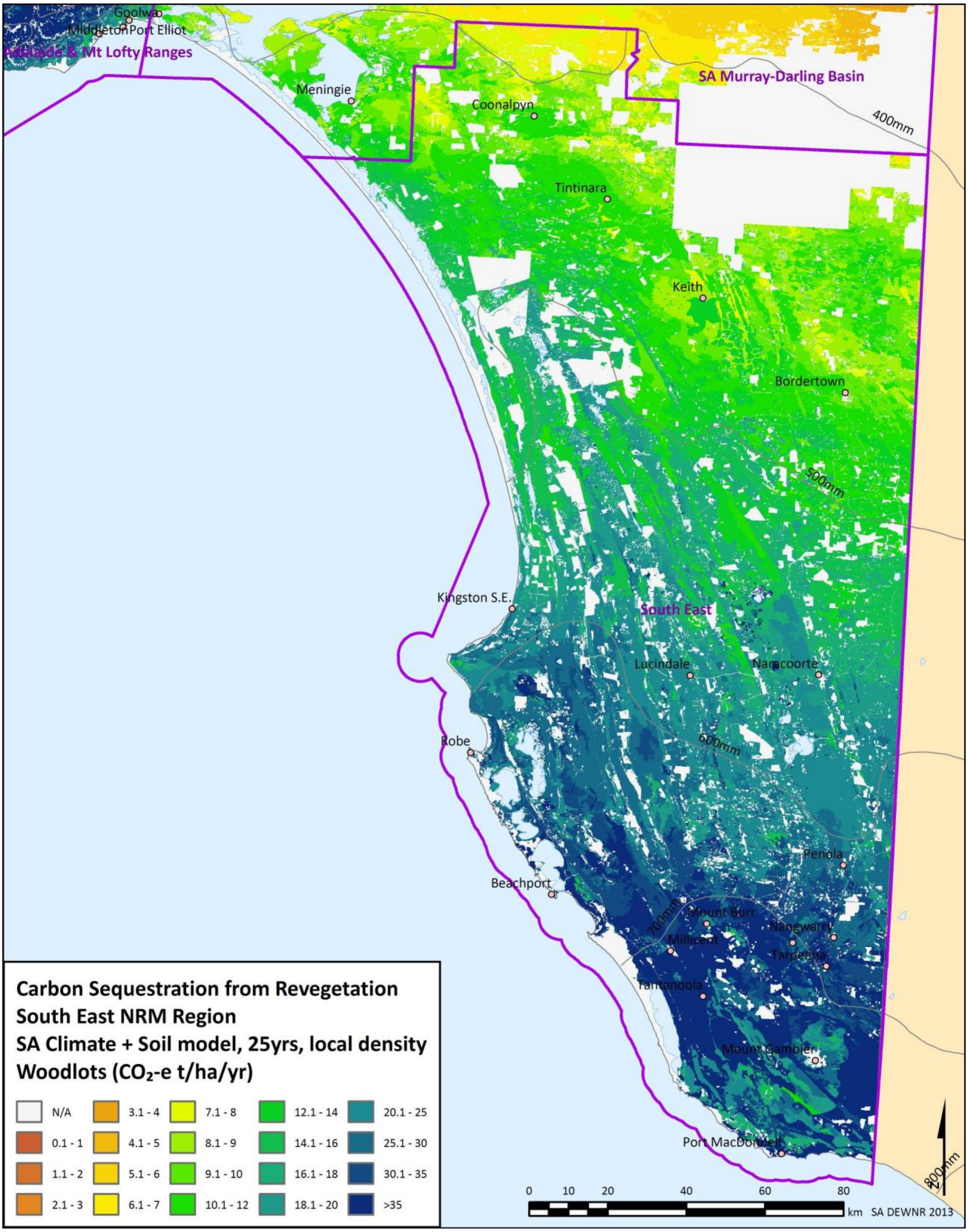


Figure 29. Estimated average carbon sequestration rates (first 25 years) from Woodlots in the South East NRM Region.

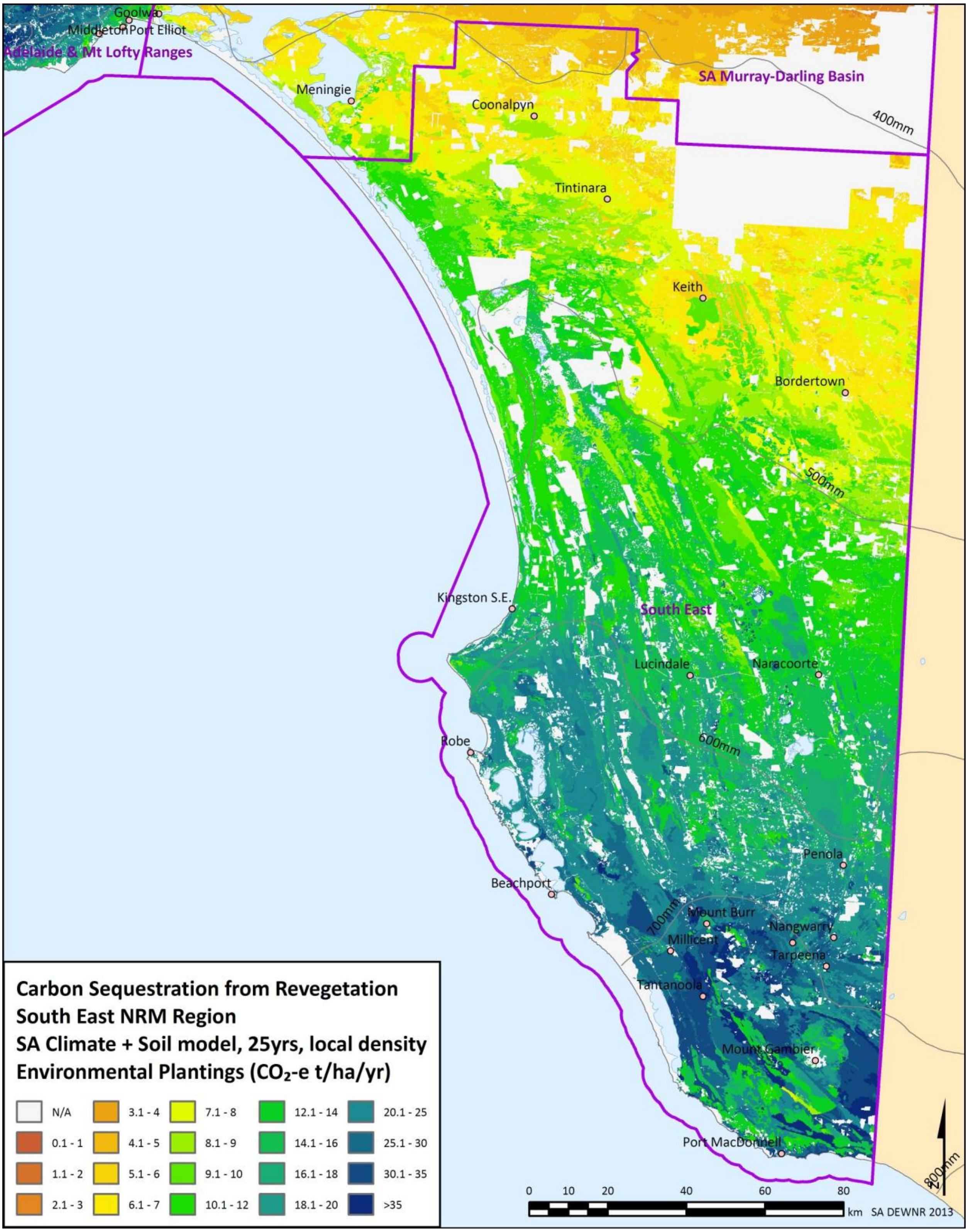


Figure 30. Estimated average carbon sequestration rates (first 25 years) from typical Environmental Plantings (88% trees) in the South East NRM Region.

Kangaroo Island NRM Region

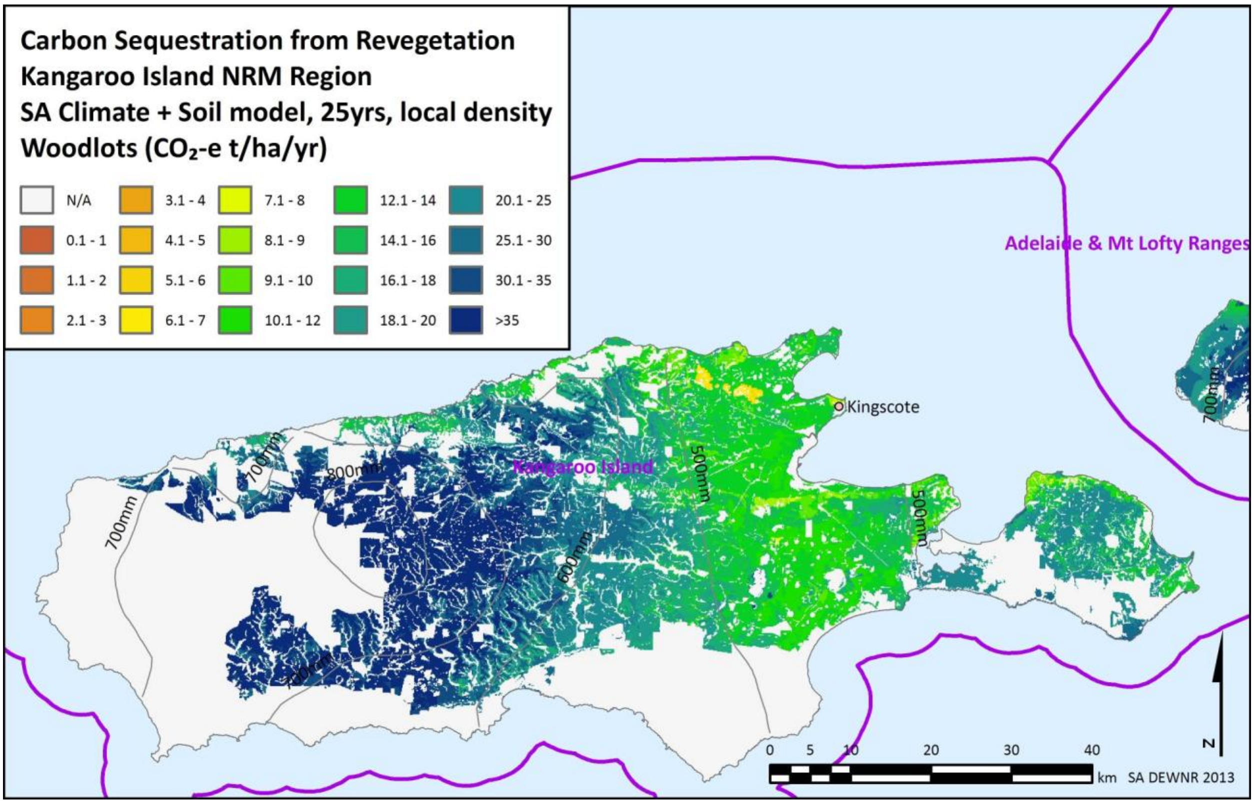


Figure 31. Estimated average carbon sequestration rates (first 25 years) from Woodlots in the Kangaroo Island NRM Region.

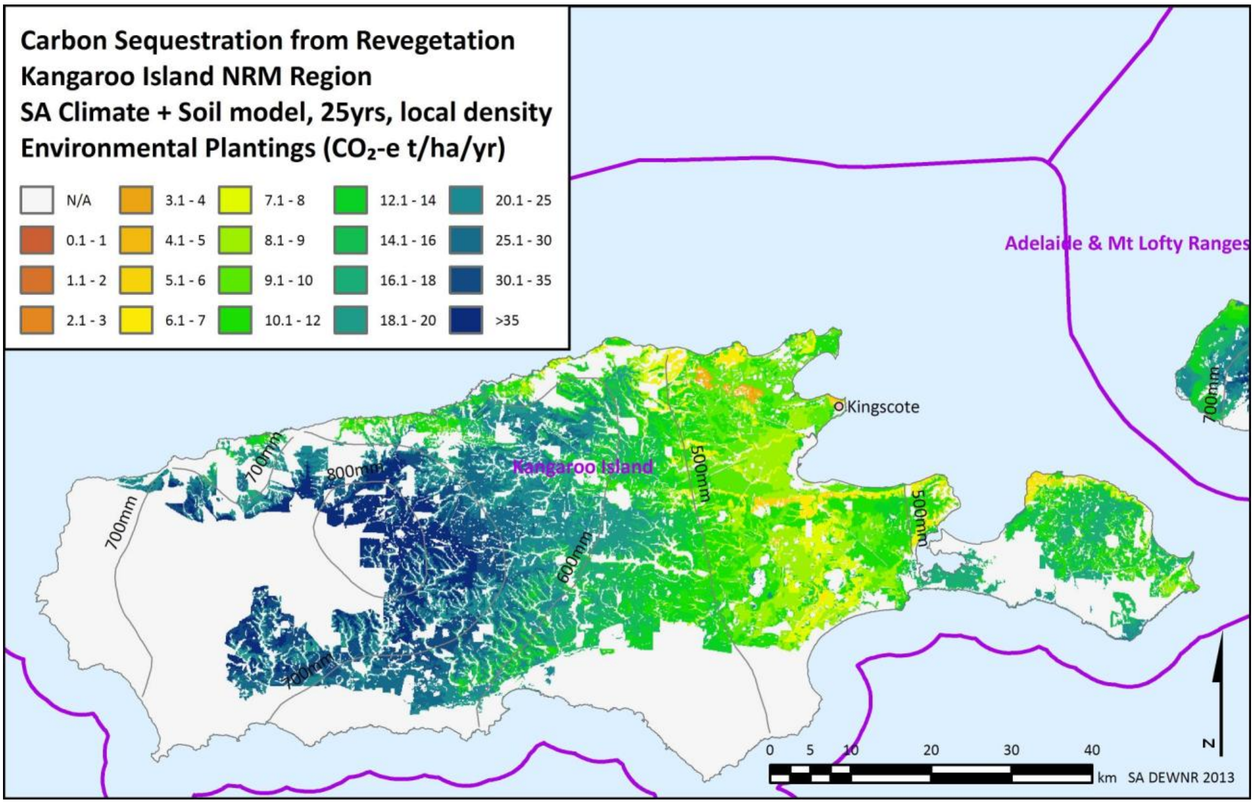


Figure 32. Estimated average carbon sequestration rates (first 25 years) from typical Environmental Plantings (88% trees) in the Kangaroo Island NRM Region.

Cropping Districts

Table 25. Summary of average annual rainfall, and estimated planting density and carbon sequestration rates for revegetation (Woodlots - 100% trees; Environmental Plantings - 88% trees) in agricultural lands by Cropping Districts of South Australia.

			Woodlots			Environmental Plantings		
				Carbon Sequestration Rate (CO_2-e t/ha/yr)			Carbon Sequestration Rate (CO_2-e t/ha/yr)	
Cropping District	Agricultural Land (ha)	Annual Rainfall (mm/yr)	Plant Density (plants/ha)	Mean	*s.d.*	Plant Density (plants/ha)	Mean	*s.d.*
Central Hills/Fleurieu Pen	374,810	643	854	22.81	*13.02*	932	16.54	*9.53*
Lower Eyre Pen	465,470	410	554	8.09	*4.17*	604	5.80	*3.14*
Eastern Eyre Pen	762,010	326	396	3.04	*0.98*	432	2.01	*0.75*
Western Eyre Pen	1,513,830	311	327	3.14	*1.25*	356	2.13	*0.96*
Kangaroo Island	222,800	590	951	24.86	*13.42*	1038	17.98	*9.84*
Lower North	302,930	462	561	7.48	*3.92*	612	5.33	*2.94*
Mid North	817,550	419	511	5.63	*2.54*	558	3.94	*1.91*
Upper North	755,460	410	475	4.48	*2.09*	519	3.09	*1.57*
Yorke Pen	711,980	385	493	6.63	*2.63*	537	4.74	*1.99*
Northern Murray	643,410	266	321	1.91	*0.33*	350	1.16	*0.25*
Southern Murray	715,350	333	420	3.87	*1.32*	458	2.64	*1.01*
Lower Murray	476,140	333	439	3.82	*2.09*	479	2.59	*1.57*
Upper South East	1,424,070	462	618	11.97	*4.78*	674	8.71	*3.53*
Lower South East	994,410	638	1052	27.70	*9.50*	1148	19.99	*6.90*

Planning Divisions

Table 26. Summary of average annual rainfall, and estimated planting density and carbon sequestration rates for revegetation (Woodlots - 100% trees; Environmental Plantings - 88% trees) in agricultural lands by government Planning Divisions of South Australia.

			Woodlots			Environmental Plantings		
				Carbon Sequestration Rate (CO_2-e t/ha/yr)			Carbon Sequestration Rate (CO_2-e t/ha/yr)	
Planning Divisions	Agricultural Land (ha)	Annual Rainfall (mm/yr)	Plant Density (plants/ha)	Mean	*s.d.*	Plant Density (plants/ha)	Mean	*s.d.*
Adelaide Hills	107,750	718	859	24.09	*10.39*	938	17.53	*7.64*
Eastern Adelaide	750	719	835	19.30	*4.66*	911	14.11	*3.28*
Southern Adelaide	41,310	649	852	20.46	*7.06*	931	14.86	*5.19*
Western Adelaide	1,900	423	495	6.08	*0.54*	540	4.45	*0.42*
Northern Adelaide	35,430	480	571	7.73	*3.25*	623	5.56	*2.45*
Fleurieu & Kangaroo Island	452,590	599	900	23.69	*14.14*	982	17.14	*10.34*
Eyre & Western	2,742,870	332	384	3.95	*2.75*	419	2.72	*2.07*
Yorke & Mid North	2,258,480	406	494	5.61	*2.56*	540	3.94	*1.93*
Barossa, Light, Lower North	278,970	461	560	7.52	*4.00*	612	5.36	*3.00*
Far North	28,150	342	384	1.61	*0.92*	420	0.97	*0.64*
Murray & Mallee	2,477,130	339	430	4.80	*3.45*	469	3.34	*2.62*
Limestone Coast	1,776,290	575	888	21.68	*10.37*	969	15.69	*7.49*

Local Government Regions

Table 27. Summary of average annual rainfall, and estimated planting density and carbon sequestration rates for revegetation (Woodlots - 100% trees; Environmental Plantings - 88% trees) in agricultural lands by Local Government regions of South Australia.

Local Government	Agricul-tural Land (ha)	Annual Rainfall (mm/yr)	Woodlots Plant Density (plants/ha)	Woodlots Carbon Sequestration Rate (CO_2-e t/ha/yr) Mean	Woodlots Carbon Sequestration Rate (CO_2-e t/ha/yr) *s.d.*	Environmental Plantings Plant Density (plants/ha)	Environmental Plantings Carbon Sequestration Rate (CO_2-e t/ha/yr) Mean	Environmental Plantings Carbon Sequestration Rate (CO_2-e t/ha/yr) *s.d.*
Adelaide Hills	55,780	773	883	25.91	*8.37*	963	18.89	*6.11*
Alexandrina	137,800	522	716	15.17	*11.94*	781	10.96	*8.80*
Barossa	76,880	560	644	11.63	*5.13*	703	8.43	*3.85*
Barunga West	150,500	353	397	3.94	*0.77*	433	2.72	*0.59*
Berri Barmera	16,180	238	295	1.66	*0.27*	322	0.97	*0.22*
Burnside	510	775	918	21.64	*3.32*	1002	15.69	*2.43*
Campbelltown	190	605	660	14.59	*2.30*	719	10.98	*1.76*
Ceduna	378,570	276	283	2.23	*0.29*	308	1.44	*0.23*
Clare And Gilbert Valleys	175,490	507	606	8.44	*2.43*	662	6.04	*1.83*
Cleve	319,870	342	421	3.71	*0.94*	459	2.52	*0.73*
Copper Coast	73,030	356	418	4.92	*0.84*	456	3.47	*0.64*
Elliston	303,200	357	406	4.69	*1.06*	443	3.30	*0.81*
Flinders Ranges	25,220	348	390	1.59	*0.97*	426	0.96	*0.67*
Franklin Harbour	167,650	305	388	2.46	*0.85*	424	1.56	*0.64*
Gawler	2,970	479	586	7.91	*1.07*	640	5.67	*0.79*
Goyder	319,530	407	508	4.94	*2.18*	555	3.41	*1.63*
Grant	175,350	726	1264	34.24	*11.21*	1380	24.57	*8.33*
Kangaroo Island	222,920	590	951	24.85	*13.42*	1038	17.98	*9.84*
Karoonda East Murray	359,360	315	406	3.45	*0.97*	442	2.33	*0.74*
Kimba	274,460	318	372	2.62	*0.52*	406	1.70	*0.40*
Kingston	259,800	543	799	19.11	*4.85*	872	13.93	*3.56*
Light	120,750	455	558	6.80	*1.71*	610	4.82	*1.29*
Lower Eyre Peninsula	246,040	440	577	9.77	*4.28*	630	7.07	*3.21*
Loxton Waikerie	557,710	268	324	1.94	*0.32*	353	1.18	*0.25*
Mallala	78,370	374	480	4.57	*0.73*	524	3.15	*0.58*
Marion	1,880	563	734	13.56	*3.70*	802	9.84	*2.81*
Mid Murray	338,040	324	418	3.38	*2.24*	456	2.25	*1.68*
Mitcham	2,030	740	882	22.85	*6.65*	963	16.64	*4.84*
Mount Barker	51,970	660	834	22.13	*11.88*	910	16.08	*8.76*
Mount Gambier	1,000	729	1455	26.21	*3.83*	1590	18.46	*2.77*
Mount Remarkable	172,720	396	456	3.94	*2.39*	499	2.68	*1.79*
Murray Bridge	138,100	355	491	4.91	*1.07*	536	3.41	*0.82*
Naracoorte Lucindale	399,880	566	882	20.56	*4.53*	963	14.92	*3.38*
Northern Areas	277,420	461	531	6.00	*1.42*	581	4.22	*1.08*
Onkaparinga	37,390	648	857	20.68	*7.02*	936	15.02	*5.15*
Orroroo/Carrieton	88,920	365	441	2.88	*1.57*	482	1.88	*1.15*
Peterborough	47,660	339	433	2.48	*0.63*	473	1.55	*0.47*
Playford	23,960	468	567	7.10	*2.83*	620	5.05	*2.12*
Port Augusta	1,500	302	342	1.84	*0.31*	374	1.09	*0.26*
Port Lincoln	1,410	513	715	14.07	*4.25*	780	10.23	*3.25*
Port Pirie	142,040	392	438	4.38	*1.07*	478	3.03	*0.81*
Renmark Paringa	57,570	257	301	1.67	*0.23*	329	0.98	*0.18*

Local Government	Agricul-tural Land (ha)	Annual Rainfall (mm/yr)	Woodlots Plant Density (plants/ha)	Woodlots Carbon Sequestration Rate (CO_2-e t/ha/yr) Mean	*s.d.*	Environmental Plantings Plant Density (plants/ha)	Environmental Plantings Carbon Sequestration Rate (CO_2-e t/ha/yr) Mean	*s.d.*
Robe	81,660	640	1075	28.41	*3.38*	1174	20.50	*2.51*
Salisbury	6,980	442	513	6.65	*0.96*	559	4.86	*0.77*
Southern Mallee	355,990	351	434	4.28	*1.48*	473	2.96	*1.14*
Streaky Bay	377,870	320	320	3.52	*1.29*	349	2.44	*1.00*
Tatiara	522,030	470	619	11.51	*2.53*	676	8.38	*1.90*
Tea Tree Gully	4,090	611	689	13.10	*3.12*	752	9.62	*2.38*
The Coorong	642,220	423	543	9.46	*2.98*	592	6.88	*2.25*
Tumby Bay	218,070	377	526	6.14	*3.03*	575	4.33	*2.29*
Victor Harbor	30,760	746	1037	35.49	*9.77*	1132	25.76	*7.12*
Wakefield	322,530	383	463	4.79	*1.75*	505	3.33	*1.32*
Wattle Range	336,560	677	1136	32.61	*8.18*	1240	23.50	*5.96*
Wudinna	322,580	302	323	2.54	*0.48*	352	1.66	*0.38*
Yankalilla	61,120	727	1061	32.71	*11.55*	1158	23.65	*8.42*
Yorke Peninsula	488,520	399	533	7.72	*2.44*	582	5.55	*1.86*

Interim Biogeographic Regions

Table 28. Summary of average annual rainfall, and estimated planting density and carbon sequestration rates for revegetation (Woodlots - 100% trees; Environmental Plantings - 88% trees) in agricultural lands by IBRA subregions of South Australia.

IBRA Subregion	Agricul-tural Land (ha)	Annual Rainfall (mm/yr)	Woodlots Plant Density (plants/ha)	Woodlots Carbon Sequestration Rate (CO_2-e t/ha/yr) Mean	*s.d.*	Environmental Plantings Plant Density (plants/ha)	Environmental Plantings Carbon Sequestration Rate (CO_2-e t/ha/yr) Mean	*s.d.*
Bridgewater	343,220	650	1113	29.29	*9.34*	1215	21.08	*6.73*
Broughton	920,610	454	543	6.14	*2.29*	594	4.32	*1.73*
Eyre Hills	803,540	368	477	5.33	*4.13*	521	3.72	*3.10*
Eyre Mallee	1,454,900	302	330	2.81	*0.84*	360	1.87	*0.64*
Fleurieu	321,190	584	774	18.53	*14.56*	845	13.38	*10.65*
Glenelg Plain	140,680	697	1082	35.06	*8.90*	1181	25.40	*6.59*
Kangaroo Island	222,840	590	951	24.86	*13.42*	1038	17.98	*9.84*
Lowan Mallee	511,790	403	501	7.69	*4.41*	546	5.53	*3.32*
Lucindale	634,160	572	885	21.47	*6.09*	966	15.58	*4.44*
Mount Gambier	79,130	746	1325	34.66	*11.74*	1447	24.81	*8.73*
Mount Lofty Ranges	210,420	648	785	19.11	*10.01*	857	13.89	*7.35*
Murray Lakes and Coorong	97,860	413	578	9.27	*2.69*	630	6.70	*2.03*
Murray Mallee	1,655,890	310	397	3.39	*1.64*	433	2.27	*1.24*
Murray Scroll Belt	58,120	247	303	1.64	*0.30*	330	0.95	*0.24*
Southern Flinders	175,910	388	445	3.54	*2.66*	487	2.39	*1.98*
Southern Yorke	346,880	398	544	8.32	*2.44*	593	6.00	*1.86*
St Vincent	955,110	379	453	4.78	*1.55*	494	3.33	*1.17*
Talia	454,790	367	402	5.29	*1.95*	439	3.77	*1.47*
Tintinara	568,100	458	585	11.29	*2.67*	637	8.24	*2.02*
Wimmera	127,490	512	807	15.25	*4.28*	882	11.01	*3.14*

Trees For Life Zones

Table 29. Summary of average annual rainfall, and estimated planting density and carbon sequestration rates for revegetation (Woodlots - 100% trees; Environmental Plantings - 88% trees) in agricultural lands by Trees For Life zones of South Australia.

Trees For Life Zones	Agricul-tural Land (ha)	Annual Rainfall (mm/yr)	Woodlots Plant Density (plants/ha)	Woodlots Carbon Sequestration Rate (CO_2-e t/ha/yr) Mean	Woodlots Carbon Sequestration Rate (CO_2-e t/ha/yr) *s.d.*	Environmental Plantings Plant Density (plants/ha)	Environmental Plantings Carbon Sequestration Rate (CO_2-e t/ha/yr) Mean	Environmental Plantings Carbon Sequestration Rate (CO_2-e t/ha/yr) *s.d.*
AH Adelaide Hills	122,550	690	839	22.20	*11.14*	915	16.13	*8.18*
AP Adelaide Plains	137,990	396	498	5.24	*1.25*	544	3.67	*0.97*
AS Adelaide South	4,130	621	769	16.50	*5.64*	839	12.04	*4.19*
BV Barossa Region	125,700	482	584	7.67	*2.69*	638	5.46	*2.02*
CH Central Hills	80,130	604	683	14.36	*6.95*	746	10.46	*5.18*
NO Noarlunga	9,930	556	727	14.69	*3.96*	794	10.68	*2.96*
VI Victor Harbor	30,850	746	1037	35.51	*9.77*	1132	25.78	*7.13*
WN Willunga	15,790	639	904	21.04	*5.14*	988	15.24	*3.74*
YA Yankalilla D.C.	60,990	727	1061	32.70	*11.55*	1158	23.65	*8.41*
CD Ceduna D.C.	378,640	276	283	2.23	*0.29*	308	1.44	*0.23*
CV Cleve D.C.	319,800	342	421	3.71	*0.94*	459	2.52	*0.73*
EL Elliston D.C.	303,270	357	406	4.69	*1.06*	443	3.30	*0.81*
FH Franklin Harbour D.C.	167,640	305	388	2.46	*0.85*	424	1.56	*0.64*
KB Kimba D.C.	273,270	319	372	2.63	*0.51*	406	1.70	*0.39*
LH Le Hunte D.C.	322,640	302	323	2.54	*0.48*	352	1.66	*0.38*
LE Lower Eyre Peninsula D.C.	248,720	440	577	9.77	*4.29*	630	7.07	*3.22*
SK Streaky Bay D.C.	377,760	320	320	3.52	*1.29*	349	2.44	*1.00*
TU Tumby Bay D.C.	216,760	377	527	6.15	*3.04*	575	4.33	*2.29*
KI Kangaroo Island	222,870	590	951	24.85	*13.42*	1038	17.98	*9.84*
CY Central Yorke Peninsula	245,840	394	509	6.38	*1.65*	555	4.53	*1.26*
CG Clare & Gilbert	175,420	507	606	8.44	*2.43*	662	6.04	*1.83*
FN Far North	202,780	305	327	2.22	*0.81*	357	1.43	*0.59*
FR Flinders Ranges	225,130	408	472	4.18	*2.10*	516	2.85	*1.57*
ML Minlaton	88,510	391	538	7.20	*1.20*	587	5.15	*0.92*
LN Northern Lofty Ranges	242,580	466	530	6.17	*1.31*	579	4.36	*1.00*
YU Upper Yorke Peninsula	345,210	365	414	4.25	*0.95*	451	2.95	*0.72*
WA Wakefield	322,600	383	463	4.79	*1.75*	505	3.33	*1.32*
WR Warooka	84,840	426	565	11.67	*1.43*	616	8.56	*1.09*
YO Yorketown	69,240	390	576	8.32	*1.27*	629	5.98	*0.98*
PH Alexandrina Hills	60,660	667	868	24.87	*12.04*	947	18.11	*8.88*
PP Alexandrina Plains	77,230	408	597	7.54	*2.91*	651	5.35	*2.18*
GO Goyder	319,550	407	508	4.94	*2.18*	555	3.41	*1.63*
NP North East Pastoral	138,910	333	415	2.84	*1.64*	453	1.84	*1.23*
MN Northern Murray Mallee	792,790	271	332	2.06	*0.44*	362	1.27	*0.34*
MS Southern Murray Mallee	886,220	344	449	4.50	*1.46*	490	3.12	*1.11*
MW Western Murray Mallee	187,610	321	417	2.99	*1.25*	455	1.96	*0.94*
BL Borderlands	135,500	500	761	13.72	*3.26*	831	9.90	*2.39*
CO Coorong	148,640	477	669	13.80	*3.76*	730	10.06	*2.76*
MX Lower Mallee	695,910	438	542	9.74	*2.65*	590	7.10	*2.01*
SE Lower South East	586,500	658	1090	29.80	*8.23*	1190	21.50	*6.02*
SC Lower South East Coastal	181,040	696	1214	32.53	*10.49*	1326	23.36	*7.69*
SU Upper South East	560,310	528	759	17.19	*4.81*	828	12.53	*3.57*

PRELIMINARY ESTIMATES OF CARBON STOCKS IN REMNANT VEGETATION

A regional analysis of the estimated above-ground standing carbon (CO_2-e) for current and historic native vegetation was conducted using the DEWNR "Climate" and "Climate plus Soil Model" (see Table 16) and national mapping of the spatial extent of remnant (i.e. extant) and pre-1750 vegetation (NVIS Version 4.1, DSEWPC 2012b). Woody plant communities (e.g. forests, woodlands, mallees & shrublands) were identified using major group classifications of the NVIS for current remnant vegetation and pre-1750 vegetation extent. Non-woody and very sparse tree/shrub plant communities (e.g. grasslands, herbfields, sedgelands, low shrublands, very sparse woodland/shrublands) were excluded from this analysis. Results are spatially constrained to non-arid NRM Regions and the limits of South Australian soil mapping (Hall et al. 2009).

The area and estimated carbon content (t CO_2-e) of above-ground biomass of Kyoto-compliant plants (≥2metres tall) found within woody native vegetation has been collated for the agricultural regions of state (Table 30, Table 31, Table 32). It does not include roots, plant litter, shrubs <2m tall, grasses or herbaceous plants. The reliability and accuracy of classification and spatial extent of remnant and pre-1750 native vegetation mapping, and DEWNR carbon models, generally decreases in northern parts of the state. These preliminary estimates of carbon stocks in woody native vegetation would be enhanced with more detailed vegetation mapping, additional on-ground surveys and reanalysis.

Results have also been summarised for 2 groups of tenure and management: **1) Parks** and reserves (publicly owned); and **2) Private** and leasehold lands. A clear result of this study is that woody native vegetation communities on privately managed lands significantly contribute (~66% by area; ~59% by stock) to the woody vegetation carbon accounts for the state. Land clearing in the agricultural regions of the state has also reduced carbon stocks in woody native vegetation to around 26% of previous levels. Additional woody remnant vegetation carbon stocks located outside of the soil mapping region, but within southern NRM Regions, is approximately 45 Mt CO_2-e (EP +10.0, NY +2.4, SAMDB +32.6).

Table 30. Area of woody remnant vegetation in government Parks and reserves or Privately managed lands, and pre-1750 woody vegetation extent, by NRM Region and rainfall zone in South Australia.

	Area of Woody Vegetation[1] (ha '000s)								
	Remnant by Rainfall Zone (mm/yr)								Pre-1750
NRM Region*	≤250	251-350	351-450	451-550	551-650	651-750	>750	Total	*Cur.Extent*
AMLR		0.8	4.0	7.7	12.6	15.4	31.8	**72.3**	**615.2**
Parks		0.0%	0.0%	5.1%	27.4%	13.6%	23.9%	18.7%	*11.7%*
Private		100.0%	100.0%	94.9%	72.6%	86.4%	76.1%	81.3%	
EP#	59.2	1,130.1	370.7	115.2	2.9			**1,678.2**	**4,359.8**
Parks	92.2%	34.6%	21.7%	34.6%	0.0%			33.8%	*38.5%*
Private	7.8%	65.4%	78.3%	65.4%	100.0%			66.2%	
KI			1.6	61.4	40.5	66.9	38.8	**209.2**	**426.4**
Parks			0.0%	52.1%	38.4%	63.6%	74.7%	56.9%	*49.1%*
Private			100.0%	47.9%	61.6%	36.4%	25.3%	43.1%	
NY#	5.2	147.6	81.6	59.6	18.6			**312.6**	**2,319.7**
Parks	0.0%	0.3%	12.5%	26.8%	49.8%			11.5%	*13.5%*
Private	100.0%	99.7%	87.5%	73.2%	50.2%			88.5%	
SAMDB#	90.8	459.5	217.9	6.6	3.3	4.6	5.0	**787.6**	**3,147.0**
Parks	17.6%	18.8%	71.5%	0.0%	8.2%	12.4%	7.9%	33.0%	*25.0%*
Private	82.4%	81.2%	28.5%	100.0%	91.8%	87.6%	92.1%	67.0%	
SE			170.0	148.5	59.5	29.2	6.7	**413.8**	**2,545.4**
Parks			65.0%	28.5%	12.2%	22.2%	9.8%	40.4%	*16.3%*
Private			35.0%	71.5%	87.8%	77.8%	90.2%	59.6%	
Remnant	**155.1**	**1,738.0**	**845.8**	**398.9**	**137.5**	**116.1**	**82.2**	**3,473.6**	**13,413.6**
Parks	45.5%	27.5%	42.2%	32.7%	26.1%	44.5%	45.8%	33.5%	*25.9%*
Private	54.5%	72.5%	57.8%	67.3%	73.9%	55.5%	54.2%	66.5%	
Pre-1750	**323.6**	**5,708.0**	**3,556.1**	**2,061.8**	**848.4**	**624.7**	**291.0**	**13,413.6**	
Current Extent	*47.9%*	*30.4%*	*23.8%*	*19.3%*	*16.2%*	*18.6%*	*28.2%*	*25.9%*	

[1] Excludes non-woody (e.g. grasslands, herbfields, sedgelands, low shrublands) and very sparse tree/shrub plant communities.
* NRM Regions: Adelaide & Mt Lofty Ranges (AMLR); Eyre Peninsula (EP); Kangaroo Island (KI); Northern & Yorke (NY); SA Murray-Darling Basin (SAMDB); South East (SE). #Excludes more arid portions of these NRM Regions and bounded by limits of SA soil mapping.

Table 31. Average above-ground standing carbon of woody remnant vegetation in government Parks and reserves or Privately managed lands by NRM Region and rainfall zone in South Australia.

	Average Above-ground Carbon held by Woody Vegetation (t CO_2-e/ha)							
	Remnant by Rainfall Zone (mm/yr)							
NRM Region*	≤250	251-350	351-450	451-550	551-650	651-750	>750	Average
AMLR		112	106	217	398	581	891	**615**
Parks		0	0	265	431	563	866	691
Private		112	106	214	386	584	899	597
EP[#]	30	60	105	238	302			**81**
Parks	30	65	114	244	0			81
Private	33	57	103	234	302			81
KI			126	286	409	624	781	**509**
Parks			0	320	473	673	769	575
Private			126	250	369	539	817	421
NY[#]	16	38	153	210	324			**118**
Parks	0	45	192	244	319			246
Private	16	38	148	198	329			101
SAMDB[#]	27	52	157	211	385	554	796	**88**
Parks	26	69	169	0	447	669	854	129
Private	27	47	130	211	380	537	791	68
SE			207	263	421	635	767	**297**
Parks			215	255	444	851	771	262
Private			192	267	418	573	767	321
Average	**28**	**56**	**144**	**250**	**399**	**618**	**823**	**149**
Parks	29	66	171	266	423	691	789	181
Private	26	52	124	242	390	560	852	133

Table 32. Estimated above-ground standing carbon held by woody remnant vegetation in government Parks and reserves or Privately managed lands, and pre-1750 extent, by NRM Region and rainfall zone.

	Estimated Above-ground Carbon held by Woody Vegetation[1] (Mt CO_2-e)								
	Remnant by Rainfall Zone (mm/yr)								Pre-1750
NRM Region*	≤250	251-350	351-450	451-550	551-650	651-750	>750	Total	*Cur.Extent*
AMLR		0.09	0.43	1.66	5.04	8.94	28.29	**44.44**	**220.36**
Parks		0.0%	0.0%	6.3%	29.6%	13.2%	23.3%	21.1%	*20.2%*
Private		100.0%	100.0%	93.7%	70.4%	86.8%	76.7%	78.9%	
EP[#]	1.80	67.62	38.97	27.39	0.89			**136.67**	**337.31**
Parks	91.6%	37.8%	23.5%	35.5%	0.0%			33.7%	*40.5%*
Private	8.4%	62.2%	76.5%	64.5%	100.0%			66.3%	
KI			0.20	17.59	16.57	41.79	30.29	**106.43**	**188.33**
Parks			0.0%	58.1%	44.5%	68.5%	73.5%	64.4%	*56.5%*
Private			100.0%	41.9%	55.5%	31.5%	26.5%	35.6%	
NY[#]	0.08	5.64	12.51	12.51	6.02	0.00	0.00	**36.75**	**228.50**
Parks	0.0%	0.4%	15.7%	31.2%	49.0%			24.1%	*16.1%*
Private	100.0%	99.6%	84.3%	68.8%	51.0%			75.9%	
SAMDB[#]	2.41	23.68	34.31	1.39	1.28	2.55	3.96	**69.57**	**279.55**
Parks	17.4%	25.2%	76.6%	0.0%	9.5%	15.0%	8.5%	48.2%	*24.9%*
Private	82.6%	74.8%	23.4%	100.0%	90.5%	85.0%	91.5%	51.8%	
SE			35.17	39.11	25.02	18.51	5.11	**122.93**	**770.52**
Parks			67.5%	27.6%	12.9%	29.8%	9.8%	35.6%	*16.0%*
Private			32.5%	72.4%	87.1%	70.2%	90.2%	64.4%	
Remnant	**4.28**	**97.02**	**121.58**	**99.65**	**54.81**	**71.79**	**67.66**	**516.79**	**2,024.57**
Parks	48.2%	32.5%	50.3%	34.9%	27.7%	49.7%	43.9%	40.6%	25.5%
Private	51.8%	67.5%	49.7%	65.1%	72.3%	50.3%	56.1%	59.4%	
Pre-1750	**8.47**	**307.73**	**425.76**	**437.47**	**286.43**	**328.47**	**230.25**	**2,024.57**	
Current Extent	*50.6%*	*31.5%*	*28.6%*	*22.8%*	*19.1%*	*21.9%*	*29.4%*	*25.5%*	

[1] Excludes non-woody (e.g. grasslands, herbfields, sedgelands, low shrublands) and very sparse tree/shrub plant communities.

* NRM Regions: Adelaide & Mt Lofty Ranges (AMLR); Eyre Peninsula (EP); Kangaroo Island (KI); Northern & Yorke (NY); SA Murray-Darling Basin (SAMDB); South East (SE). [#]Excludes more arid portions of these NRM Regions and bounded by limits of SA soil mapping.

7. DISCUSSION

CARBON MARKETS, DRIVERS AND POLICIES

The emergence of the Carbon Farming Initiative (CFI), tradeable Australian Carbon Credit Units, carbon pricing and carbon markets reflects the Australian community and governments' concern over the potential impacts of climate change on the health and prosperity of rural landscapes and communities. Two broad approaches exist to assist in managing this issue:

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 and abatement. The development of renewable woody bioenergy crops could further reduce reliance on non-renewable fossil fuels. Recognition of the potential of revegetation to help address some of the issues of climate change, natural resource management and rural prosperity has gained considerable support through policies and initiatives designed to encourage revegetation activities in South Australia and nationally.

The recent expansion of existing carbon offset/credit programs, informal "green-friendly" markets and the adoption of national Carbon farming Initiative has seen an increase of interest in, and momentum towards, dedicated carbon sequestration crops, using both monocultures and environmental plantings. 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.

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. The Kyoto Protocol specifies a minimum area of only 0.2 hectares, tree crown cover of 20 per cent and a mature tree height of two metres to qualify for carbon accounting purposes (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 the needs of dominant carbon trading schemes.

The economic viability and success of any carbon sequestration plantings is highly dependent on the primary productivity of the species (or mix of species) chosen. Results from recent studies across the agricultural lands of South Australia (this study) and in the Mid-North (Neumann *et al.* 2010), Murray-Darling Basin (Hobbs *et al.* 2010) and Upper South East (Hobbs *et al.* 2006) regions suggest that monocultures of woodlot and other commercial species are often more productive than environmental plantings at the same plant density (plants/ha) particularly in higher rainfall areas. Other productivity studies within lower to medium rainfall environments have identified some highly productive species which are climatically suited many agricultural districts of the state, including Sugar Gum (Figure 33, *Eucalyptus cladocalyx*), WA Swamp Yate (*E. occidentalis*), WA York Gum (*E. loxophleba)*, Blue Mallee (*E. polybractea),* WA Swamp Mallet (*E. spathulata*) and WA Blue Mallet (*E. gardneri*) (Bennell *et al.* 2008, Kiddle *et al.* 1987, Boardman 1992, Fairlamb & Bulman 1994). In lower rainfall areas local species woodlots and environmental plantings provide opportunities to sequester carbon where traditional forestry species are climatically unsuited.

The majority of existing permanent environmental plantings in South Australia were intended to address a range of natural resource management or other

Photo: C.R. Neumann

Figure 33. Productive and well managed woodlots can sequester significant amounts of carbon in lower to medium rainfall regions of the state (30 year old coppice regrowth from Sugar Gums *Eucalyptus cladocalyx* planted in 1900, near Hamley Bridge, SA).

environmental issues, including groundwater recharge, dryland salinity, saline river discharges, wind erosion, biodiversity loss, livestock protection and amenity. Mixed species environmental plantings are seldom exact re-creations of the 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 the establishment success of each species. Species preferences and fashions are evident in many environmental plantings. Notably, many species native to Western Australian were "fashionable" in the 1970s and are commonly encountered in revegetation from that era.

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 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.

If carbon prices are the primary driver for investment in carbon crops, and monocultures are more productive than mixed species environmental plantings, then government subsidies are likely to be required to encourage greater investment in environmental plantings for biodiversity or other environmental outcomes that benefit the broader community. Ultimately it is the decision of investors, environmental policies and planning authorities to determine the right balance of compromise between carbon price-driven investments and the value of increasing local biodiversity.

CARBON ACCOUNTING, MODELS AND ASSESSMENTS

There are two key approaches to carbon accounting from revegetation in Australia:

1. Models of plantation productivity and carbon balance; and
2. Assessments or inventory of carbon stores in plantations.

Models can provide the advantage of estimating carbon sequestration into the future under a range of scenarios. These models are highly dependent on the validity of the analytical approach taken and the quality of data used for calibrations. Models represent averaged responses under a set of predefined conditions, and rely on the user providing accurate inputs for the model to function correctly. Models generally provide rapid and low-cost estimates of carbon dynamics and stores, but their reliability for carbon accounting purposes are limited. On-ground assessments, or inventory, typically provide more accurate estimates of carbon stores in plantations but usually incur higher costs from sites inspections, measurements and sampling.

The Australian Government Department of the Environment (DOTE) has identified the Reforestation Modelling Tool (RMT) and National Carbon Accounting Toolbox (NCAT) as preferred model systems for carbon accounting within Australia. At present the FullCAM model (and sub-models) within the RMT/NCAT has been predominantly populated by parameters drawn from studies of higher rainfall commercial forestry plantations. Prior research on carbon sequestration rates from revegetation in dryland agricultural zones of South Australia (Hobbs *et al.* 2010) has demonstrated that currently the RMT/NCAT can severely under-predict carbon sequestration rates in woodlots and environmental planting (27% of observed above-ground carbon sequestration) in medium to lower rainfall regions.

Recent collaborations between CSIRO, DEWNR and other research partners has been undertaken to improve the reliably of FullCAM calibrations for environmental and mallee plantings (Paul *et al.* 2012). It is envisaged that these improvements will be implemented into FullCAM in the near future and will reduce the historic bias (i.e. under prediction) in FullCAM model in South Australian landscapes. Models are useful tools to estimate average carbon sequestration rate in regions, but cannot always account for local variations in productivity. Carbon assessments using models should be used in conjunction with on-site assessments (and recalibration) to ensure the reliability of results.

On-site assessments or inventories of carbon sequestration in revegetation provide more accurate assessments of carbon stocks than model predictions, but also increases the cost of assessment. These carbon assessments can be attained using sampling or allometric estimation techniques or a combination of both. Destructively sampling a number of representative plants within a larger population can provide an estimate of the carbon stored within a site. This approach requires a statistically valid number of samples (~30 or more) to provide accurate estimates, is labour intensive, typically high cost, and removes living plants (and carbon stores) from the plantation. Allometric estimation is a commonly used technique to non-destructively assess plantation productivity and carbon stores from a limited number of measurements at a site. It provides significant advantages in cost effectiveness over destructive sampling techniques and permits repeated measurement over time on the same site without loss of individual plants.

This current study has relied on the accuracy of DEWNR allometric models developed from destructive sampling and measurements in South Australia to provide reliable estimates of above-ground plant growth and carbon sequestration from non-destructive surveys across the agricultural regions of South Australia. Great care has been taken to evaluate the reliability and robustness of the DEWNR allometric models through tests of predictions beyond sampled size ranges and validation processes using independently collected destructive data from other part of Australia. Through collaborations with CSIRO and DOTE preliminary models to estimate below-ground (root) biomass from above-ground measurements have also been developed.

Productivity and carbon sequestration in woodlots and environmental plantings in low to medium rainfall zones of South Australia is highly dependent on climate (e.g. rainfall, potential evaporation) and plant density (plants/ha). Plant density is also influenced by climate, revegetation type (e.g. woodlots, environmental plantings) and soil types (e.g. clay content). Blends of lifeform types (e.g. tree, mallee & shrub species), age of revegetation, soil depth and clay content also influence sequestration rates.

Key influences on sequestration rates can be summarised as:

- increasing rainfall (and decreasing potential evaporation) increases sequestration rates and plant density
- sequestration rates and plant density decrease with age
- higher proportions of trees at a site increases sequestration rates
- deep sandy soils are more productive than shallow or clay-rich soils
- plant density is slightly higher on clay-rich soils
- increasing inherent soil fertility does not increase sequestration rates in lower to medium rainfall regions

In this study, the age, plant density, species mixes, lifeforms and carbon sequestration rates of 264 revegetation sites (i.e. 132 woodlots, 132 environmental plantings) have been assessed across the agricultural regions of South Australia (average age = 22 years; range 3 to 131). In the past, typical environmental planting were established using tube stock plants and contained a high proportion of trees species (average 83% to 89% trees). The results presented in this report are representative of that revegetation method under current climatic conditions. However, there is an increasing trend to use direct seeding as a cost effective method to establish revegetation, and to plant higher proportions of shrubs species in "biodiverse" plantings. Direct seedling often initially produces plant densities that are much higher than those typically observed from this current study. Although competition between plants and natural attrition in directly seeded revegetation may result in longer-term plant densities similar to those experienced in this study, some caution must be exercised by users of these models when estimating carbon sequestration rates within sites established by direct seeding. Equally, surveys included relatively few shrub-dominated revegetation sites so the reliability of these models is unquantified for shrubby revegetation.

Regional models of biomass production and carbon sequestration rates from revegetation are a core component of regional industry potential analyses that 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 2009b, Hobbs *et al.* 2009c, Crossman *et al.* 2010). Additional surveys resulting from this current study and the availability of more comprehensive soils and climate datasets has created an opportunity to significantly improve the reliability and scope of spatial productivity and carbon sequestration models in South Australia. The quantification of relationships between revegetation types and designs, climate and soils, and carbon sequestration rates over time is a significant improvement over models previously developed by DEWNR and other current models (e.g. DOTE's Reforestation Modelling Tool) used by for national carbon accounting. New DEWNR biomass and carbon growth models can now provide strong guidance to those seeking to evaluate the potential of carbon sequestration from a variety of revegetation activities, and estimate biomass production rates for renewable energy industries in the South Australia.

The value of DEWNR's commitment to research on carbon sequestration from revegetation is strongly acknowledged by the DOTE. In recent years, strong partnerships have formed between DEWNR, DOTE CFI Methodologies, CSIRO and the Future Farm Industries Cooperative Research Centre (FFI CRC). During 2011-2013, the DOTE CFI Methodologies group commissioned a project to undertake additional surveys (including Moorlands sites) and research to redevelop environmental and mallee plantings FullCAM models used in DOTE National Carbon Accounting Toolbox (NCAT) and CFI Reforestation Modelling Tool (RMT). FullCAM models now incorporate extensive data from carbon sequestration surveys in agricultural landscapes across South Australia. The new models will be incorporated into the forthcoming revisions of NCAT and CFI RMT planned in 2013/2014.

High resolution spatial analyses of annual and woody crop yields and profitability can help to facilitate a better understanding of the optimal productive arrangements of annual and woody crops in a farming enterprise (e.g. Lyle *et al.* 2009). Through this understanding the issue of perceived competition between annual and woody crop options can largely be avoided. It has been crucial to improve estimates of carbon sequestration in the low to medium rainfall regions of South Australia so that more accurate comparisons between the economic returns (and risks) of potential carbon crops and existing annual crops/pastures can be made. With better information the most profitable and sustainable land use options within farming enterprises and regions can be more readily identified.

Current "*Landscape Futures Analysis*" research undertaken within a partnership between DEWNR NRM Boards, University of Adelaide and CSIRO is starting to reveal potential influences of climate change on landuse options and natural resource management issues in the Eyre Peninsula and SA Murray-Darling Basin NRM Regions. Carbon sequestration from revegetation is a significant landuse option being explored within this research and the outcomes of these types of analyses will help inform the development of future climate change adaption plans in South Australia.

CONCLUSIONS AND RECOMMENDATIONS

This study provides a significant advancement in the science of carbon assessment methodologies and an increased understanding of the potential for revegetation to sequester carbon in the agricultural regions of South Australia. Numerous measurements and targeted surveys conducted over recent years has greatly increased the diversity of species, revegetation types, ages and locations represented in DEWNR's research on carbon sequestration from revegetation. This has allowed more meaningful evaluations of regional carbon sequestration rates and the development of more flexible and reliable predictive models. Mixed species environmental plantings from South Australian conditions are now well represented within DEWNR models of carbon sequestration and this data has also been incorporated into models that underpin nationally approved carbon accounting tools and methodologies.

Much of the complexity of environmental conditions (e.g. climate and soils), revegetation design, lifeform types, variable planting densities, age and their interactions on above-ground carbon sequestration rates from revegetation have now been quantified for the agricultural regions of South Australia. Greater refinement of these resulting models is desirable especially in highly diverse environmental plantings and direct seeded revegetation sites. This current study provides some insight into relationships between above-ground plant measurements and biomass with below-ground (root) biomass. Ultimately assessments of total carbon sequestration of revegetation should include root zone sequestration. In the future, additional destructive surveys and analyses will be required to improve the reliability of current estimates of the contribution of plant roots to carbon stores in native revegetation sites.

From limited surveys in this study, evidence suggests that the standing carbon stores in mature revegetation are likely to be higher than those found in intact native vegetation. This may dispel the common belief that the peak biomass of remnant vegetation is an indicator of a site's potential for storing carbon - a potentially false assumption made by some carbon sequestration prediction models. DEWNR surveys of remnant vegetation communities provide preliminary estimates of above-ground carbon stocks and their relationships with rainfall and average plant height. To more reliably estimate carbon stocks of all remnant vegetation in South Australia, and its contribution to the State's carbon budget, there is a need to conduct many more surveys across a range of environmental and vegetation communities in the future.

Current policies, natural resource management drivers, emergent carbon markets and economic evaluations indicate there are substantial opportunities for carbon sequestration from a variety of different revegetation types in the dryland agricultural regions of South Australia. These opportunities will include a regionally targeted and often distinct mix of woody carbon crops, permanent environmental plantings and extractive agroforestry/biomass industries. The extent of government support for revegetation in the form of incentives, support mechanisms, regional planning and policy development will be influenced by complex interactions between economic feasibility of carbon markets, regional/state priorities and strategic targets for natural resource management.

Recent studies (e.g. Hobbs 2009b, Hobbs *et al.* 2009c, Polglase *et al.* 2008, Crossman *et al.* 2010, Lyle *et al.* 2009) show that the scale and profitability of carbon sequestration crops is highly dependent on primary productivity of both native plants and agricultural crops, market prices for carbon and agricultural commodities, operating and investment costs associated with these activities, and longer-term opportunity costs of existing land uses. Current Australian carbon prices have only been set for limited time (1st July 2012 - 30th June 2014; $23.00 - $24.15/t CO_2-e) and will migrate to international market prices from 1st July 2014 onwards.

In recent years, international carbon prices have been very dynamic (~€3 – €17/t CO_2-e in the last 3 years; European Energy Exchange 2013) and are likely to continue to be dynamic in the future. This is equally true for wide range of agricultural commodities in the past and into the future. Policy makers and investors should be mindful of the potential instability of carbon and agricultural commodity prices and the potential investment risks associated with any markets. 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 land use planning, carbon crop reforestation driven by market prices alone could 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.

Climate change and variability will undoubtedly affect both agricultural and carbon productivity and profitably into the future. It is unclear on what the balance between these industry types will be in South Australia given the overwhelming influence of agricultural and carbon commodity prices on the long-term economic feasibility of these sectors. Based on decreases in both agricultural and carbon productivity into the future and assumptions of stability in current prices and costs, it could be anticipated that carbon crops will emerge in drier parts of our agricultural landscapes. Especially in specific locations where the viability of current agricultural pursuits diminish (e.g. low fertility soils) and targeted locations where other natural resource management issues and policies drive change towards revegetation (e.g. biodiversity, soil protection, dryland salinity).

Adaption of current agricultural landscapes and communities through drivers of climate change, sustainability and new carbon markets is inevitable in South Australia. Targeted placement of new woody biomass and carbon crops to maximise benefits and profitability of whole farm enterprises and environmental health of 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 the greatest potential for investment in carbon crops.

To promote and develop new carbon markets and carbon sequestration activities in South Australia 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. 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.
4. Exercise caution in the use of forecasts of potential carbon sequestration, especially as our climate evolves. DEWNR sequestration models provide an estimate of average carbon sequestration rates under current climatic conditions. DEWNR research also demonstrates a moderate degree of unexplained variation in carbon sequestration rates resulting from undocumented influences of species blends, management and other environmental factors.
5. Always utilise proven, reliable and repeatable site assessment techniques, and statistically sound survey methodologies, to accurately determine quantities of carbon sequestered from revegetation for carbon accounting purposes.
6. 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 analyses of natural resource management and climate change adaption priorities, to guide future investments in revegetation and carbon sequestration within agricultural regions of the State.

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GLOSSARY

AICc — Akaike information criterion (corrected), a measure of the relative quality of a statistical model, for a given set of data. AIC deals with the trade-off between the complexity of the model and the goodness of fit of the model.

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).

CFI — Carbon Farming Initiative.

CO_2-e — carbon dioxide equivalent.

CRC — Cooperative Research Centre.

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

DCCEE — Department of Climate Change and Energy Efficiency (pre April 2013), now DOTE (Australian Government).

DEWNR — Department of Environment, Water and Natural Resources (Government of South Australia).

DOA — Department of Agriculture (Australian Government).

DOIC — Domestic Offsets Integrity Committee (Australian Government).

DOTE — Department of the Environment (Australian Government).

DSEWPC — Department of Sustainability, Environment, Water, Population and Communities (pre September 2013), now DOTE (Australian Government).

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 2009).

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 (Version 7.0); regions containing similar landscapes, climates and native ecosystems (Department of Sustainability, Environment, Water, Population and Communities 2012a).

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.

NVIS — National Vegetation Information System (Version 4.1); national mapping and description of native plant communities (Department of Sustainability, Environment, Water, Population and Communities 2012b).

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

Plant density — plants per hectare; average number of trees, mallees and/or tall shrubs planted per unit area; refers only to species that are Kyoto-compliant (i.e. >2m tall at maturity).

r^2 — a statistical measure of the proportion of variation of observations explained by models, when all variation is explained r^2 = 1.

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

RMT — Reforestation Modelling Tool.

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

APPENDICES

APPENDIX A - REGIONAL SPECIES LISTS

Table 33. Frequency of dominant plant species in the Adelaide & Mt Lofty Ranges NRM Region.

Height Class	Adelaide & Mt Lofty Ranges Dominant Species	Rainfall Zone (mm/yr)							Total
		200	300	400	500	600	700	800+	
Tall	Eucalyptus fasciculosa				66	547	324	448	1385
	Eucalyptus leucoxylon ssp.			20	123	468	298	356	1265
	Allocasuarina verticillata		1	20	108	363	599	168	1259
	Eucalyptus obliqua			1	1	60	184	930	1176
	Bursaria spinosa ssp.			29	89	237	245	379	979
	Banksia marginata			6	40	98	246	477	867
	Eucalyptus goniocalyx ssp.			3	10	394	137	63	607
	Eucalyptus microcarpa				46	141	290	116	593
	Eucalyptus baxteri				3	30	96	413	542
	Eucalyptus cosmophylla				1	48	80	365	494
	Eucalyptus camaldulensis var.			5	42	237	127	69	480
	Eucalyptus viminalis ssp.			1	4	54	110	290	459
	Callitris gracilis		7	46	110	199	80	9	451
	Acacia retinodes			2	29	39	158	197	425
	Eucalyptus odorata			47	123	138	60	11	379
	Eucalyptus porosa			21	214	78	30	13	356
	Acacia melanoxylon			15	4	16	53	267	355
	Pittosporum angustifolium		6	55	95	34	74	2	266
	Acacia provincialis				3	30	38	142	213
	Melaleuca lanceolata		2	49	51	40	21	15	178
Moderately Tall	Acacia pycnantha			45	148	819	892	605	2509
	Hakea rostrata				22	215	435	675	1347
	Leptospermum myrsinoides			1	39	198	398	690	1326
	Dodonaea viscosa ssp.		7	23	102	427	445	199	1203
	Exocarpos cupressiformis			3	18	162	358	590	1131
	Acacia paradoxa			14	130	305	388	179	1016
	Allocasuarina muelleriana ssp.			9	34	258	360	248	909
	Leptospermum continentale				3	46	84	446	579
	Hardenbergia violacea			7	35	80	194	137	453
	Allocasuarina striata				9	96	89	199	393
	Melaleuca decussata				5	60	72	182	319
	Acacia verticillata ssp.			4	2	18	58	232	314
	Leptospermum lanigerum				5	29	41	159	234
	Acacia verniciflua				9	10	42	122	183
	Rhagodia candolleana ssp.		11	47	41	61	1	4	165
	Leucopogon parviflorus			17	48	72	8	14	159
	Callistemon sieberi			1	14	36	36	41	128
	Acacia ligulata		7	37	65	6	6		121
	Acacia cupularis		1	21	43	33	6	1	105
	Melicytus dentatus				10	30	52	12	104
Medium	Xanthorrhoea semiplana ssp.				20	514	419	886	1839
	Olearia ramulosa		3	3	27	213	708	442	1396
	Pultenaea daphnoides				6	15	217	828	1066
	Hakea carinata			2	15	159	421	452	1049
	Calytrix tetragona			8	106	341	351	157	963
	Grevillea lavandulacea ssp.			5	70	180	230	423	908
	Epacris impressa				3	10	154	687	854
	Acacia myrtifolia				7	89	303	334	733
	Daviesia leptophylla			2	8	48	103	511	672
	Spyridium parvifolium			1	12	154	144	222	533
	Acacia acinacea			42	125	95	109	69	440
	Xanthorrhoea quadrangulata			4	7	144	259	20	434
	Daviesia ulicifolia ssp.				9	68	106	222	405
	Goodenia ovata			1	4	10	48	310	373
	Hakea rugosa				28	125	65	62	280
	Acacia spinescens			14	19	75	57	64	229
	Eutaxia microphylla			6	64	67	68	24	229
	Prostanthera behriana			2	16	96	73	29	216
	Persoonia juniperina					7	17	187	211
	Cullen australasicum			13	43	45	40	42	183

Source: DEWNR eFloraSA, 2012.

Appendix A - Regional Species Lists

Table 34. Frequency of dominant plant species in the Eyre Peninsula NRM Region.

Height Class	Eyre Peninsula Dominant Species	Rainfall Zone (mm/yr)							Total
		200	300	400	500	600	700	800+	
Tall	Melaleuca lanceolata	14	862	343	205	2			1426
	Eucalyptus oleosa ssp.	9	836	84	43				972
	Pittosporum angustifolium	10	537	281	87				915
	Eucalyptus dumosa	8	492	114	6				620
	Eucalyptus diversifolia ssp.		164	244	209	3			620
	Eucalyptus socialis ssp.	1	390	80	8				479
	Eucalyptus calcareana	2	371	88	7				468
	Allocasuarina verticillata		68	214	108	8			398
	Eucalyptus porosa		208	158	11				377
	Callitris gracilis	2	238	123	3	1			367
	Acacia euthycarpa		165	91	21	1			278
	Bursaria spinosa ssp.		88	112	67	7			274
	Myoporum insulare	1	123	34	66				224
	Myoporum platycarpum ssp.	6	215	3					224
	Eucalyptus odorata		36	116	67	4			223
	Melaleuca halmaturorum		32	104	38				174
	Eucalyptus peninsularis		63	82	23				168
	Acacia longifolia ssp.		6	56	85				147
	Eucalyptus rugosa	1	20	41	72				134
	Eucalyptus albopurpurea			9	112	6			127
Moderately Tall	Exocarpos aphyllus	9	649	180	84				922
	Eucalyptus gracilis	11	683	109	49	1			853
	Melaleuca uncinata	1	505	234	99	7			846
	Santalum acuminatum	13	527	138	39				717
	Eucalyptus incrassata	7	459	124	36				626
	Rhagodia candolleana ssp.	4	264	173	165				606
	Melaleuca pauperiflora ssp.	3	574	14					591
	Eucalyptus leptophylla	4	405	138	41	1			589
	Eucalyptus brachycalyx	9	461	71	1				542
	Melaleuca acuminata ssp.	1	345	146	19				511
	Dodonaea viscosa ssp.	3	268	129	76				476
	Acacia ligulata	7	320	79	15				421
	Exocarpos sparteus	1	223	98	79	10			411
	Leptospermum coriaceum	5	288	81	37				411
	Acacia rigens	4	267	75	2				348
	Allocasuarina muelleriana ssp.	1	126	92	75	9			303
	Acacia calamifolia	1	157	113	23	1			295
	Acacia oswaldii	10	256	10	1				277
	Leucopogon parviflorus		8	92	174	1			275
	Eucalyptus yalatensis		145	124	4				273
Medium	Geijera linearifolia	12	688	52	23				775
	Eutaxia microphylla	2	392	247	107	3			751
	Acacia spinescens		364	223	125	1			713
	Beyeria lechenaultii	2	374	150	142				668
	Senna artemisioides ssp.	15	546	73	1				635
	Calytrix tetragona	1	245	126	109	5			486
	Alyxia buxifolia	7	293	67	89				456
	Rhagodia preissii ssp.	8	389	38					435
	Calytrix involucrata	1	283	118	15	2			419
	Phebalium bullatum	3	357	56	2				418
	Babingtonia behrii		159	129	102	11			401
	Templetonia retusa		169	149	82				400
	Nitraria billardierei	1	196	85	98				380
	Pimelea flava ssp.		84	174	97	19			374
	Acacia rupicola		35	133	134	15			317
	Eremophila scoparia	10	300	2	1				313
	Acacia sclerophylla var.	8	215	67	21				311
	Scaevola spinescens	6	284	10					300
	Acacia merrallii	8	267	5					280
	Correa backhouseana var.		60	127	66	7			260

Source: DEWNR eFloraSA, 2012.

Appendix A - Regional Species Lists

Table 35. Frequency of dominant plant species in the Kangaroo Island NRM Region.

Height Class	Kangaroo Island Dominant Species	Rainfall Zone (mm/yr)							Total
		200	300	400	500	600	700	800+	
Tall	Eucalyptus diversifolia ssp.			6	197	99	95	9	406
	Melaleuca lanceolata			3	170	62	77		312
	Banksia marginata			2	49	65	94	65	275
	Eucalyptus cosmophylla			6	60	75	83	29	253
	Eucalyptus rugosa			3	136	42	36	6	223
	Eucalyptus cneorifolia			14	140	34	1		189
	Eucalyptus albopurpurea				85	41	44	1	171
	Eucalyptus cladocalyx				24	53	79	15	171
	Eucalyptus baxteri				6	46	64	40	156
	Myoporum insulare			1	87	39	25		152
	Eucalyptus fasciculosa			3	27	44	61	11	146
	Allocasuarina verticillata				42	47	41	1	131
	Acacia uncifolia				47	25	31	7	110
	Eucalyptus leucoxylon ssp.			3	13	55	29	4	104
	Eucalyptus obliqua			1	5	27	28	32	93
	Eucalyptus oleosa ssp.			1	62	17	4		84
	Acacia retinodes			1	10	17	35	10	73
	Acacia provincialis			2	7	16	28	10	63
	Acacia longifolia ssp.				32	17	6	1	56
	Eucalyptus odorata			5	28	22	1		56
Moderately Tall	Hakea mitchellii			3	74	118	105	25	325
	Allocasuarina striata			3	71	100	81	69	324
	Hakea rostrata				50	100	82	72	304
	Acacia paradoxa			5	107	101	64	16	293
	Leucopogon parviflorus			2	128	42	76		248
	Dodonaea viscosa ssp.			2	93	78	55	4	232
	Allocasuarina muelleriana ssp.			4	56	64	48	22	194
	Leptospermum continentale			5	22	34	65	60	186
	Melaleuca uncinata			7	80	68	23	1	179
	Eucalyptus remota				2	28	47	75	152
	Leptospermum myrsinoides			1	29	27	48	24	129
	Melaleuca brevifolia				39	41	42	4	126
	Rhagodia candolleana ssp.				76	20	19	2	117
	Acacia pycnantha			2	45	24	23	6	100
	Callistemon rugulosus			5	35	32	22		94
	Callitris rhomboidea			2	17	24	22	4	69
	Exocarpos cupressiformis			2	19	20	15	6	62
	Acacia verticillata ssp.				6	14	26	12	58
	Hardenbergia violacea				32	12	10		54
	Eucalyptus phenax ssp.			7	32	7	5	2	53
Medium	Melaleuca gibbosa			14	155	146	138	37	490
	Olearia microdisca			264	91		3		358
	Xanthorrhoea semiplana ssp.			2	59	109	105	62	337
	Calytrix tetragona			4	101	74	70	28	277
	Beyeria lechenaultii			1	130	54	73	2	260
	Lasiopetalum schulzenii				106	56	87	8	257
	Choretrum glomeratum var.			6	113	58	49	9	235
	Logania ovata				94	71	56	11	232
	Adenanthos terminalis			2	30	63	73	53	221
	Pomaderris halmaturina ssp.			41	36	140	2		219
	Adenanthos macropodianus			9	65	21	77	39	211
	Daviesia asperula ssp.			4	47	52	78	27	208
	Grevillea quinquenervis					25	73	88	186
	Pimelea flava ssp.			7	56	56	60	3	182
	Banksia ornata				25	27	54	62	168
	Acacia myrtifolia				51	31	48	30	160
	Pomaderris obcordata			1	90	23	29		143
	Acacia leiophylla			1	82	20	26	4	133
	Pomaderris paniculosa ssp.			5	72	26	26		129
	Eutaxia microphylla				46	34	38	6	124

Source: DEWNR eFloraSA, 2012.

Appendix A - Regional Species Lists

Table 36. Frequency of dominant plant species in the Northern & Yorke NRM Region.

Height Class	Northern & Yorke Dominant Species	Rainfall Zone (mm/yr) 200	300	400	500	600	700	800+	Total
Tall	Bursaria spinosa ssp.	3	58	277	248	71			657
	Eucalyptus odorata		35	201	289	67			592
	Allocasuarina verticillata		29	251	235	60			575
	Melaleuca lanceolata		81	379	100	5			565
	Eucalyptus porosa	5	106	288	75	20			494
	Pittosporum angustifolium		126	283	36	8			453
	Eucalyptus socialis ssp.	5	103	206	52	30			396
	Eucalyptus leucoxylon ssp.		3	62	181	125			371
	Eucalyptus oleosa ssp.		63	168	44	1			276
	Callitris glaucophylla	1	93	67	64	21			246
	Acacia victoriae ssp.	13	125	65	28	4			235
	Eucalyptus diversifolia ssp.			158	64	3			225
	Callitris gracilis		36	68	49	17			170
	Myoporum insulare		42	107	8				157
	Myoporum platycarpum ssp.	7	63	47	10	3			130
	Eucalyptus rugosa		1	68	47				116
	Eucalyptus microcarpa		1	27	68	19			115
	Eucalyptus dumosa		30	65	8	4			107
	Eucalyptus goniocalyx ssp.			1	53	52			106
	Eucalyptus cladocalyx		1	15	45	43			104
Moderately Tall	Dodonaea viscosa ssp.	4	146	177	181	31			539
	Exocarpos aphyllus	3	138	307	63	7			518
	Acacia pycnantha		28	131	197	72			428
	Rhagodia candolleana ssp.		66	277	46				389
	Eucalyptus gracilis	5	118	191	41	4			359
	Acacia ligulata	3	128	158	50	8			347
	Cassinia laevis	3	46	97	131	25			302
	Santalum acuminatum		75	139	45	8			267
	Pimelea microcephala ssp.	8	105	84	47	11			255
	Acacia hakeoides		69	137	28	5			239
	Acacia calamifolia	2	84	89	48	3			226
	Leucopogon parviflorus		5	180	32				217
	Alectryon oleifolius ssp.	3	111	79	5	7			205
	Acacia oswaldii	3	89	89	8	5			194
	Myoporum montanum	6	34	78	62	6			186
	Eucalyptus phenax ssp.		15	157	8				180
	Melaleuca acuminata ssp.		20	131	21	1			173
	Acacia notabilis	2	20	110	21	14			167
	Eremophila longifolia	1	77	72	11	6			167
	Exocarpos cupressiformis		6	26	78	54			164
Medium	Rhagodia parabolica	5	211	237	68	7			528
	Senna artemisioides ssp.	2	208	188	37	8			443
	Beyeria lechenaultii	2	47	295	90	8			442
	Eutaxia microphylla		17	177	158	27			379
	Calytrix tetragona		11	167	139	46			363
	Pomaderris paniculosa ssp.		32	190	65	10			297
	Acacia continua	1	26	64	132	55			278
	Alyxia buxifolia		25	210	36	3			274
	Xanthorrhoea quadrangulata		8	46	135	47			236
	Nitraria billardierei	9	119	71	31				230
	Templetonia retusa		2	137	89	1			229
	Acacia spinescens		6	156	53	1			216
	Geijera linearifolia		96	111	3	1			211
	Acacia nematophylla		1	158	42				201
	Olearia decurrens	2	41	78	63	16			200
	Maireana pyramidata	20	112	14	3	1			150
	Scaevola spinescens		90	52	4				146
	Acacia rupicola		1	76	50	16			143
	Acacia wattsiana		2	26	68	42			138
	Spyridium parvifolium		1	1	84	51			137

Source: DEWNR eFloraSA, 2012.

Appendix A - Regional Species Lists

Table 37. Frequency of dominant plant species of South Australian Murray-Darling Basin NRM Region.

Height Class	South Australian Murray-Darling Basin Dominant Species	Rainfall Zone (mm/yr) 200	300	400	500	600	700	800+	Total
Tall	Eucalyptus largiflorens	846	184	8	1				1039
	Eucalyptus socialis ssp.	108	678	214	13	1	2		1016
	Melaleuca lanceolata	61	568	254	18	2			903
	Eucalyptus oleosa ssp.	99	627	39	5				770
	Eucalyptus camaldulensis var.	471	226	28	5	3	5	9	747
	Eucalyptus dumosa	92	554	96	1				743
	Myoporum platycarpum ssp.	155	390	103	7				655
	Bursaria spinosa ssp.	1	64	208	70	21	14	40	418
	Eucalyptus porosa	12	156	214	6				388
	Eucalyptus leucoxylon ssp.		30	182	68	29	32	41	382
	Callitris gracilis	30	136	186	25	2	1		380
	Eucalyptus fasciculosa		4	98	37	55	55	121	370
	Acacia stenophylla	284	81						365
	Eucalyptus odorata	1	37	150	108	35	16	6	353
	Pittosporum angustifolium	38	210	99	6				353
	Allocasuarina verticillata		17	147	77	11	15	12	279
	Eucalyptus cosmophylla			1	7	40	62	119	229
	Acacia euthycarpa		64	150	8	3		1	226
	Banksia marginata		2	54	24	25	20	93	218
	Casuarina pauper	110	90	3					203
Moderately Tall	Eucalyptus gracilis	114	718	114	4				950
	Eucalyptus incrassata	27	494	280	29	8	3	1	842
	Eucalyptus leptophylla	33	515	248	19	17	7		839
	Dodonaea viscosa ssp.	139	259	192	27	12	15	9	653
	Leptospermum coriaceum	4	313	243	3	1			564
	Acacia pycnantha		66	231	88	45	42	48	520
	Callitris verrucosa	58	288	121					467
	Melaleuca acuminata ssp.		251	172	11	1		1	436
	Allocasuarina muelleriana ssp.		129	155	28	42	28	31	413
	Exocarpos aphyllus	122	251	5					378
	Melaleuca uncinata		170	180	14	7		1	372
	Acacia rigens	42	217	106	2				367
	Alectryon oleifolius ssp.	112	201	9					322
	Leptospermum myrsinoides		2	74	18	42	48	125	309
	Acacia brachybotrya	31	170	91	3			1	296
	Eucalyptus brachycalyx	22	226	45	2				295
	Hakea mitchellii	1	95	173	22	3			294
	Santalum acuminatum	29	185	62	14		1		291
	Eucalyptus calycogona ssp.	2	174	94	8	1			279
	Eucalyptus phenax ssp.	2	83	161	21	5	4		276
Medium	Senna artemisioides ssp.	235	487	71	4				797
	Muehlenbeckia florulenta	213	259	68	4				544
	Calytrix tetragona		141	203	36	40	27	37	484
	Acacia spinescens	1	115	226	21	29	16	7	415
	Babingtonia behrii		226	169					395
	Eutaxia microphylla	28	157	145	31	3	6		370
	Acacia nyssophylla	87	240	8	2				337
	Phebalium bullatum	9	188	121					318
	Geijera linearifolia	19	268	4	1				292
	Maireana pyramidata	202	81	1					284
	Beyeria lechenaultii	9	186	86	1				282
	Xanthorrhoea semiplana ssp.			21	20	41	52	140	274
	Rhagodia parabolica	50	183	32	7				272
	Acacia sclerophylla var.	39	179	44					262
	Grevillea huegelii	87	156	8					251
	Eremophila scoparia	82	163	2					247
	Correa glabra var.		56	139	27	18	5		245
	Olearia pimeleoides ssp.	79	145	12	1				237
	Acacia wilhelmiana	32	167	26					225
	Grevillea lavandulacea ssp.		7	88	21	26	31	48	221

Source: DEWNR eFloraSA, 2012.

Appendix A - Regional Species Lists

Table 38. Frequency of dominant plant species of South East NRM Region.

Height Class	South East Dominant Species	Rainfall Zone (mm/yr)							Total
		200	300	400	500	600	700	800+	
Tall	Banksia marginata			114	365	223	84	41	827
	Eucalyptus leucoxylon ssp.			162	319	151	55		687
	Acacia longifolia ssp.			4	205	180	139	49	577
	Eucalyptus fasciculosa			45	328	179	20	2	574
	Eucalyptus diversifolia ssp.			170	306	73	17		566
	Bursaria spinosa ssp.			83	190	135	36	34	478
	Melaleuca lanceolata			128	170	90	58	7	453
	Eucalyptus viminalis ssp.			19	85	150	86	50	390
	Eucalyptus arenacea			50	182	76	67	11	386
	Acacia melanoxylon				30	110	77	79	296
	Melaleuca halmaturorum				151	71	31		253
	Allocasuarina verticillata			15	77	89	35	11	227
	Eucalyptus baxteri			3	40	48	34	72	197
	Eucalyptus obliqua				4	39	95	57	195
	Myoporum insulare			1	90	33	23	9	156
	Acacia mearnsii				15	60	29	46	150
	Melaleuca squarrosa			1	1	1	72	74	149
	Acacia oxycedrus				12	18	33	76	139
	Eucalyptus camaldulensis var.			3	49	56	3		111
	Eucalyptus ovata var.				2	23	38	31	94
Moderately Tall	Leptospermum myrsinoides			163	339	171	71	59	803
	Leucopogon parviflorus				144	149	215	70	578
	Allocasuarina muelleriana ssp.			208	295	58	12	1	574
	Acacia pycnantha			70	183	118	65	29	465
	Leptospermum continentale			3	138	159	94	71	465
	Melaleuca brevifolia			16	267	156	21		460
	Hakea mitchellii			199	214	17			430
	Eucalyptus incrassata			217	198				415
	Hakea rostrata			19	253	111	16	5	404
	Dodonaea viscosa ssp.			13	141	170	29	11	364
	Eucalyptus leptophylla			198	159			1	358
	Rhagodia candolleana ssp.				120	52	97	11	280
	Acacia verticillata ssp.			1	66	117	54	41	279
	Exocarpos cupressiformis			3	60	88	56	35	242
	Melaleuca uncinata			75	145	9			229
	Exocarpos sparteus			98	124	3	3		228
	Leptospermum coriaceum			163	24		1		188
	Hakea nodosa				46	83	13	23	165
	Allocasuarina paludosa				19	67	36	35	157
	Exocarpos syrticola				71	35	50		156
Medium	Calytrix tetragona			213	344	156	36	7	756
	Correa reflexa var.			192	286	84	68	26	656
	Banksia ornata			186	325	124	12		647
	Acacia spinescens			192	288	29	1	2	512
	Allocasuarina pusilla			167	175	21	12	1	376
	Epacris impressa			3	96	145	67	55	366
	Leucopogon ericoides			1	147	138	41	39	366
	Acacia myrtifolia			29	158	70	40	35	332
	Hakea vittata			57	180	68	8		313
	Adenanthos terminalis			130	173	7			310
	Babingtonia behrii			167	127				294
	Hakea rugosa			33	168	78	12		291
	Acacia leiophylla			11	95	67	62	3	238
	Grevillea ilicifolia ssp.			110	116	7	2		235
	Persoonia juniperina			44	132	33	12		221
	Allocasuarina mackliniana ssp.			13	116	61	13	6	209
	Eutaxia microphylla			79	105	10	1	1	196
	Calytrix alpestris			49	127	13	3	1	193
	Dillwynia glaberrima			3	16	75	48	35	177
	Solanum laciniatum				38	48	45	28	159

Source: DEWNR eFloraSA, 2012.

APPENDIX B - REVEGETATION SPECIES

Table 39. Dominant revegetation species of the Adelaide & Mt Lofty Ranges NRM Region.

Height Class	Adelaide & Mt Lofty Ranges Dominant Species	Trees For Life Zone - % of total per zone									10 Year Total
		AH	AP	AS	BV	CH	NO	VI	WN	YA	
Tall	Eucalyptus leucoxylon	44		2	12	18	2	5	5	13	309,700
	Eucalyptus fasciculosa	45		2		16	3	8	8	19	227,475
	Eucalyptus camaldulensis	41	12	1	11	16	1	4	4	11	225,750
	Allocasuarina verticillata	34	11	3	11	13	2	4	7	14	225,350
	Acacia melanoxylon	59				18		4	5	15	148,475
	Eucalyptus viminalis	63		3		9		4	6	15	126,150
	Melaleuca lanceolata	<1	40	3	17		6	3	11	21	85,025
	Acacia retinodes	54			17	25				5	75,275
	Eucalyptus odorata	<1	39	<1	36	19			6		72,000
	Bursaria spinosa	45	8	4	10	11	3	3	6	9	65,825
	Eucalyptus obliqua	51				18		6	7	18	59,175
	Eucalyptus porosa		40	7	16	17	9		11		57,875
	Eucalyptus cosmophylla	57						10	8	25	48,875
	Acacia provincialis	66		2		1		5	8	16	47,000
	Eucalyptus baxteri	46				20		8	6	21	42,625
	Banksia marginata	36			12	30	4	7	11		40,525
	Callitris gracilis		26	6	17	24	6			21	39,550
	Eucalyptus dalrympleana	100									32,400
	Eucalyptus socialis		71		29						27,400
	Pittosporum angustifolium		34	4	28		13		20		23,000
	Eucalyptus microcarpa			27			28		44		16,425
	Melaleuca halmaturorum		70	2				28			16,175
	Eucalyptus oleosa		94		6						12,650
Mod-Tall	Acacia pycnantha	37	12	4	10	13	3	5	5	10	215,350
	Acacia paradoxa	43	<1	6	10	16	4	6	6	8	127,850
	Dodonaea viscosa	44	<1	5	11	17	5	4	5	9	122,750
	Leptospermum continentale	52		2	6	14	2	4	5	14	79,775
	Melaleuca decussata	61		2			3	5	9	20	69,625
	Callistemon sieberi	81				15	4				66,975
	Allocasuarina muelleriana	47		3		23	3	5	5	15	65,300
	Leptospermum lanigerum	69				19		6	6		57,900
	Hardenbergia violacea	37		14	5	17	5	6	16		37,075
	Acacia verniciflua	72		4		19	5				36,675
	Allocasuarina striata	59		4			3	6	7	21	34,600
	Acacia notabilis		61		39						28,075
	Acacia ligulata		58	2	19	21					27,750
	Eucalyptus gracilis	<1	78		22						25,775
	Acacia oswaldii	<1	100								17,000
	Eucalyptus brachycalyx	<1	100								14,775
	Acacia hakeoides		100								14,700
	Melaleuca acuminata		100								14,025
	Eucalyptus incrassata		56		44						13,225
Medium	Acacia myrtifolia	53		3	1	18	2	3	6	14	104,750
	Acacia acinacea	14	28	8	18	13	5	6	8		70,750
	Xanthorrhoea semiplana	49		3		15	4	4	13	12	48,775
	Olearia ramulosa	53		6		11	6	4	8	12	45,325
	Pultenaea daphnoides	74				16			10		31,125
	Rhagodia parabolica		52		48						30,275
	Gahnia sieberiana	66				17				18	15,850
	Acacia rupicola	<1		19			22			58	13,850
Tall	Total Tall	39	11	2	9	14	2	4	6	13	2,073,625
Mod-Tall	Total Mod-Tall	40	15	3	10	13	3	4	5	8	1,163,925
Medium	Total Medium	34	15	4	10	16	3	2	6	9	441,325
Med-Low	Total Med-Low	29	23	2	14	16	5	<1	8	3	74,000
Low	Total Low	49	12	1	6	13	4		7	8	65,700
Ground	Total Ground	12	25	10	15	18	9		10		75,900
Undefined	Total Undefined native species	31	9	11	6	9	6	4	17	6	425,625
All	**Grand Total**	**37**	**13**	**4**	**9**	**14**	**3**	**4**	**7**	**10**	**4,320,100**

Source: Trees For Life records, 1999-2008.

Appendix B - Revegetation Species

Table 40. Dominant revegetation species of the Eyre Peninsula NRM Region.

Height Class	Eyre Peninsula Dominant Species	Trees For Life Zone - % of total per zone									10 Year Total
		CD	CV	EL	FH	KB	LE	LH	SK	TU	
Tall	Eucalyptus petiolaris				1		69			30	61,525
	Eucalyptus camaldulensis			19			81				53,725
	Allocasuarina verticillata		17	8	1		45		9	21	43,900
	Melaleuca lanceolata	8	12	8	2	4	32	8	11	16	43,650
	Melaleuca halmaturorum		4	7	<1		55	3	2	30	37,100
	Eucalyptus cladocalyx						77			23	28,800
	Eucalyptus porosa	5	19	7	5	3	16	6	24	14	24,125
	Eucalyptus oleosa	8	9	9	4	8	8	14	30	10	22,775
	Eucalyptus dumosa	9	23	1	4	7	3	13	31	10	20,150
	Eucalyptus albopurpurea						100				13,550
	Eucalyptus diversifolia			15			59			26	12,525
	Eucalyptus socialis	16	30	3	8	17		27			11,925
	Eucalyptus odorata				3		61			36	11,700
	Callitris gracilis	6	17	13	3	2	31	2	15	12	6,625
	Pittosporum angustifolium	7	6	10		3	37	7	16	14	5,375
	Eucalyptus peninsularis			12	1		32			55	4,575
	Acacia longifolia ssp. sophorae						100				4,400
	Acacia papyrocarpa	42			24	34					4,150
	Bursaria spinosa		4	14	1		47		25	10	3,550
	Eucalyptus rugosa						100				2,725
Mod-Tall	Eucalyptus gracilis	7	17		5	6	20	7	22	16	23,200
	Acacia pycnantha		17				67			16	17,450
	Acacia oswaldii	9	19	10	4	8		17	34		16,075
	Melaleuca uncinata	5	25	3	2	3	31	4	12	15	15,800
	Callistemon rugulosus		10				80			10	14,100
	Eucalyptus incrassata	5	10	5	9	2	6	12	34	18	12,975
	Dodonaea viscosa	6	18	8	4	3	31	12	17		12,625
	Acacia calamifolia	4	18	8		6	36	9	10	11	12,425
	Eucalyptus brachycalyx	12	23	8		11		16	30		12,300
	Acacia ligulata	9	19	15	6	7		20	25		11,800
	Eucalyptus leptophylla		29		7		16	14		34	11,800
	Melaleuca acuminata	7	11	8	4	3	26	5	21	14	11,575
	Acacia notabilis	5	27	5	3	5	23	2	16	13	9,125
	Melaleuca brevifolia						63			37	9,075
	Acacia hakeoides	13	17	15		5		18	32		6,800
	Eucalyptus calycogona		25	11		9	13			42	6,525
	Melaleuca decussata						70			30	5,375
	Allocasuarina muelleriana		24				76				4,825
	Eucalyptus phenax	11		30		5	19	23		11	4,625
	Eucalyptus yalatensis			33			8		58		4,425
	Acacia cupularis			24	9		10		26	30	4,300
	Eucalyptus cretata		100								3,050
	Acacia paradoxa						77			23	2,425
Medium	Acacia sclerophylla	6	29	4	3	6	17	17	7	12	7,500
	Rhagodia parabolica		93		7						6,500
	Templetonia retusa						59			41	6,500
	Rhagodia candolleana				4		57		19	20	5,850
	Senna artemisioides	6	3	24	8		18	7	21	13	3,125
	Acacia myrtifolia						100				3,050
	Acacia leiophylla						100				2,575
Tall	Total Tall	3	7	7	2	3	50	4	7	17	421,525
Mod-Tall	Total Mod-Tall	5	17	6	3	4	28	8	16	14	247,700
Medium	Total Medium	1	22	2	3	1	43	4	5	18	43,325
Med-Low	Total Med-Low	1	7		1	1	55	11	9	14	5,025
Low	Total Low	1	6	4	2	1	46	6	16	17	8,300
Ground	Total Ground			9		3	52	12	23	1	5,225
Undefined	Total Undefined native species	<1	25	4	5	3	45	3	9	7	49,600
All	**Grand Total**	**3**	**12**	**6**	**2**	**3**	**42**	**5**	**10**	**15**	**780,700**

Source: Trees For Life records, 1999-2008.

Appendix B - Revegetation Species

Table 41. Dominant revegetation species of the Kangaroo Island NRM Region.

Height Class	Kangaroo Island Dominant Species	Trees For Life Zone - % of total per zone KI	10 Year Total
Tall	Eucalyptus cladocalyx	100	28,000
	Eucalyptus leucoxylon	100	26,925
	Allocasuarina verticillata	100	22,450
	Eucalyptus fasciculosa	100	21,250
	Eucalyptus cneorifolia	100	14,950
	Eucalyptus camaldulensis	100	13,125
	Melaleuca halmaturorum	100	12,500
	Eucalyptus cosmophylla	100	12,300
	Melaleuca lanceolata	100	9,200
	Eucalyptus diversifolia	100	8,875
	Eucalyptus viminalis	100	8,525
	Eucalyptus rugosa	100	5,750
	Eucalyptus albopurpurea	100	5,175
	Eucalyptus ovata	100	4,825
	Callitris gracilis	100	3,750
	Acacia provincialis	100	2,700
	Acacia uncifolia	100	2,400
	Eucalyptus obliqua	100	2,225
	Banksia marginata	100	2,200
	Eucalyptus baxteri	100	2,100
	Bursaria spinosa	100	1,700
	Acacia euthycarpa	100	50
	Acacia melanoxylon	100	50
Mod-Tall	Callistemon rugulosus	100	12,225
	Acacia pycnantha	100	9,075
	Melaleuca uncinata	100	6,300
	Melaleuca brevifolia	100	4,800
	Acacia paradoxa	100	4,450
	Allocasuarina muelleriana	100	3,525
	Dodonaea viscosa	100	3,175
	Eucalyptus leptophylla	100	3,150
	Allocasuarina striata	100	3,075
	Acacia cupularis	100	3,025
	Melaleuca acuminata	100	2,050
	Leptospermum continentale	100	2,000
	Leptospermum lanigerum	100	1,975
	Acacia dodonaeifolia	100	1,375
	Acacia ligulata	100	1,375
	Callitris rhomboidea	100	1,125
	Hakea rostrata	100	900
	Hakea mitchellii	100	875
	Eucalyptus remota	100	350
	Acacia calamifolia	100	50
Medium	Melaleuca gibbosa	100	7,900
	Acacia leiophylla	100	3,225
	Xanthorrhoea semiplana	100	2,100
	Banksia ornata	100	1,425
	Acacia myrtifolia	100	975
	Templetonia retusa	100	925
	Acacia triquetra	100	850
Tall	Total Tall	100	211,025
Mod-Tall	Total Mod-Tall	100	64,875
Medium	Total Medium	100	17,400
Med-Low	Total Med-Low	100	150
Low	Total Low	0	0
Ground	Total Ground	0	0
Undefined	Total Undefined native species	100	39,500
All	**Grand Total**	**100**	**332,950**

Source: Trees For Life records, 1999-2008.

Appendix B - Revegetation Species

Table 42. Dominant revegetation species of the Northern & Yorke NRM Region.

Height Class	Northern & Yorke Dominant Species	Trees For Life Zone - % of total per zone									10 Year Total
		CG	CY	FR	LN	ML	WA	WR	YO	YU	
Tall	Allocasuarina verticillata	21	11	8	11	12	9	7	5	15	106,875
	Eucalyptus camaldulensis	41		14	19		12			13	106,500
	Melaleuca lanceolata	14	13	9	13	10	12	5	6	19	102,150
	Eucalyptus porosa	10	16	9	11	15	12	3	6	20	92,475
	Eucalyptus leucoxylon	51		18	31						90,525
	Eucalyptus socialis	9	12	9	14	13	12	3	4	24	78,225
	Eucalyptus odorata	40		15	20		18			7	66,000
	Eucalyptus oleosa		14			20	17	7	7	35	46,600
	Callitris gracilis	29	7		12	8	24		4	16	22,450
	Pittosporum angustifolium	16	8	11	8	8	22	3	7	17	19,725
	Bursaria spinosa	29	4	9	5	7	22	2	8	12	15,100
	Melaleuca halmaturorum					54		17	29		11,775
	Eucalyptus dumosa			41	3		56				10,550
	Acacia victoriae			7	24		33			36	9,775
	Eucalyptus diversifolia							85	15		8,250
	Casuarina pauper									100	7,125
	Eucalyptus goniocalyx	100									6,175
	Banksia marginata	100									6,000
	Eucalyptus microcarpa			100							5,300
Mod-Tall	Acacia pycnantha	22	13	10	15	13	14		6	7	62,650
	Eucalyptus gracilis		17	<1		19	19	2	6	35	48,300
	Dodonaea viscosa	21	8	13	11	9	14	2	4	18	34,900
	Acacia notabilis	14	11	9	18	10	16			21	31,850
	Eucalyptus incrassata	16	14			17	11	8	9	27	29,575
	Acacia hakeoides		8	13	21	10	13		8	27	28,925
	Melaleuca acuminata	21	16			15	17	4	7	20	28,250
	Acacia oswaldii		11	11	16	3	22			37	27,750
	Eucalyptus brachycalyx		14				35			51	27,125
	Callistemon rugulosus	56	13	10		14			8		25,425
	Acacia ligulata		20	2		20	21			36	19,575
	Acacia paradoxa	40	8	7	23	18			4	<1	16,800
	Eucalyptus phenax		18			19	18	5	6	35	16,375
	Eucalyptus leptophylla		33			47		6	14		15,825
	Eucalyptus calycogona		31			39	25			5	11,875
	Acacia calamifolia	41		32	28						11,800
	Melaleuca brevifolia	100									10,450
	Acacia microcarpa		31			28	27		15		9,400
	Melaleuca uncinata		47			53					9,150
	Allocasuarina muelleriana	49		1		24		11	15	1	8,325
	Acacia brachybotrya	48		10	30		12				8,300
	Hardenbergia violacea	90	1					10			6,275
	Acacia argyrophylla					66			34		6,100
Medium	Rhagodia parabolica	24		17	24		14			21	46,875
	Acacia acinacea	66			18		17				11,475
	Acacia sclerophylla		16			12	33			39	11,450
	Senna artemisioides	19	3	14	10	5	23		2	24	11,275
	Rhagodia candolleana		14			20	11	6	18	31	10,050
	Acacia wattsiana	68		17	14						9,175
	Xanthorrhoea quadrangulata	65		18	17						7,100
	Callistemon teretifolius			100							6,925
Tall	Total Tall	24	7	11	14	8	12	4	4	15	831,900
Mod-Tall	Total Mod-Tall	17	14	7	8	15	14	2	5	19	523,400
Medium	Total Medium	27	4	14	13	3	11	4	5	18	148,825
Med-Low	Total Med-Low	37	1	13	2	3	30	4	11		14,025
Low	Total Low	3	13	22		23	15	3	11	11	8,775
Ground	Total Ground	57	1	5	9	3	7	3	1	13	19,200
Undefined	Total Undefined native species	7	8	9	14	15	15	4	3	26	91,375
All	**Grand Total**	**22**	**9**	**10**	**12**	**10**	**13**	**4**	**5**	**17**	**1,637,500**

Source: Trees For Life records, 1999-2008.

Appendix B - Revegetation Species

Table 43. Dominant revegetation species of the SA Murray-Darling Basin NRM Region.

Height Class	SA Murray-Darling Basin Dominant Species	Trees For Life Zone - % of total per zone						10 Year Total
		GO	MN	MS	MW	PH	PP	
Tall	Eucalyptus camaldulensis	13	26	21	3	14	23	158,625
	Melaleuca lanceolata	13	21	27	8		31	143,075
	Allocasuarina verticillata	15		20	7	14	45	136,400
	Eucalyptus fasciculosa			<1	2	33	65	111,175
	Eucalyptus leucoxylon	34				42	24	103,950
	Eucalyptus socialis	13	22	36	12		17	88,200
	Eucalyptus porosa	12	16	37	10		26	79,600
	Eucalyptus largiflorens		52	37	10	<1		66,200
	Eucalyptus odorata	36		1	9		54	57,950
	Eucalyptus oleosa	14	29	40	13		3	54,825
	Eucalyptus dumosa	13	30	39	13		4	53,400
	Callitris gracilis	9	18	22	15		36	39,775
	Melaleuca halmaturorum						100	37,950
	Pittosporum angustifolium	9	16	23	10		42	28,425
	Acacia melanoxylon					100		22,550
	Bursaria spinosa	9	3	12	6	27	44	18,725
	Eucalyptus viminalis					100		16,350
	Casuarina pauper	31	69					12,925
	Acacia provincialis					100	<1	11,475
Mod-Tall	Acacia pycnantha	14		28	3	19	36	93,750
	Eucalyptus gracilis	15	23	29	11		22	77,850
	Dodonaea viscosa	<1	14	20	11	17	38	67,275
	Eucalyptus leptophylla		23	40	11		26	47,950
	Acacia brachybotrya		20	33	11		36	44,400
	Acacia ligulata	7	32	26	11		25	43,250
	Eucalyptus brachycalyx	18	24	44	14			41,300
	Eucalyptus incrassata		19	31	8		42	41,050
	Eucalyptus calycogona		17	42	11		30	34,875
	Melaleuca uncinata			52			48	31,925
	Callistemon rugulosus						100	31,525
	Melaleuca acuminata			44			56	31,275
	Acacia oswaldii	15	63		22			30,950
	Acacia calamifolia	22		35	11		33	28,450
	Acacia paradoxa					43	57	26,700
	Acacia hakeoides	20	31	29	12		8	25,675
	Acacia microcarpa		18	27	11		44	24,075
	Eucalyptus phenax		14	44	13		29	21,775
	Callistemon sieberi					83	17	20,500
	Acacia rigens		31	30	9		30	18,425
	Acacia argyrophylla	38		34	29			16,325
	Allocasuarina muelleriana			42		58		14,025
	Eucalyptus cyanophylla		100					13,825
	Callitris verrucosa		64	36				12,725
	Leptospermum lanigerum					87	13	12,475
	Melaleuca decussata					100		12,350
Medium	Acacia acinacea	12			2	34	52	29,825
	Rhagodia parabolica	69	4		27			17,800
	Senna artemisioides	15	28	14	7		36	15,000
	Acacia sclerophylla		44	39	16			14,525
	Acacia myrtifolia					100		12,050
Tall	Total Tall	13	15	19	6	17	30	1,305,050
Mod-Tall	Total Mod-Tall	7	16	27	8	12	30	942,150
Medium	Total Medium	19	13	11	9	28	21	154,300
Med-Low	Total Med-Low	19	27	17	10	8	19	31,475
Low	Total Low	26	22	22	5		25	22,875
Ground	Total Ground	16	21	25	8	11	19	32,675
Undefined	Total Undefined native species	4	12	16	4	20	44	233,325
All	**Grand Total**	**11**	**15**	**21**	**7**	**16**	**30**	**2,721,850**

Source: Trees For Life records, 1999-2008.

Appendix B - Revegetation Species

Table 44. Dominant revegetation species of the South East NRM Region.

Height Class	South East Dominant Species	Trees For Life Zone - % of total per zone						10 Year Total
		BL	CO	MX	SC	SE	SU	
Tall	Eucalyptus leucoxylon	1	2	32	2	34	28	146,725
	Eucalyptus fasciculosa	4	4	38	2	26	26	82,675
	Allocasuarina verticillata	1	4	25	4	45	22	66,950
	Eucalyptus camaldulensis	3				54	43	65,725
	Melaleuca lanceolata	4	3	33	5	36	19	50,250
	Melaleuca halmaturorum		8	23	3	41	26	49,475
	Acacia melanoxylon				3	97		31,375
	Eucalyptus diversifolia		8	35	7	41	10	30,425
	Eucalyptus ovata				3	97		25,250
	Eucalyptus viminalis	3		<1		62	35	23,175
	Eucalyptus baxteri			40		47	13	16,950
	Eucalyptus dumosa	1		91			8	15,525
	Melaleuca squarrosa				10	90		15,400
	Eucalyptus socialis			100				11,925
	Banksia marginata		6	15	6	53	20	11,300
	Eucalyptus obliqua				7	84	9	10,650
	Eucalyptus willisii					100		7,950
	Acacia mearnsii				10	90		7,450
	Allocasuarina luehmannii	51					49	7,425
	Acacia longifolia ssp. sophorae		13	30	16	38	3	6,725
	Eucalyptus odorata	32					68	5,600
	Bursaria spinosa	2	6	14	3	50	25	5,525
	Eucalyptus arenacea	6		26		43	26	3,525
	Eucalyptus oleosa			100				3,300
	Eucalyptus porosa			100				3,025
Mod-Tall	Acacia pycnantha	3	4	29	3	34	27	40,275
	Callistemon rugulosus	4		28		37	31	38,575
	Melaleuca brevifolia	2	3	17		50	28	24,700
	Dodonaea viscosa	3	3	30	4	35	25	17,850
	Eucalyptus incrassata	1	7	73			19	17,825
	Leptospermum continentale	4	5		7	56	28	13,125
	Allocasuarina paludosa	4			8	88		13,075
	Melaleuca uncinata	4		51			45	10,825
	Eucalyptus gracilis		8	92				7,700
	Acacia cupularis		4	20	8	31	37	7,575
	Eucalyptus leptophylla	10		20			70	6,650
	Allocasuarina muelleriana	3	6	60			32	6,300
	Leptospermum lanigerum				19	81		5,675
	Acacia microcarpa	11		76			13	4,675
	Hakea nodosa					85	15	3,875
	Acacia paradoxa	23					77	3,075
	Eucalyptus behriana	17		2			81	3,050
	Acacia rigens			100				2,475
Medium	Melaleuca wilsonii	10		50			40	10,750
	Acacia myrtifolia	5	5	10	2	52	26	9,850
	Acacia leiophylla		11		6	74	9	7,525
	Banksia ornata		3	25		42	30	3,800
	Allocasuarina mackliniana	3		56			41	3,400
	Acacia farinosa	14		72			14	2,850
	Xanthorrhoea australis			12		60	28	2,450
Tall	Total Tall	3	3	25	3	44	22	713,125
Mod-Tall	Total Mod-Tall	4	3	31	2	33	27	233,075
Medium	Total Medium	5	5	29	2	37	23	48,475
Med-Low	Total Med-Low		10	5	9	67	9	4,200
Low	Total Low				9	91		825
Ground	Total Ground			100				225
Undefined	Total Undefined native species	1	5	33	3	32	26	72,325
All	**Grand Total**	**3**	**3**	**27**	**3**	**41**	**23**	**1,072,250**

Source: Trees For Life records, 1999-2008.

Appendix B - Revegetation Species

Table 45. Dominant revegetation species of the Arid Zone region.

Height Class	Arid Zone* Dominant Species	Trees For Life Zone - % of total per zone FN	NP	10 Year Total
Tall	Eucalyptus camaldulensis	74	26	10,850
	Melaleuca lanceolata	68	32	8,025
	Eucalyptus socialis	65	35	5,950
	Acacia papyrocarpa	100		5,425
	Eucalyptus oleosa	62	38	5,025
	Eucalyptus dumosa	60	40	5,000
	Eucalyptus intertexta	100		3,025
	Casuarina pauper	50	50	2,925
	Eucalyptus porosa	28	72	2,425
	Callitris glaucophylla	55	45	2,125
	Acacia aneura	90	10	2,050
	Pittosporum angustifolium	70	30	2,000
	Eucalyptus odorata	100		1,825
	Acacia salicina	100		1,750
	Allocasuarina verticillata		100	1,500
	Acacia victoriae	77	23	1,200
	Eucalyptus youngiana	100		850
	Acacia euthycarpa	86	14	700
	Acacia stenophylla	100		650
	Bursaria spinosa	83	17	575
	Acacia burkittii	100		525
	Eucalyptus largiflorens		100	325
Mod-Tall	Eucalyptus gracilis	56	44	6,175
	Acacia oswaldii	56	44	5,400
	Dodonaea viscosa	68	32	2,650
	Acacia calamifolia	70	30	2,400
	Eucalyptus gillii	100		2,300
	Acacia hakeoides	52	48	2,125
	Eucalyptus concinna	100		1,825
	Acacia ligulata	54	46	1,525
	Acacia notabilis	100		1,375
	Hakea leucoptera	71	29	875
	Eucalyptus incrassata		100	850
	Acacia kempeana	100		700
	Acacia tetragonophylla	100		600
	Acacia rivalis	100		575
	Acacia ramulosa	100		450
	Acacia brachystachya	100		250
	Eucalyptus leptophylla		100	200
	Acacia beckleri	100		75
	Callitris verrucosa		100	50
Medium	Rhagodia parabolica	100		1,450
	Acacia sclerophylla		100	1,375
	Senna artemisioides	44	56	1,125
	Templetonia egena		100	625
	Acacia nyssophylla		100	425
	Olearia pimeleoides		100	375
	Acacia colletioides		100	275
	Acacia tarculensis	100		100
Tall	Total Tall	71	29	64,725
Mod-Tall	Total Mod-Tall	68	32	30,400
Medium	Total Medium	36	64	5,750
Med-Low	Total Med-Low	21	79	2,775
Low	Total Low		100	475
Ground	Total Ground		100	125
Undefined	Total Undefined native species	26	74	9,100
All	**Grand Total**	**63**	**37**	**113,350**

Source: Trees For Life records, 1999-2008. *includes SA Arid Lands & Alinytjara Wilurara NRM Regions, and arid parts of other NRM Regions.

APPENDIX C - DESTRUCTIVE SAMPLING AND BIOMETRIC STUDIES

Table 46. Summary of average biophysical attributes of plant species measured and destructively sampled for biometric studies.

Species	Rain fall (mm)	Age (years)	Obs. Plants (n)	Height (m)	Lifeform (Tree/ Mallee/ Shrub)	Crown Width (m)	Crown Area (m^2)	Foliage Density (%)	Basal Area[#] (cm^2)	Stemwood Volume x 1000 (m^3)	Basic Density (kg/m^3)	Dry Biomass (kg/plant)	Proportion Dry Biomass by Weight			
													Wood	Bark	Branch	Leaf
Acacia calamifolia	348	15.4	6	1.8	S	2.4	5.0	-	148[#1]	13.1	-	37.7	-	-	-	-
Acacia ligulata	249	8.5	3	1.8	S	3.0	6.9	81	63[#2]	4.7	840	15.9	0.07	0.02	0.67	0.24
Acacia ligulata	260	13.8	3	3.2	S	4.4	15.5	62	182	45.0	820	52.9	0.66	0.16	0.13	0.05
Acacia mearnsii	492	12.5	3	9.9	T	3.3	9.7	57	180	96.1	650	73.5	0.67	0.13	0.12	0.08
Acacia oswaldii	249	8.5	2	1.4	S	2.1	3.5	57	30[#1]	1.9	878	4.6	0.09	0.02	0.60	0.29
Acacia oswaldii	336	12.5	3	2.0	S	2.9	6.6	95	132[#2]	12.4	859	25.8	0.19	0.03	0.48	0.30
Acacia pycnantha	338	13.5	3	4.1	T	3.8	11.5	43	68	16.2	785	32.4	0.44	0.09	0.29	0.18
Acacia pycnantha	386	7.0	3	3.4	S	3.2	8.3	86	97	21.5	675	35.2	0.33	0.08	0.24	0.35
Acacia rigens	336	12.5	3	2.6	S	2.1	3.7	100	92	10.4	776	24.3	0.22	0.06	0.38	0.34
Acacia rigens	356	31.2	3	2.8	S	7.2	41.9	71	448	75.5	874	168.6	0.52	0.09	0.21	0.18
Acacia salicina	356	4.8	24	1.3	T	1.0	1.0	32	4	0.2	687	0.9	0.31	0.08	0.29	0.32
Acacia saligna ssp. lindleyi	356	4.8	24	3.2	T	1.5	1.9	36	33	4.4	632	4.3	0.59	0.18	0.14	0.09
Allocasuarina verticillata	336	12.5	3	5.7	T	3.3	8.4	43	184	54.8	723	48.3	0.55	0.13	0.18	0.14
Allocasuarina verticillata	348	15.4	7	3.8	T	2.5	5.4	31	132	30.8	-	37.2	-	-	-	-
Allocasuarina verticillata	493	10.9	3	9.6	T	4.9	19.1	38	484	207.4	724	202.3	0.68	0.15	0.07	0.10
Atriplex nummularia	252	7.5	3	1.2	S	1.6	2.1	34	37[#1]	1.2	762	3.3	0.13	0.01	0.80	0.06
Atriplex nummularia	253	7.5	3	1.9	S	3.2	8.2	81	133[#1]	7.9	793	16.9	0.16	0.01	0.65	0.18
Atriplex nummularia	463	3.0	3	1.8	S	2.5	4.8	86	68[#2]	6.3	626	7.6	0.35	0.00	0.39	0.26
Callitris gracilis	249	8.5	3	2.1	S	1.4	1.5	76	17[#2]	1.4	619	2.5	0.11	0.03	0.39	0.47
Callitris gracilis	348	15.4	1	2.0	S	1.8	2.5	-	85	9.8	-	25.7	-	-	-	-
Callitris gracilis	376	42.0	3	8.6	T	5.7	26.1	86	844	350.6	525	216.4	0.64	0.09	0.13	0.14
Callitris verrucosa	356	31.3	3	4.6	S	4.8	18.1	86	643	158.8	642	160.8	0.53	0.09	0.19	0.19
Corymbia maculata	493	10.8	3	8.0	T	3.2	7.8	52	114	39.8	601	23.8	0.47	0.24	0.13	0.16
Dodonaea bursariifolia	348	15.4	4	1.4	S	1.4	2.0	-	55[#1]	3.7	-	6.7	-	-	-	-
Dodonaea viscosa ssp.	260	13.8	3	2.9	S	2.9	6.7	29	142	24.0	830	20.1	0.69	0.12	0.13	0.06
Eucalyptus calycogona ssp.	260	8.5	3	2.7	M	2.5	5.1	57	76[#2]	8.4	775	17.0	0.24	0.06	0.26	0.44
Eucalyptus calycogona ssp.	349	20.4	6	6.1	M	5.8	28.0	57	367	115.3	-	167.4	-	-	-	-
Eucalyptus calycogona ssp.	381	42.0	3	6.9	M	8.2	52.8	43	548	198.5	906	274.3	0.77	0.07	0.07	0.09
Eucalyptus camaldulensis var.	356	4.8	24	3.0	T	1.9	2.9	30	19	2.4	562	2.4	0.40	0.14	0.21	0.25
Eucalyptus camaldulensis var.	458	10.7	3	11.2	T	4.9	19.1	57	450	202.0	483	92.3	0.60	0.18	0.10	0.12
Eucalyptus cladocalyx	356	4.8	24	3.6	T	2.0	3.2	59	34	5.0	699	7.6	0.29	0.10	0.26	0.35

Appendix C - Destructive Sampling and Biometric Studies

Species	Rain fall (mm)	Age (years)	Obs. Plants (n)	Height (m)	Lifeform (Tree/ Mallee/ Shrub)	Crown Width (m)	Crown Area (m^2)	Foliage Density (%)	Basal Area[#] (cm^2)	Stemwood Volume x 1000 (m^3)	Basic Density (kg/m^3)	Dry Biomass (kg/plant)	Proportion Dry Biomass by Weight			
													Wood	Bark	Branch	Leaf
Eucalyptus cladocalyx	459	6.7	3	5.8	T	2.4	4.5	86	142	38.3	600	34.4	0.45	0.13	0.17	0.25
Eucalyptus cladocalyx	460	6.7	3	7.1	T	2.7	5.7	71	119	38.4	634	31.0	0.40	0.14	0.21	0.25
Eucalyptus cneorifolia	356	4.8	24	1.7	M	1.3	1.4	61	18	1.7	779	3.0	0.17	0.06	0.29	0.48
Eucalyptus cneorifolia	381	42.0	3	5.4	M	4.9	19.2	66	450	145.1	821	159.3	0.66	0.14	0.10	0.10
Eucalyptus cyanophylla	260	9.5	3	2.9	M	2.5	5.2	62	62	9.0	787	22.3	0.20	0.08	0.26	0.46
Eucalyptus cyanophylla	349	20.4	4	3.9	M	4.5	16.4	47	192	42.3	-	64.2	-	-	-	-
Eucalyptus diversifolia ssp.	348	15.4	1	0.5	M	0.5	0.2	-	2[#1]	0.04	-	1.9	-	-	-	-
Eucalyptus diversifolia ssp.	461	12.7	3	5.5	M	4.3	15.6	66	209	67.8	581	91.7	0.32	0.06	0.42	0.20
Eucalyptus dumosa	349	20.4	1	2.1	M	4.2	13.9	57	235	26.1	-	33.7	-	-	-	-
Eucalyptus dumosa	385	12.0	3	3.3	M	2.7	6.5	62	63	11.7	767	20.4	0.35	0.10	0.33	0.22
Eucalyptus fasciculosa	348	15.4	2	2.6	M	2.6	5.3	57	218	25.1	-	20.2	-	-	-	-
Eucalyptus fasciculosa	348	15.4	1	3.9	T	2.4	4.5	43	100	25.1	-	19.8	-	-	-	-
Eucalyptus globulus	458	10.7	3	13.8	T	3.5	10.1	57	224	142.2	530	90.8	0.63	0.09	0.10	0.18
Eucalyptus gracilis	260	6.6	3	1.8	M	2.0	3.0	91	31[#1]	1.5	830	6.1	0.06	0.02	0.35	0.57
Eucalyptus gracilis	349	20.4	4	6.8	M	5.5	24.5	50	307	117.6	-	129.7	-	-	-	-
Eucalyptus gracilis	356	31.2	3	10.0	M	7.5	48.1	71	702	368.5	908	422.1	0.79	0.12	0.05	0.04
Eucalyptus incrassata	349	20.4	1	2.4	T	3.1	7.5	57	32	5.6	-	14.3	-	-	-	-
Eucalyptus incrassata	349	20.4	10	3.7	M	4.4	16.3	56	176	40.7	-	65.6	-	-	-	-
Eucalyptus incrassata	356	31.2	3	5.8	M	7.5	44.9	43	423	128.1	824	221.5	0.63	0.10	0.14	0.13
Eucalyptus incrassata	356	4.8	24	1.7	M	1.5	1.7	52	13	1.2	778	2.6	0.14	0.06	0.20	0.60
Eucalyptus incrassata	461	12.7	3	3.6	M	4.3	14.8	71	133	29.0	726	50.9	0.33	0.11	0.29	0.27
Eucalyptus intertexta	381	42.0	3	12.5	T	5.6	24.6	43	1157	664.4	896	352.7	0.79	0.12	0.05	0.04
Eucalyptus largiflorens	260	10.5	3	3.8	M	2.6	5.4	52	95	19.8	687	19.2	0.41	0.14	0.22	0.23
Eucalyptus largiflorens	381	42.0	3	9.5	T	6.5	34.0	43	643	282.1	920	248.6	0.79	0.14	0.04	0.03
Eucalyptus leptophylla	348	15.4	3	3.9	M	4.6	18.1	71	190	40.9	-	67.7	-	-	-	-
Eucalyptus leptophylla	349	20.4	6	3.5	M	4.1	14.4	64	186	36.6	-	61.4	-	-	-	-
Eucalyptus leptophylla	349	20.4	2	3.0	T	1.6	2.0	29	19	3.6	-	6.1	-	-	-	-
Eucalyptus leptophylla	356	31.3	3	6.6	M	9.0	65.2	71	666	257.1	844	388.8	0.68	0.08	0.13	0.11
Eucalyptus leptophylla	376	42.0	3	6.9	M	7.7	47.9	57	368	125.9	919	169.1	0.66	0.13	0.12	0.09
Eucalyptus leucoxylon ssp.	348	15.4	4	4.9	T	2.9	6.5	46	198	47.6	-	44.9	-	-	-	-
Eucalyptus leucoxylon ssp.	376	42.0	3	8.8	T	8.8	60.5	57	615	268.4	835	269.8	0.70	0.15	0.06	0.09
Eucalyptus leucoxylon ssp.	494	10.7	3	9.7	T	2.9	6.6	43	172	72.9	657	42.7	0.56	0.23	0.08	0.13
Eucalyptus loxophleba ssp.	356	4.8	24	3.5	M	1.9	2.9	53	18	2.9	737	5.9	0.27	0.07	0.21	0.45
Eucalyptus occidentalis	356	4.8	24	4.5	T	1.8	2.7	50	37	8.2	668	10.2	0.33	0.09	0.21	0.37

Appendix C - Destructive Sampling and Biometric Studies

Species	Rain fall (mm)	Age (years)	Obs. Plants (n)	Height (m)	Lifeform (Tree/ Mallee/ Shrub)	Crown Width (m)	Crown Area (m^2)	Foliage Density (%)	Basal Area[#] (cm^2)	Stemwood Volume x 1000 (m^3)	Basic Density (kg/m^3)	Dry Biomass (kg/plant)	Proportion Dry Biomass by Weight			
													Wood	Bark	Branch	Leaf
Eucalyptus occidentalis	381	42.0	3	14.6	T	8.0	53.4	43	1811	1392.6	801	1247.3	0.82	0.12	0.02	0.04
Eucalyptus occidentalis	459	6.7	3	8.6	T	2.3	4.5	57	134	59.9	604	39.8	0.58	0.09	0.12	0.21
Eucalyptus occidentalis	460	5.7	3	10.0	T	3.3	8.7	57	238	113.0	538	68.1	0.65	0.09	0.09	0.17
Eucalyptus oleosa ssp.	260	10.4	3	2.9	M	3.5	9.9	76	86	10.9	793	25.1	0.26	0.08	0.27	0.39
Eucalyptus oleosa ssp.	348	15.4	1	3.3	M	4.0	12.6	43	124	28.7	-	42.9	-	-	-	-
Eucalyptus oleosa ssp.	349	20.4	1	1.2	M	1.8	2.5	86	11	0.8	-	4.4	-	-	-	-
Eucalyptus oleosa ssp.	352	31.2	3	6.4	M	8.5	57.9	57	556	199.1	841	343.2	0.61	0.10	0.13	0.16
Eucalyptus phenax ssp.	349	20.4	5	3.5	M	3.9	13.1	54	170	33.5	-	44.6	-	-	-	-
Eucalyptus polybractea	356	4.8	24	2.4	M	1.6	2.2	57	21	2.8	832	4.5	0.23	0.04	0.24	0.49
Eucalyptus porosa	260	9.5	3	2.4	M	3.1	7.8	76	68	7.3	668	11.6	0.20	0.06	0.39	0.35
Eucalyptus porosa	336	12.4	3	4.5	M	3.6	10.3	71	218	49.6	663	55.4	0.44	0.13	0.18	0.25
Eucalyptus porosa	348	15.4	31	4.5	M	3.9	13.2	67	267	70.6	-	78.1	-	-	-	-
Eucalyptus porosa	349	20.4	2	6.0	M	6.9	38.3	71	571	193.9	-	239.7	-	-	-	-
Eucalyptus porosa	386	6.7	3	3.9	M	3.8	11.7	71	93	17.7	577	23.3	0.29	0.08	0.26	0.37
Eucalyptus socialis ssp.	260	10.5	3	3.3	M	4.5	16.0	71	137	25.8	757	51.5	0.27	0.08	0.29	0.36
Eucalyptus socialis ssp.	348	15.4	2	4.0	M	3.2	9.2	72	188	42.6	-	75.1	-	-	-	-
Eucalyptus socialis ssp.	349	20.4	8	5.4	M	6.0	29.7	64	393	123.8	-	177.1	-	-	-	-
Eucalyptus socialis ssp.	352	26.1	3	5.6	M	7.2	40.8	71	517	142.0	778	185.9	0.64	0.13	0.11	0.12
Eucalyptus socialis ssp.	356	4.8	24	1.9	M	2.2	3.8	75	24	2.1	754	5.6	0.13	0.05	0.23	0.59
Eucalyptus viminalis ssp.	460	5.7	3	11.1	T	3.9	12.6	52	313	151.4	487	75.4	0.57	0.13	0.10	0.20
Melaleuca armillaris ssp.	348	15.4	1	2.7	T	3.0	7.1	-	750[#1]	97.5	-	47.9	-	-	-	-
Melaleuca armillaris ssp.	348	15.4	4	2.8	S	2.7	5.8	-	472[#1]	64.1	-	49.9	-	-	-	-
Melaleuca halmaturorum	348	15.4	1	2.1	S	2.0	3.1	-	145[#1]	14.7	-	22.8	-	-	-	-
Melaleuca lanceolata	348	15.4	5	2.7	S	3.3	8.6	-	385[#1]	52.1	-	54.5	-	-	-	-
Melaleuca lanceolata	356	31.2	3	4.0	S	5.2	21.6	71	487	106.6	776	148.8	0.56	0.15	0.15	0.14
Melaleuca uncinata	336	12.4	3	1.8	S	1.7	2.3	100	73[#1]	2.9	711	10.7	0.11	0.03	0.45	0.41
Melaleuca uncinata	348	15.4	2	2.3	S	2.5	5.5	-	374[#1]	41.2	-	40.4	-	-	-	-
Melaleuca uncinata	358	16.3	3	2.3	S	2.2	3.9	71	89[#2]	10.1	769	11.6	0.39	0.09	0.28	0.24
Pittosporum phylliraeoides	352	16.2	3	2.5	S	2.2	4.0	43	97	13.2	754	18.0	0.55	0.11	0.24	0.10
Senna artemisioides ssp.	348	15.4	2	1.9	S	1.1	1.0	-	47[#1]	4.2	-	7.8	-	-	-	-
Senna artemisioides ssp. coriacea	260	13.4	3	1.6	S	1.9	2.9	62	34[#1]	2.7	955	5.4	0.00	0.00	0.65	0.35

[#] basal area at 0.5m height unless otherwise indicated ([#1] 0.1m [#2] 0.2m).

APPENDIX D - PRODUCTIVITY AND CARBON SEQUESTRATION STUDIES

Table 47. Observed above-ground biomass and carbon sequestration from revegetation sites in agricultural regions of South Australia.

REVEGETATION	SITE DETAIL				FIELD SURVEY					STANDING BIOMASS			ROOT	SEQUESTRATION			
NRM REGION SPECIES Proportion of site biomass by species	Rain [mm]	NCAT Max. Dry Matter [t/ha]	NCAT Forest Prod. Index	Bios Equil [t C/ha/yr]	Age [years]	Plant Density [trees/ha]	Observations	Proportion Trees	Height [m]	Dry Biomass [t/ha]	Carbon [t/ha]	CO_2e [t/ha]	Root/Shoot Ratio	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]
Adelaide & Mt Lofty Ranges																	
Acacia implexa	487	117.3	7.1	2.2	7.4	830	36	1.00	6.0	33.45	16.59	60.89	0.57	3.52	4.52	2.24	8.23
Callitris gracilis	491	117.2	7.1	2.2	7.4	219	36	0.00	2.2	0.79	0.39	1.44	1.32	0.06	0.11	0.05	0.19
Corymbia maculata	490	118.2	7.2	2.2	7.4	380	36	1.00	6.1	20.06	9.95	36.51	0.57	2.17	2.71	1.34	4.93
Eucalyptus camaldulensis	565	81.2	5.5	2.6	14.9	833	36	1.00	10.8	156.44	77.60	284.78	0.40	9.60	10.52	5.22	19.15
E. camaldulensis/goniocalyx, Ac. retinodes, +6sp	595	89.0	5.9	2.6	10.9	1722	60	0.88	7.6	122.53	60.78	223.05	0.57	9.84	11.24	5.57	20.45
E. goniocalyx ssp. goniocalyx (40.0%), E. camaldulensis var. (29.4%), Ac. retinodes (12.5%), Ac. pycnantha (10.5%), Ac. paradoxa (2.7%), Al. verticillata (2.7%), Dodonaea viscosa ssp. (1.7%), Hakea carinata (0.3%), Al. muelleriana ssp. (0.1%)																	
Eucalyptus cladocalyx	541	137.2	8.0	2.4	10.4	736	36	1.00	9.1	65.46	32.47	119.15	0.43	5.28	6.29	3.12	11.46
Eucalyptus cladocalyx [coppice]	435	100.8	6.4	2.0	29.9	488	36	1.00	10.5	92.68	45.97	168.71	0.38	2.78	3.10	1.54	5.64
E. fasciculosa, Ac. retinodes/pycnantha, +3sp	592	128.7	7.6	2.4	14.9	1245	60	0.85	6.0	64.74	32.11	117.85	0.66	3.65	4.34	2.15	7.91
E. fasciculosa (72.7%), Ac. retinodes (15.6%), E. leucoxylon ssp. (7.3%), Ac. pycnantha (2.1%), Al. verticillata (1.6%), Mel. lanceolata (0.8%)																	
E. fasciculosa, Ac. retinodes/pycnantha, +4sp	592	128.7	7.6	2.4	14.9	660	60	0.80	6.5	78.13	38.75	142.22	0.48	4.81	5.24	2.60	9.54
Corymbia maculata (50.5%), E. fasciculosa (30.2%), Ac. retinodes (13.1%), E. viminalis ssp. cygnetensis (4.8%), Ac. pycnantha (1.1%), Al. verticillata (0.3%), Mel. lanceolata (<0.1%)																	
E. fasciculosa, M. lanceolata, +3sp	519	120.4	7.3	2.4	16.9	1480	36	0.75	5.7	106.50	52.83	193.87	0.53	5.46	6.30	3.12	11.46
E. fasciculosa (53.1%), E. leucoxylon ssp. (21.9%), E. camaldulensis var. (15.5%), Al. verticillata (7.5%), Mel. lanceolata (2.1%)																	
Eucalyptus globulus ssp. globulus	826	145.3	8.4	3.4	13.9	441	36	1.00	24.4	385.80	191.36	702.28	0.23	28.87	27.80	13.79	50.60
Eucalyptus leucoxylon ssp.	672	92.3	6.0	3.0	96.9	545	36	1.00	20.6	431.03	213.79	784.61	0.28	4.62	4.45	2.21	8.10
E. leucoxylon/camaldulensis, Ac. pycnantha, +4sp	711	88.6	5.9	3.2	11.8	2714	60	0.85	5.1	53.86	26.72	98.05	1.08	3.39	4.55	2.26	8.28
E. leucoxylon ssp. (34.5%), Ac. pycnantha (29.9%), E. camaldulensis var. (25.0%), Ac. retinodes (8.8%), Dodonaea viscosa ssp. (0.9%), Ac. dodonaeifolia (0.6%), Ac. paradoxa (0.3%)																	
E. leucoxylon/sideroxylon, Al. verticillata, +5sp	485	113.3	7.0	2.2	19.8	295	60	1.00	9.6	83.43	41.38	151.87	0.43	4.03	4.20	2.09	7.65
E. leucoxylon ssp. (37.2%), E. sideroxylon (24.8%), E. cladocalyx (20.7%), Al. verticillata (6.1%), E. camaldulensis var. (5.4%), E. viminalis ssp. cygnetensis (3.3%), E. odorata (2.5%), E. socialis ssp. (<0.1%)																	
E. porosa/odorata, Ac. notabilis, +9sp	414	93.1	6.1	1.6	18.8	1005	60	0.43	3.6	20.73	10.28	37.73	1.09	0.84	1.10	0.55	2.01
E. porosa (47.2%), E. odorata (24.0%), Callitris gracilis (8.4%), Ac. notabilis (7.4%), E. incrassata (4.3%), Ac. oswaldii (3.3%), Ac. brachybotrya (2.1%), Ac. sclerophylla var. sclerophylla (1.4%), E. socialis ssp. (0.8%), Ac. acinacea (0.7%), Ac. ligulata (0.3%), Mel. lanceolata (0.1%)																	
E. viminalis/sideroxylon/leucoxylon, +11sp	595	130.2	7.7	2.7	12.8	806	60	0.62	5.9	72.81	36.11	132.54	0.56	5.15	5.69	2.82	10.35
E. sideroxylon (38.5%), E. viminalis ssp. cygnetensis (20.4%), E. camaldulensis var. (9.3%), Casuarina cunninghamiana (7.0%), E. leucoxylon ssp. (6.5%), Ac. retinodes (5.1%), Ac. pycnantha (3.5%), Al. verticillata (2.1%), Ac. paradoxa (2.0%), E. fasciculosa (1.9%), E. odorata (1.3%), Dodonaea viscosa ssp. (1.2%), E. baxteri (1.1%), Grevillea robusta (0.1%)																	
Eyre Peninsula																	
Ac. calamifolia/notabilis/ligulata, +5sp	340	41.2	3.8	1.6	9.8	1333	60	0.35	2.9	16.09	7.98	29.29	1.18	1.15	1.64	0.81	2.98
Ac. calamifolia (54.1%), Ac. ligulata (11.8%), Ac. notabilis (10.4%), E. brachycalyx (6.8%), E. incrassata (6.0%), E. phenax ssp. (5.4%), E. dumosa (4.4%), Ac. iteaphylla (1.2%)																	
Eucalyptus camaldulensis var.	452	61.9	4.7	2.1	21.2	1111	36	1.00	7.7	136.26	67.58	248.03	0.42	5.70	6.42	3.18	11.69

Appendix D - Productivity and Carbon Sequestration Studies

REVEGETATION	SITE DETAIL				FIELD SURVEY					STANDING BIOMASS			ROOT	SEQUESTRATION			
NRM REGION SPECIES Proportion of site biomass by species	Rain [mm]	NCAT Max. Dry Matter [t/ha]	NCAT Forest Prod. Index	Bios Equil [t C/ha/yr]	Age [years]	Plant Density [trees/ha]	Observations	Proportion Trees	Height [m]	Dry Biomass [t/ha]	Carbon [t/ha]	CO_2e [t/ha]	Root/Shoot Ratio	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]
Eucalyptus cladocalyx	410	80.5	5.5	1.9	72.8	714	36	1.00	14.9	183.64	91.08	334.28	0.27	2.34	2.52	1.25	4.59
E. dumosa/brachycalyx/calycogona, +4sp	317	36.6	3.6	1.5	19.8	836	60	0.92	3.2	12.10	6.00	22.03	1.03	0.43	0.61	0.30	1.11
E. dumosa (37.2%), E. brachycalyx (25.6%), E. oleosa ssp. (19.3%), E. calycogona ssp. (13.2%), Ac. notabilis (2.4%), Ac. ligulata (1.6%), Mel. pauperiflora ssp. mutica (0.7%)																	
Eucalyptus dundassii	355	47.7	4.1	1.7	29.3	269	36	1.00	9.6	51.27	25.43	93.33	0.54	1.57	1.75	0.87	3.19
E. gomphocephala/camaldulensis, +3sp	428	54.5	4.4	1.9	21.1	957	60	0.93	11.4	291.60	144.63	530.80	0.34	13.33	13.85	6.87	25.21
E. gomphocephala (67.6%), E. camaldulensis var. (27.7%), E. calycogona ssp. (2.6%), Al. verticillata (1.0%), Mel. lanceolata (1.0%), Mel. uncinata (0.1%)																	
Eucalyptus loxophleba	319	38.4	3.7	1.5	26.8	169	36	1.00	9.7	51.17	25.38	93.15	0.46	1.80	1.91	0.95	3.47
E. occidentalis, Al. verticillata, +3sp	425	53.6	4.3	2.0	33.5	188	60	0.98	14.4	138.39	68.64	251.92	0.37	4.25	4.14	2.05	7.53
E. occidentalis (68.2%), Al. verticillata (18.7%), E. sargentii (11.0%), E. camaldulensis var. (2.0%), Mel. lanceolata (<0.1%)																	
E. oleosa/gracilis/socialis, +13sp	294	35.1	3.5	1.4	19.8	245	60	0.70	4.7	22.74	11.28	41.39	0.63	0.99	1.15	0.57	2.09
E. oleosa ssp. (18.1%), E. gracilis (13.9%), E. vegrandis (13.1%), E. petiolaris (9.7%), E. socialis ssp. (9.2%), E. stricklandii (7.7%), E. brachycalyx (6.6%), Ac. calamifolia (6.1%), E. astringens ssp. astringens (3.7%), Mel. lanceolata (2.8%), E. torquata (2.5%), E. incrassata (2.1%), Ac. notabilis (1.9%), E. spreta (0.8%), E. erythronema var. marginata (0.8%), Ac. ligulata (0.8%)																	
E. petiolaris/brockwayi/porosa, +8sp	298	30.7	3.3	1.2	22.8	170	60	0.83	5.8	21.44	10.63	39.02	0.53	0.84	0.94	0.47	1.71
E. petiolaris (61.1%), E. brockwayi (13.2%), E. porosa (9.4%), Callitris gracilis (9.0%), Al. verticillata (1.8%), Ac. ligulata (1.5%), Senna artemisioides ssp. (1.0%), Ac. calamifolia (0.9%), Mel. lanceolata (0.8%), Exocarpos sparteus (0.8%), Mel. nesophila (0.3%)																	
E. socialis/oleosa, + 6sp	293	32.3	3.4	1.2	19.1	366	60	0.88	4.7	23.42	11.62	42.64	0.76	1.02	1.23	0.61	2.24
E. socialis ssp. (52.5%), E. oleosa ssp. (27.1%), E. incrassata (8.5%), E. calycogona ssp. (4.8%), Mel. lanceolata (3.0%), Al. verticillata (2.7%), Ac. ligulata (1.1%), Ac. oswaldii (0.3%)																	
E. spathulata, Al. verticillata, + 3sp	367	96.4	6.2	1.7	35.4	489	60	0.80	6.3	87.49	43.40	159.26	0.41	2.28	2.47	1.23	4.50
E. spathulata (62.2%), Al. verticillata (28.7%), E. platypus (4.7%), Mel. lanceolata (3.7%), Hakea leucoptera ssp. leucoptera (0.6%)																	
Kangaroo Island																	
Al. verticillata, +2sp	503	71.3	5.1	2.3	16.6	332	36	1.00	6.8	30.99	15.37	56.41	0.55	1.60	1.86	0.92	3.39
Al. verticillata (99.5%), E. cneorifolia (0.4%), E. diversifolia ssp. diversifolia (0.1%)																	
Al. verticillata, E. diversifolia, +6sp	503	69.5	5.0	2.3	16.6	1485	60	0.83	5.0	55.16	27.36	100.41	0.83	2.66	3.32	1.65	6.04
Al. verticillata (44.1%), E. fasciculosa (21.2%), E. diversifolia ssp. diversifolia (18.2%), E. cneorifolia (6.9%), Mel. halmaturorum (6.7%), E. cosmophylla (1.5%), Mel. gibbosa (1.3%), Ac. retinodes var. uncifolia (0.1%)																	
E. camaldulensis, M. decussata, +3sp	659	94.0	6.1	2.7	14.6	2453	60	0.67	8.8	362.96	180.03	660.70	0.45	23.32	24.81	12.31	45.17
E. camaldulensis var. (99.2%), Mel. decussata (0.5%), Mel. gibbosa (0.2%), Mel. uncinata (0.1%), Callistemon rugulosus (<0.1%)																	
E. cladocalyx/cosmophylla/fasciculosa	603	92.6	6.0	2.7	18.7	470	60	1.00	5.2	45.76	22.70	83.30	0.55	2.13	2.45	1.21	4.45
E. cosmophylla (55.3%), E. cladocalyx (32.6%), E. fasciculosa (12.1%)																	
E. cladocalyx/occidentalis, Al. verticillata, +6sp	476	68.4	5.0	2.1	15.6	8575	60	0.68	4.7	241.30	119.69	439.25	0.70	13.53	15.44	7.66	28.10
E. cladocalyx (65.0%), E. occidentalis (17.6%), Al. verticillata (11.1%), Ac. pycnantha (3.8%), E. viminalis ssp. cygnetensis (0.8%), E. leucoxylon ssp. (0.6%), E. diversifolia ssp. diversifolia (0.5%), E. camaldulensis var. (0.4%), E. cneorifolia (0.1%)																	
E. cladocalyx/ovata/fasciculosa, +1sp	596	89.1	5.9	2.6	15.6	728	60	0.68	8.0	139.43	69.16	253.80	0.44	8.40	8.92	4.43	16.25
E. cladocalyx (45.6%), E. ovata var. (31.4%), E. fasciculosa (21.5%), Mel. uncinata (1.6%)																	
E. viminalis/ovata, +8sp	660	93.5	6.1	2.7	11.6	554	60	0.90	13.1	294.48	146.06	536.05	0.36	25.73	25.33	12.56	46.10
E. viminalis ssp. cygnetensis (80.1%), E. ovata var. (9.3%), E. camaldulensis var. (3.9%), E. cladocalyx (3.2%), E. obliqua (2.8%), Ac. dodonaeifolia (0.3%), Mel. gibbosa (0.2%), Al. verticillata (0.1%), Ac. retinodes (0.1%), Mel. uncinata (<0.1%)																	

Appendix D - Productivity and Carbon Sequestration Studies

REVEGETATION	SITE DETAIL				FIELD SURVEY					STANDING BIOMASS			ROOT	SEQUESTRATION			
NRM REGION SPECIES Proportion of site biomass by species	Rain [mm]	NCAT Max. Dry Matter [t/ha]	NCAT Forest Prod. Index	Bios Equil [t C/ha/yr]	Age [years]	Plant Density [trees/ha]	Observations	Proportion Trees	Height [m]	Dry Biomass [t/ha]	Carbon [t/ha]	CO_2e [t/ha]	Root/Shoot Ratio	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]
Northern & Yorke																	
Ac. pycnantha/ligulata, D. viscosa, +8sp	418	99.5	6.3	1.7	13.4	3037	60	0.33	3.3	25.90	12.85	47.15	1.39	1.31	1.93	0.96	3.52
Dodonaea viscosa ssp. (24.5%), Ac. pycnantha (23.4%), Ac. ligulata (22.2%), Ac. wattsiana (10.3%), E. leptophylla (8.4%), E. cyanophylla (4.3%), E. socialis ssp. (2.9%), Ac. brachybotrya (1.7%), Ac. anceps (1.0%), Al. verticillata (0.7%), Ac. notabilis (0.7%)																	
Allocasuarina verticillata	443	104.8	6.6	2.0	43.9	485	36	0.97	9.7	70.72	35.08	128.73	0.48	1.43	1.61	0.80	2.93
Casuarina glauca	399	85.6	5.7	1.5	21.3	427	36	1.00	8.2	44.86	22.25	81.65	0.65	1.78	2.10	1.04	3.83
Casuarina pauper	433	90.6	6.0	1.7	97.9	371	36	1.00	12.7	196.47	97.45	357.65	0.37	2.00	2.01	1.00	3.65
Eucalyptus vegrandis	418	99.5	6.3	1.7	13.4	635	36	1.00	7.6	58.17	28.85	105.88	0.55	3.67	4.34	2.15	7.90
E. astringens/spathulata, Al. verticillata, +9sp	387	92.3	6.0	1.8	19.8	451	60	0.92	5.9	31.67	15.71	57.65	0.65	1.33	1.60	0.79	2.91
Al. verticillata (45.2%), E. sargentii (13.7%), E. occidentalis (11.1%), E. spathulata (8.0%), E. astringens ssp. astringens (5.8%), E. dundasii (4.1%), E. pterocarpa (3.4%), E. ceratocorys (2.8%), E. dumosa (2.2%), E. diptera (1.7%), E. socialis ssp. (1.1%), Mel. lanceolata (0.9%)																	
Eucalyptus calycogona	367	44.6	3.9	1.5	15.8	419	36	1.00	3.4	11.78	5.84	21.44	1.08	0.55	0.74	0.37	1.35
E. calycogona/porosa/gracilis, +11sp	325	35.1	3.5	1.6	19.8	242	60	0.88	5.4	25.60	12.70	46.59	0.68	1.12	1.29	0.64	2.35
E. calycogona ssp. (29.5%), E. porosa (17.9%), E. phenax ssp. (10.4%), E. socialis ssp. (10.3%), E. gracilis (9.5%), E. oleosa ssp. (8.6%), Callitris gracilis (3.5%), E. incrassata (3.1%), Ac. notabilis (1.9%), E. odorata (1.8%), Al. verticillata (1.5%), E. brachycalyx (1.5%), Senna artemisioides ssp. (0.3%), Ac. ligulata (0.2%)																	
E. calycogona/socialis, +10sp	361	45.2	4.0	1.7	21.3	387	60	0.73	3.9	18.73	9.29	34.09	0.84	0.71	0.88	0.44	1.60
E. calycogona ssp. (41.8%), E. odorata (14.2%), E. socialis ssp. (11.5%), Mel. lanceolata (7.5%), E. oleosa ssp. (7.3%), E. salicola (4.4%), Ac. oswaldii (3.8%), Al. verticillata (3.3%), E. gracilis (3.1%), E. leptophylla (1.7%), Ac. ligulata (1.1%), Senna artemisioides ssp. petiolaris (0.3%)																	
Eucalyptus camaldulensis var.	404	86.4	5.8	1.6	15.8	833	36	1.00	10.3	86.29	42.80	157.07	0.67	4.64	5.45	2.70	9.93
Eucalyptus camaldulensis var. camaldulensis	444	105.0	6.6	2.0	43.9	568	36	1.00	12.2	169.21	83.93	308.02	0.33	3.65	3.85	1.91	7.01
Eucalyptus camaldulensis var. camaldulensis	490	114.0	7.0	2.0	130.9	410	36	1.00	24.4	740.06	367.07	1347.15	0.22	6.38	5.65	2.80	10.29
Eucalyptus camaldulensis var. camaldulensis	561	112.4	6.9	2.5	25.8	1243	36	1.00	18.3	340.81	169.04	620.38	0.26	12.42	13.21	6.55	24.05
E. camaldulensis/cladocalyx, +10sp	564	70.0	5.1	2.6	18.8	936	60	0.83	8.5	121.72	60.37	221.57	0.50	5.83	6.48	3.21	11.79
E. cladocalyx (42.6%), E. camaldulensis var. camaldulensis (34.1%), E. leucoxylon ssp. (11.2%), E. fasciculosa (2.9%), E. porosa (2.9%), Al. verticillata (2.6%), Callitris gracilis (1.5%), E. socialis ssp. (1.4%), Dodonaea viscosa ssp. (0.4%), Mel. acuminata ssp. acuminata (0.2%), Corymbia maculata (0.2%), Callistemon rugulosus (0.1%)																	
E. camaldulensis/occidentalis, C. citriodora, +3sp	471	54.9	4.4	2.1	22.9	219	60	1.00	9.9	55.12	27.34	100.33	0.40	2.26	2.41	1.19	4.38
E. camaldulensis var. camaldulensis (36.3%), E. occidentalis (20.5%), E. astringens ssp. astringens (17.9%), Corymbia citriodora (13.7%), E. leucoxylon ssp. (6.5%), E. cladocalyx (5.1%)																	
Eucalyptus cladocalyx	356	89.0	5.9	1.3	15.2	477	36	1.00	8.2	50.96	25.28	92.76	0.47	2.89	3.35	1.66	6.09
Eucalyptus cladocalyx	369	47.3	4.1	1.7	15.2	736	36	1.00	9.3	70.10	34.77	127.61	0.49	3.89	4.60	2.28	8.38
Eucalyptus cladocalyx	379	95.0	6.2	1.8	9.8	388	36	1.00	6.4	24.38	12.09	44.37	0.66	2.01	2.48	1.23	4.51
Eucalyptus cladocalyx	417	100.4	6.4	1.9	15.2	692	36	1.00	8.2	48.11	23.86	87.57	0.63	2.60	3.16	1.57	5.75
Eucalyptus cladocalyx	446	55.8	4.4	2.0	11.8	609	36	1.00	10.1	97.78	48.50	178.00	0.42	7.39	8.26	4.10	15.03
Eucalyptus cladocalyx	459	61.0	4.7	1.9	19.8	805	36	1.00	9.0	84.49	41.91	153.80	0.50	3.63	4.26	2.11	7.75
Eucalyptus cladocalyx	460	103.7	6.5	1.9	99.9	243	36	1.00	16.6	121.58	60.30	221.31	0.34	1.20	1.22	0.60	2.22
Eucalyptus cladocalyx	484	100.2	6.4	2.0	99.9	322	36	1.00	16.5	177.51	88.04	323.12	0.34	1.77	1.78	0.88	3.23
Eucalyptus cladocalyx	489	103.1	6.5	2.0	99.9	222	36	1.00	28.0	514.06	254.98	935.76	0.23	5.81	5.15	2.55	9.37
Eucalyptus cladocalyx	497	122.4	7.3	2.1	126.9	199	36	1.00	35.4	917.38	455.02	1669.92	0.18	8.82	7.23	3.58	13.15

Appendix D - Productivity and Carbon Sequestration Studies

REVEGETATION	SITE DETAIL				FIELD SURVEY					STANDING BIOMASS			ROOT	SEQUESTRATION			
NRM REGION SPECIES Proportion of site biomass by species	Rain [mm]	NCAT Max. Dry Matter [t/ha]	NCAT Forest Prod. Index	Bios Equil [t C/ha/yr]	Age [years]	Plant Density [trees/ha]	Observations	Proportion Trees	Height [m]	Dry Biomass [t/ha]	Carbon [t/ha]	CO_2e [t/ha]	Root/Shoot Ratio	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]
Eucalyptus cladocalyx	561	112.4	6.9	2.5	25.8	1312	36	1.00	19.3	519.29	257.57	945.27	0.22	19.57	20.13	9.99	36.65
E. dumosa/oleosa/socialis, +8sp	451	99.5	6.3	2.1	14.8	596	60	0.90	5.3	33.52	16.63	61.02	0.87	1.85	2.26	1.12	4.12
E. dumosa (32.5%), E. oleosa ssp. (26.5%), E. socialis ssp. (23.9%), E. gracilis (6.4%), Ac. notabilis (4.1%), Callitris gracilis (3.3%), E. odorata (1.0%), Al. verticillata (0.9%), E. brachycalyx (0.9%), Mel. lanceolata (0.4%), Ac. victoriae ssp. victoriae (0.1%)																	
E. dumosa/socialis, Al. verticillata, +6sp	349	42.1	3.8	1.3	14.8	336	60	0.70	3.8	11.81	5.86	21.50	0.85	0.62	0.80	0.40	1.45
E. dumosa (46.7%), E. socialis ssp. (20.8%), Al. verticillata (9.7%), E. brachycalyx (6.1%), Mel. lanceolata (5.0%), E. gracilis (4.7%), Ac. notabilis (4.5%), E. oleosa ssp. (2.5%)																	
Eucalyptus dundasi	443	104.8	6.6	2.0	43.9	476	36	1.00	18.0	215.10	106.69	391.56	0.36	4.77	4.89	2.43	8.91
E. gracilis/leucoxylon/odorata, +5sp	469	105.6	6.6	2.2	23.2	333	60	0.93	5.7	30.07	14.91	54.74	0.76	1.11	1.30	0.64	2.36
E. gracilis (33.8%), E. odorata (20.1%), Al. verticillata (15.8%), E. socialis ssp. (13.1%), E. largiflorens (8.1%), E. camaldulensis var. (5.3%), Ac. notabilis (2.1%), E. phenax ssp. (1.8%)																	
Eucalyptus largiflorens	433	90.6	6.0	1.7	97.9	136	36	1.00	8.8	48.92	24.27	89.06	0.49	0.48	0.50	0.25	0.91
Eucalyptus largiflorens	444	105.0	6.6	2.0	48.9	568	36	1.00	10.3	105.09	52.13	191.30	0.49	1.93	2.15	1.07	3.91
Eucalyptus largiflorens	499	122.7	7.4	2.3	119.9	494	36	1.00	11.8	186.51	92.51	339.50	0.43	1.51	1.55	0.77	2.83
Eucalyptus leucoxylon ssp.	386	92.2	6.0	1.8	29.8	916	36	1.00	4.5	34.72	17.22	63.21	0.93	0.92	1.16	0.58	2.12
Eucalyptus leucoxylon ssp.	440	98.0	6.3	2.0	47.9	335	36	1.00	9.0	49.46	24.53	90.03	0.59	0.91	1.03	0.51	1.88
Eucalyptus leucoxylon ssp.	474	107.2	6.7	2.2	22.2	673	36	1.00	6.9	56.00	27.78	101.94	0.58	2.12	2.53	1.25	4.60
Eucalyptus leucoxylon ssp.	489	114.8	7.0	2.0	129.9	228	36	1.00	15.5	148.13	73.47	269.65	0.37	1.16	1.14	0.57	2.08
E. leucoxylon/porosa, +4sp	399	91.2	6.0	1.5	18.9	413	60	0.95	6.6	37.25	18.48	67.80	0.56	1.70	1.98	0.98	3.60
E. leucoxylon ssp. (39.2%), E. porosa (28.6%), E. largiflorens (23.1%), E. camaldulensis var. (4.4%), Al. verticillata (4.2%), Ac. notabilis (0.4%)																	
E. leucoxylon/socialis, Al. verticillata, +2sp	396	83.5	5.6	1.9	21.9	318	60	0.93	4.9	20.17	10.01	36.72	0.70	0.76	0.92	0.46	1.68
E. leucoxylon ssp. (35.6%), Al. verticillata (27.2%), E. socialis ssp. (22.1%), E. porosa (12.9%), E. cyanophylla (2.2%)																	
Eucalyptus loxopheba	446	104.7	6.6	2.0	36.9	522	36	1.00	10.6	95.35	47.29	173.56	0.56	2.37	2.58	1.28	4.70
Eucalyptus occidentalis	350	87.3	5.8	1.3	14.7	739	36	1.00	12.7	138.14	68.52	251.46	0.47	8.48	9.38	4.65	17.08
Eucalyptus occidentalis	357	86.2	5.8	1.7	15.2	725	36	1.00	9.9	77.73	38.55	141.49	0.47	4.37	5.11	2.53	9.29
Eucalyptus occidentalis	407	81.4	5.6	1.9	19.3	339	36	1.00	10.9	73.28	36.35	133.40	0.50	3.46	3.80	1.89	6.92
Eucalyptus occidentalis	447	58.7	4.6	2.1	10.8	660	36	1.00	10.1	70.30	34.87	127.96	0.55	5.52	6.49	3.22	11.81
Eucalyptus occidentalis	459	61.0	4.7	1.9	11.8	810	36	1.00	10.0	67.13	33.30	122.19	0.57	4.73	5.67	2.81	10.31
E. odorata, Al. verticillata, Ac. wattsiana, +2sp	474	60.7	4.8	2.2	18.7	1156	60	0.67	5.1	52.17	25.88	94.97	0.86	2.32	2.79	1.38	5.08
E. odorata (75.3%), Ac. wattsiana (15.3%), Al. verticillata (8.9%), Ac. pycnantha (0.4%), Ac. paradoxa (0.1%)																	
Eucalyptus oleosa ssp.	441	98.1	6.3	2.0	49.9	581	36	1.00	8.6	64.35	31.92	117.13	0.76	1.11	1.29	0.64	2.35
Eucalyptus porosa	334	87.5	5.8	1.6	20.8	95	36	1.00	9.5	36.55	18.13	66.53	0.58	1.68	1.76	0.87	3.20
Eucalyptus porosa	367	46.2	4.0	1.5	15.8	192	36	1.00	3.7	12.96	6.43	23.60	0.76	0.67	0.82	0.41	1.49
E. porosa/calycogona/incrassata, Al. vertic., +5sp	418	95.4	6.2	1.7	10.8	711	60	0.75	3.7	17.83	8.84	32.45	0.93	1.26	1.64	0.82	2.99
E. oleosa ssp. (23.8%), Al. verticillata (22.1%), E. calycogona ssp. (16.2%), E. porosa (13.8%), E. incrassata (13.1%), Ac. pycnantha (8.5%), E. odorata (1.4%), E. socialis ssp. (0.6%), E. brachycalyx (0.6%)																	
E. porosa/odorata, Al. verticillata, +8sp	381	52.5	4.3	1.5	12.9	487	60	0.75	4.8	25.75	12.77	46.88	0.72	1.64	2.00	0.99	3.64
E. porosa (27.8%), E. odorata (22.9%), E. brachycalyx (16.4%), Al. verticillata (15.4%), E. oleosa ssp. (10.2%), Mel. lanceolata (4.0%), E. dumosa (1.3%), Ac. ligulata (0.7%), E. phenax ssp. (0.6%), Senna artemisioides ssp. (0.4%), Pittosporum angustifolium (0.4%)																	

Appendix D - Productivity and Carbon Sequestration Studies

REVEGETATION	SITE DETAIL				FIELD SURVEY					STANDING BIOMASS			ROOT	SEQUESTRATION			
NRM REGION SPECIES Proportion of site biomass by species	Rain [mm]	NCAT Max. Dry Matter [t/ha]	NCAT Forest Prod. Index	Bios Equil [t C/ha/yr]	Age [years]	Plant Density [trees/ha]	Observations	Proportion Trees	Height [m]	Dry Biomass [t/ha]	Carbon [t/ha]	CO_2e [t/ha]	Root/Shoot Ratio	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]
E. rugosa/socialis, +7sp	410	90.1	5.9	1.6	15.9	1834	60	0.78	3.7	32.51	16.13	59.18	0.85	1.51	2.05	1.02	3.73
E. socialis ssp. (45.2%), E. rugosa (42.1%), Mel. lanceolata (5.2%), Al. verticillata (2.0%), Ac. notabilis (1.2%), Senna artemisioides ssp. X coriacea (1.2%), Ac. pycnantha (1.2%), E. odorata (1.1%), E. cladocalyx (0.7%)																	
Eucalyptus salmonophloia	443	104.5	6.3	2.0	46.9	692	36	1.00	10.8	107.20	53.17	195.14	0.43	2.03	2.28	1.13	4.16
Eucalyptus sideroxylon	442	100.7	6.4	2.0	45.9	587	36	1.00	10.1	151.60	75.19	275.96	0.36	3.06	3.30	1.64	6.01
Eucalyptus sideroxylon	505	127.1	7.6	2.1	120.9	782	36	1.00	19.4	987.89	489.99	1798.27	0.20	8.93	8.17	4.05	14.87
E. socialis/oleosa/brachycalyx, +5sp	333	86.3	5.8	1.6	15.8	210	60	0.98	5.3	15.78	7.83	28.72	0.66	0.84	1.00	0.49	1.82
E. socialis ssp. (62.5%), E. brachycalyx (12.3%), E. oleosa ssp. (8.9%), E. gracilis (8.4%), Al. verticillata (3.9%), E. calycogona ssp. (2.8%), E. dumosa (0.8%), Ac. ligulata (0.4%)																	
E. socialis/oleosa/phenax, +4sp	327	41.4	3.8	1.6	19.8	413	60	0.98	4.9	23.14	11.48	42.13	0.81	0.94	1.17	0.58	2.13
E. socialis ssp. (40.4%), E. oleosa ssp. (22.9%), E. phenax ssp. (18.1%), E. dumosa (9.8%), E. gracilis (7.0%), E. brachycalyx (1.7%), Al. verticillata (0.1%)																	
SA Murray-Darling Basin																	
Acacia Iigulata	260	22.9	3.0	1.1	13.8	511	30	0.07	2.7	20.69	10.26	37.67	0.75	1.19	1.50	0.74	2.73
Acacia pycnantha	334	44.8	3.9	1.6	13.8	1644	30	0.30	3.7	42.23	20.95	76.88	0.86	2.28	3.05	1.51	5.55
Ac. pycnantha/microcarpa, +6sp	366	68.8	5.0	1.7	18.0	7005	60	0.53	4.0	57.25	28.40	104.22	1.65	2.10	3.19	1.58	5.80
Ac. pycnantha (38.5%), Ac. microcarpa (36.9%), E. incrassata (12.7%), E. leucoxylon ssp. (6.2%), Dodonaea viscosa ssp. cuneata (3.5%), Ac. paradoxa (1.2%), Al. verticillata (0.6%), Ac. calamifolia (0.5%)																	
Acacia salicina	356	46.7	4.0	1.7	4.8	2014	232	0.00	0.9	1.80	0.89	3.28	2.20	0.05	0.37	0.18	0.68
Acacia saligna ssp. Lindleyi	356	46.7	4.0	1.7	4.8	1476	170	0.02	2.9	8.25	4.09	15.02	1.36	1.11	1.71	0.85	3.11
Allocasuarina verticillata	414	71.4	5.1	1.9	21.8	1963	36	0.83	4.8	39.37	19.53	71.66	1.05	1.33	1.81	0.90	3.29
Al. verticillata, E. leucoxylon, +1sp	394	94.9	6.1	1.9	33.0	264	60	0.95	6.0	37.90	18.80	68.99	0.51	1.02	1.15	0.57	2.09
Al. verticillata (47.9%), E. leucoxylon ssp. (38.8%), Callitris gracilis (13.4%)																	
Al. verticillata, E. socialis, +7sp	397	49.9	4.2	1.6	15.0	1040	36	0.81	4.8	34.70	17.21	63.17	0.85	1.81	2.32	1.15	4.22
Al. verticillata (44.7%), E. socialis ssp. (29.4%), E. incrassata (7.9%), E. oleosa ssp. (7.0%), E. camaldulensis var. (5.7%), Ac. rigens (3.1%), Dodonaea viscosa ssp. spatulata (1.1%), Callitris gracilis (0.6%), E. leptophylla (0.4%)																	
Callitris gracilis, E. platypus/dundasii, +7sp	361	48.7	4.1	1.7	18.9	198	60	0.80	7.2	56.75	28.15	103.30	0.41	2.94	3.00	1.49	5.46
E. platypus (29.4%), E. leucoxylon ssp. (29.1%), E. dundasii (16.7%), Callitris gracilis (10.7%), E. camaldulensis var. (6.3%), Mel. lanceolata (2.6%), E. socialis ssp. (1.7%), E. leptophylla (1.4%), Mel. halmaturorum (1.2%), Al. verticillata (0.9%)																	
Callitris gracilis, E. leucoxylon/porosa, +6sp	379	108.9	6.8	1.8	31.9	259	60	0.97	7.0	47.87	23.74	87.13	0.58	1.40	1.50	0.74	2.73
E. spathulata (36.3%), E. porosa (23.2%), E. leucoxylon ssp. (15.0%), Callitris gracilis (9.7%), E. gomphocephala (4.9%), E. gardneri (4.9%), E. campaspe (3.2%), E. phenax ssp. (2.7%), Brachychiton populeneus (0.1%)																	
Casuarina cunninghamiana	567	121.8	7.3	2.5	14.9	649	36	1.00	6.3	30.52	15.14	55.56	0.86	1.62	2.05	1.02	3.73
Casuarina cunninghamiana, +5sp	515	116.9	7.1	2.3	14.9	379	36	0.92	5.6	22.76	11.29	41.43	0.67	1.25	1.53	0.76	2.78
Casuarina cunninghamiana (66.1%), E. cladocalyx (17.8%), E. leucoxylon ssp. (7.5%), Corymbia maculata (4.0%), Ac. pycnantha (2.4%), Al. verticillata (2.3%)																	
Corymbia maculata	601	86.2	5.8	2.6	8.4	811	36	1.00	8.7	73.78	36.59	134.30	0.56	7.42	8.78	4.36	15.99
Dodonaea viscosa	260	22.9	3.0	1.1	13.8	791	30	0.00	2.6	10.38	5.15	18.89	1.18	0.52	0.75	0.37	1.37
Eucalyptus camaldulensis var.	361	48.2	4.1	1.7	7.6	96	30	1.00	5.7	4.93	2.45	8.97	0.66	0.52	0.65	0.32	1.19
Eucalyptus camaldulensis var.	375	48.5	4.1	1.6	15.0	914	36	1.00	15.5	259.71	128.82	472.76	0.35	16.64	17.35	8.61	31.58
Eucalyptus camaldulensis var.	375	50.8	4.2	1.5	7.7	1007	30	1.00	9.6	101.49	50.34	184.74	0.43	11.35	13.18	6.54	23.99
Eucalyptus camaldulensis var. camaldulensis	356	46.7	4.0	1.7	4.8	2118	244	1.00	2.8	7.62	3.78	13.87	2.13	0.91	1.57	0.78	2.87

Appendix D - Productivity and Carbon Sequestration Studies

REVEGETATION	SITE DETAIL				FIELD SURVEY					STANDING BIOMASS			ROOT	SEQUESTRATION			
NRM REGION SPECIES Proportion of site biomass by species	Rain [mm]	NCAT Max. Dry Matter [t/ha]	NCAT Forest Prod. Index	Bios Equil [t C/ha/yr]	Age [years]	Plant Density [trees/ha]	Observations	Proportion Trees	Height [m]	Dry Biomass [t/ha]	Carbon [t/ha]	CO_2e [t/ha]	Root/Shoot Ratio	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]
E. camaldulensis, Cas. cunninghamiana, +1sp	561	115.3	7.0	2.4	14.9	507	60	0.98	6.1	24.71	12.26	44.98	0.70	1.39	1.66	0.82	3.02
E. camaldulensis var. (75.3%), Casuarina cunninghamiana (23.8%), E. sideroxylon (0.9%)																	
E. camaldulensis/goniocalyx, M. acuminata, +9sp	596	141.1	8.2	2.7	17.9	1549	60	0.77	7.7	211.20	104.76	384.46	0.46	11.16	11.80	5.85	21.47
E. camaldulensis var. (52.5%), E. goniocalyx ssp. goniocalyx (15.5%), Al. verticillata (9.7%), E. viminalis ssp. cygnetensis (6.2%), Ac. melanoxylon (4.6%), Ac. retinodes (4.3%), E. ovata var. (2.4%), Mel. sp. (2.2%), Mel. acuminata ssp. acuminata (1.7%), E. fasciculosa (0.5%), Ac. pycnantha (0.3%), Callistemon rugulosus (0.2%)																	
E. camaldulensis/largiflorens, Ac. ligulata, +6sp	386	47.2	4.1	1.8	11.9	959	60	0.67	4.6	43.43	21.54	79.06	0.72	2.98	3.64	1.80	6.62
Ac. ligulata (45.3%), E. largiflorens (29.1%), E. camaldulensis var. (17.7%), Ac. calamifolia (3.6%), Cal. canescens (2.1%), Ac. rigens (1.3%), E. socialis ssp. (0.6%), Dodonaea viscosa ssp. angustissima (0.4%), E. oleosa ssp. (0.1%)																	
E. camaldulensis/leucoxylon	370	47.2	4.1	1.5	15.0	550	60	1.00	6.6	33.18	16.46	60.39	0.86	1.87	2.22	1.10	4.03
E. camaldulensis var. (58.6%), E. leucoxylon ssp. (41.4%)																	
E. camaldulensis/oleosa, +6sp	386	47.2	4.1	1.8	9.9	928	60	0.80	4.5	36.67	18.19	66.76	0.78	3.00	3.69	1.83	6.71
E. camaldulensis var. (48.3%), E. oleosa ssp. (20.4%), Ac. rigens (13.7%), E. socialis ssp. (9.8%), Al. muelleriana ssp. (3.5%), Al. verticillata (3.2%), E. incrassata (0.8%), E. cyanophylla (0.2%)																	
E. camaldulensis/tricarpa/cladocalyx, +4sp	481	108.0	6.7	2.2	20.9	1133	60	1.00	13.0	219.80	109.02	400.11	0.53	9.62	10.49	5.21	19.10
E. cladocalyx (31.3%), E. camaldulensis var. (26.8%), E. tricarpa (16.7%), E. leucoxylon ssp. (12.6%), E. sideroxylon (9.5%), E. spathulata (1.8%), E. platypus (1.3%)																	
Eucalyptus cladocalyx	335	39.5	3.7	1.6	98.0	249	36	1.00	10.7	53.03	26.30	96.52	0.36	0.50	0.54	0.27	0.98
Eucalyptus cladocalyx	354	53.4	4.3	1.7	9.4	582	36	1.00	6.1	26.53	13.16	48.30	0.63	2.29	2.82	1.40	5.14
Eucalyptus cladocalyx	356	46.7	4.0	1.7	4.8	2188	252	1.00	3.6	16.02	7.95	29.17	1.62	2.10	3.31	1.64	6.03
Eucalyptus cladocalyx	372	37.6	3.7	1.4	97.8	233	36	1.00	10.0	65.91	32.69	119.97	0.26	0.63	0.67	0.33	1.23
Eucalyptus cladocalyx	391	45.6	4.0	1.8	8.4	676	36	1.00	6.3	19.43	9.64	35.38	0.64	1.77	2.31	1.15	4.21
Eucalyptus cladocalyx	392	45.6	4.0	1.9	8.4	262	36	1.00	5.4	8.12	4.03	14.78	0.80	0.73	0.97	0.48	1.76
Eucalyptus cladocalyx	400	103.5	6.5	1.9	7.4	646	36	1.00	5.3	13.04	6.47	23.74	0.86	1.28	1.76	0.87	3.21
Eucalyptus cladocalyx	404	52.2	4.3	1.7	8.4	444	36	1.00	9.9	63.23	31.36	115.09	0.42	6.65	7.53	3.73	13.70
Eucalyptus cladocalyx	409	87.5	5.8	1.9	8.4	578	35	1.00	6.3	23.78	11.79	43.28	0.70	2.22	2.83	1.40	5.15
Eucalyptus cladocalyx	412	65.9	4.9	1.9	8.4	583	36	1.00	6.0	20.25	10.04	36.86	0.79	1.86	2.41	1.20	4.39
Eucalyptus cladocalyx	437	76.9	5.4	1.8	10.0	543	36	1.00	11.5	112.88	55.99	205.48	0.41	10.39	11.29	5.60	20.55
Eucalyptus cladocalyx	438	75.7	5.3	2.0	7.4	465	36	1.00	11.9	79.55	39.46	144.80	0.43	9.57	10.75	5.33	19.57
Eucalyptus cladocalyx	442	66.9	4.9	2.1	8.3	326	36	1.00	7.2	21.24	10.53	38.66	0.59	2.08	2.56	1.27	4.66
Eucalyptus cladocalyx	503	110.8	6.8	2.2	8.4	930	36	1.00	9.3	68.75	34.10	125.14	0.55	6.80	8.18	4.06	14.90
Eucalyptus cladocalyx	512	80.9	5.5	2.4	7.4	827	36	1.00	8.7	48.52	24.07	88.33	0.54	5.27	6.56	3.25	11.94
Eucalyptus cladocalyx	536	120.2	7.3	2.4	14.9	439	36	1.00	12.1	58.70	29.12	106.85	0.59	3.44	3.94	1.95	7.16
Eucalyptus cladocalyx	556	131.0	7.7	2.5	17.9	706	36	1.00	13.0	106.74	52.94	194.30	0.55	5.37	5.95	2.95	10.83
Eucalyptus cladocalyx	601	86.2	5.8	2.6	8.4	837	36	1.00	10.1	67.64	33.55	123.13	0.51	6.68	8.05	3.99	14.66
E. cladocalyx/camaldulensis	480	101.7	6.4	2.2	21.9	883	36	1.00	16.3	181.73	90.14	330.80	0.47	7.58	8.28	4.11	15.07
E. cladocalyx (58.2%), E. camaldulensis var. (41.8%)																	

Appendix D - Productivity and Carbon Sequestration Studies

REVEGETATION	SITE DETAIL				FIELD SURVEY					STANDING BIOMASS			ROOT	SEQUESTRATION			
NRM REGION SPECIES Proportion of site biomass by species	Rain [mm]	NCAT Max. Dry Matter [t/ha]	NCAT Forest Prod. Index	Bios Equil [t C/ha/yr]	Age [years]	Plant Density [trees/ha]	Observations	Proportion Trees	Height [m]	Dry Biomass [t/ha]	Carbon [t/ha]	CO_2e [t/ha]	Root/Shoot Ratio	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]
E. cladocalyx/camaldulensis, +1sp	480	102.2	6.5	2.2	21.9	1004	60	1.00	14.6	204.25	101.31	371.80	0.46	8.59	9.31	4.62	16.94
E. cladocalyx (51.7%), E. camaldulensis var. (48.1%), E. phenax ssp. (0.2%)																	
Eucalyptus cneorifolia	356	46.7	4.0	1.7	4.8	2161	249	1.00	1.6	6.88	3.41	12.53	1.56	0.75	1.42	0.71	2.59
Eucalyptus cyanophylla	260	22.9	3.0	1.1	13.4	362	30	1.00	3.6	16.91	8.39	30.78	1.02	0.99	1.26	0.63	2.29
E. cyanophylla/dumosa, +5sp	250	19.8	2.9	1.2	16.0	1620	60	0.92	3.3	15.80	7.84	28.76	1.39	0.66	0.99	0.49	1.80
E. cyanophylla (63.6%), E. dumosa (21.0%), E. leptophylla (5.7%), Ac. ligulata (5.2%), Mel. lanceolata (2.3%), E. socialis ssp. (1.4%), E. gracilis (0.9%)																	
E. cyanophylla/oleosa/gracilis, +9sp	252	21.4	2.9	1.0	13.0	168	60	0.90	3.2	5.82	2.89	10.60	0.93	0.35	0.45	0.22	0.82
E. cyanophylla (29.3%), E. gracilis (24.1%), E. oleosa ssp. (20.9%), E. dumosa (9.1%), E. leptophylla (8.3%), Mel. lanceolata (2.0%), Mel. acuminata ssp. acuminata (1.5%), E. socialis ssp. (1.4%), E. porosa (1.3%), Ac. oswaldii (1.2%), Callitris gracilis (0.9%)																	
Eucalyptus dumosa	385	46.4	4.0	1.8	12.0	680	31	1.00	3.8	16.62	8.24	30.26	0.99	1.03	1.39	0.69	2.53
E. fasciculosa, Ac. pycnantha/retinodes, +5sp	497	113.4	7.0	2.0	16.9	414	60	0.93	5.8	23.38	11.60	42.56	0.57	1.14	1.38	0.69	2.52
E. fasciculosa (35.4%), Ac. retinodes (28.2%), Ac. pycnantha (11.8%), E. leucoxylon ssp. (10.7%), E. camaldulensis var. (5.3%), E. viminalis ssp. cygnetensis (4.6%), Al. verticillata (3.9%), Mel. lanceolata (0.2%)																	
E. fasciculosa/leucoxylon, Al. verticillata, +3sp	538	129.5	7.7	2.4	18.0	587	60	0.97	9.5	118.76	58.91	216.19	0.47	6.25	6.60	3.27	12.02
E. fasciculosa (38.6%), E. leucoxylon ssp. (32.9%), E. camaldulensis var. (21.8%), Al. verticillata (5.4%), E. odorata (1.2%), Callistemon rugulosus (<0.1%)																	
Eucalyptus globulus ssp.	452	64.7	4.8	1.9	14.0	228	36	1.00	23.7	189.51	94.00	344.97	0.21	13.88	13.54	6.71	24.64
Eucalyptus gracilis	260	22.9	3.0	1.1	14.3	462	30	1.00	3.4	14.83	7.35	26.99	0.83	0.78	1.04	0.51	1.89
E. gracilis/porosa/incrassata, +7sp	340	46.3	4.0	1.6	15.0	288	60	0.92	4.4	21.80	10.81	39.68	0.58	1.23	1.46	0.72	2.65
E. gracilis (34.0%), E. porosa (22.5%), E. camaldulensis var. (21.6%), E. incrassata (8.4%), E. largiflorens (6.3%), E. leucoxylon ssp. (2.7%), Ac. oswaldii (1.9%), Mel. lanceolata (1.3%), Callitris gracilis (0.7%), E. calycogona ssp. (0.6%)																	
E. gracilis/socialis/incrassata, +7sp	316	46.1	4.0	1.5	16.0	419	60	0.87	3.7	22.02	10.92	40.09	0.75	1.11	1.38	0.68	2.51
E. gracilis (16.6%), E. socialis ssp. (14.1%), E. calycogona ssp. (13.5%), E. leptophylla (12.7%), E. incrassata (10.5%), E. cyanophylla (9.7%), E. oleosa ssp. (9.3%), E. odorata (6.0%), Callistemon brachyandrus (4.2%), Mel. lanceolata (3.3%)																	
E. gracilis/socialis/oleosa, +5sp	286	23.9	3.0	1.2	16.0	460	60	0.93	4.3	17.97	8.91	32.71	1.07	0.89	1.13	0.56	2.05
E. gracilis (34.5%), E. socialis ssp. (24.0%), E. oleosa ssp. (21.4%), E. dumosa (8.9%), E. leptophylla (5.8%), E. calycogona ssp. (1.9%), Ac. ligulata (1.8%), Dodonaea viscosa ssp. angustissima (1.6%)																	
E. grandis/camaldulensis	480	101.7	6.4	2.2	21.9	1389	36	1.00	18.9	334.66	165.99	609.18	0.29	14.08	15.26	7.57	27.77
E. grandis (58.3%), E. camaldulensis var. (41.7%)																	
Eucalyptus incrassata	356	46.7	4.0	1.7	4.8	2170	250	1.00	1.6	5.85	2.90	10.65	1.84	0.59	1.21	0.60	2.20
Eucalyptus incrassata	377	47.3	4.1	1.6	8.0	878	30	1.00	3.7	21.54	10.68	39.21	0.88	2.00	2.70	1.34	4.92
E. incrassata, Al. verticillata, +12sp	368	51.3	4.2	1.5	16.0	530	60	0.82	3.9	18.87	9.36	34.34	0.88	0.92	1.18	0.58	2.15
E. incrassata (17.2%), E. oleosa ssp. (15.9%), Al. verticillata (13.8%), Dodonaea viscosa ssp. (10.0%), E. leptophylla (8.8%), E. phenax ssp. (8.5%), E. leucoxylon ssp. (7.3%), E. odorata (6.3%), E. dumosa (4.7%), E. diversifolia ssp. diversifolia (3.8%), E. socialis ssp. (1.3%), Pittosporum angustifolium (1.2%), Banksia ornata (1.2%), Ac. pycnantha (0.2%)																	
E. incrassata, Al. verticillata, +5sp	446	71.3	5.1	2.1	20.6	1610	60	0.85	6.1	124.80	61.90	227.18	0.61	5.24	6.06	3.01	11.04
Al. verticillata (48.3%), E. incrassata (23.1%), Callitris gracilis (22.6%), Mel. lanceolata (3.4%), Mel. acuminata ssp. acuminata (1.5%), E. leptophylla (1.0%), Ac. pycnantha (<0.1%)																	
E. incrassata/Ac. ligulata, +8sp	399	49.1	4.1	1.6	15.0	644	60	0.43	3.2	11.39	5.65	20.74	1.27	0.55	0.76	0.38	1.39
E. incrassata (39.3%), Ac. ligulata (21.5%), Al. verticillata (8.3%), Al. muelleriana ssp. (7.6%), Callitris verrucosa (7.0%), E. socialis ssp. (6.2%), Ac. rigens (2.8%), Dodonaea viscosa ssp. spatulata (2.6%), Cal. canescens (2.4%), Callitris gracilis (2.2%)																	
E. incrassata/leptophylla, +7sp	357	49.9	4.2	1.7	28.9	1289	60	0.85	3.9	26.37	13.08	48.00	1.24	0.68	0.91	0.45	1.66
E. incrassata (52.2%), E. leptophylla (27.3%), E. brachycalyx (11.7%), Mel. uncinata (3.3%), Al. muelleriana ssp. (2.6%), Al. verticillata (1.6%), Mel. lanceolata (0.7%), Mel. acuminata ssp. acuminata (0.6%)																	

Appendix D - Productivity and Carbon Sequestration Studies

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NRM REGION SPECIES Proportion of site biomass by species	Rain [mm]	NCAT Max. Dry Matter [t/ha]	NCAT Forest Prod. Index	Bios Equil [t C/ha/yr]	Age [years]	Plant Density [trees/ha]	Observations	Proportion Trees	Height [m]	Dry Biomass [t/ha]	Carbon [t/ha]	CO_2e [t/ha]	Root/Shoot Ratio	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]
Eucalyptus largiflorens	260	22.9	3.0	1.1	14.4	343	30	1.00	4.5	20.87	10.35	37.99	0.67	1.18	1.45	0.72	2.64
E. largiflorens, Al. verticillata, +3sp	321	77.7	5.4	1.5	17.0	603	60	0.82	4.7	19.11	9.48	34.79	0.96	0.88	1.12	0.56	2.05
E. largiflorens (55.8%), E. camaldulensis var. (24.9%), Al. verticillata (10.6%), E. odorata (5.2%), Callitris gracilis (3.6%)																	
E. largiflorens/camaldulensis/socialis, +2sp	384	81.9	5.6	1.4	25.3	159	59	1.00	7.0	39.95	19.81	72.72	0.43	1.49	1.58	0.78	2.88
E. largiflorens (51.3%), E. camaldulensis var. (29.9%), E. socialis ssp. (17.6%), Al. verticillata (0.7%), E. oleosa ssp. (0.4%)																	
E. largiflorens/cladocalyx	333	39.0	3.7	1.6	98.0	329	60	1.00	7.0	33.02	16.38	60.11	0.51	0.29	0.34	0.17	0.61
E. largiflorens (87.0%), E. cladocalyx (13.0%)																	
Eucalyptus leptophylla	260	22.9	3.0	1.1	13.4	843	30	1.00	2.0	9.21	4.57	16.76	1.29	0.46	0.69	0.34	1.25
Eucalyptus leucoxylon ssp.	339	45.1	4.0	1.4	14.0	320	36	1.00	4.6	23.82	11.82	43.37	0.62	1.42	1.70	0.85	3.10
Eucalyptus leucoxylon ssp.	362	43.5	3.9	1.5	99.0	192	36	1.00	8.3	34.01	16.87	61.90	0.45	0.31	0.34	0.17	0.63
Eucalyptus leucoxylon ssp.	382	54.9	4.4	1.8	32.9	469	36	1.00	6.3	40.77	20.22	74.22	0.64	1.05	1.24	0.61	2.25
Eucalyptus leucoxylon ssp. leucoxylon	403	53.3	4.3	1.7	8.4	493	36	1.00	7.6	70.58	35.01	128.48	0.38	7.59	8.40	4.17	15.29
E. leucoxylon, +2sp	552	127.2	7.6	2.5	16.0	482	36	0.97	5.4	44.24	21.94	80.53	0.52	2.37	2.77	1.37	5.04
E. leucoxylon ssp. (85.6%), Al. verticillata (14.0%), Mel. brevifolia (0.4%)																	
E. leucoxylon, +3sp	423	117.9	7.2	2.0	33.0	492	60	1.00	5.3	35.96	17.84	65.46	0.72	0.90	1.09	0.54	1.99
E. leucoxylon ssp. (90.6%), E. fasciculosa (5.7%), E. odorata (2.3%), E. gracilis (1.4%)																	
E. leucoxylon, Ac. ligulata/brachybotrya, +3sp	348	47.3	4.1	1.4	15.9	943	60	0.33	3.9	29.84	14.80	54.31	1.19	1.49	1.87	0.93	3.41
E. leucoxylon ssp. (58.9%), Ac. ligulata (25.6%), E. cladocalyx (6.1%), Ac. brachybotrya (4.1%), Dodonaea viscosa ssp. (3.6%), Callitris verrucosa (1.7%)																	
E. leucoxylon, Ac. salicina, +7sp	401	74.8	5.3	1.9	10.7	1915	60	0.65	5.1	89.34	44.31	162.62	0.65	7.10	8.32	4.12	15.14
Ac. salicina (45.2%), E. leucoxylon ssp. (32.7%), Al. verticillata (9.6%), Ac. pycnantha (6.3%), Ac. calamifolia (2.9%), Dodonaea viscosa ssp. (2.8%), E. leptophylla (0.4%), E. porosa (0.1%)																	
E. leucoxylon, Cal. gracilis, +2sp	376	52.9	4.3	1.8	32.9	213	60	1.00	7.8	57.88	28.71	105.35	0.47	1.67	1.76	0.87	3.20
E. leucoxylon ssp. (63.1%), Callitris gracilis (28.6%), E. astringens ssp. astringens (7.7%), E. leptophylla (0.5%)																	
E. leucoxylon, Cal. gracilis, +8sp	380	57.0	4.5	1.8	32.9	232	60	0.93	6.0	28.38	14.08	51.66	0.62	0.76	0.86	0.43	1.57
E. leucoxylon ssp. (80.4%), Callitris gracilis (8.6%), E. phenax ssp. (2.9%), E. microcarpa (2.7%), E. socialis ssp. (2.0%), E. oleosa ssp. (1.1%), E. dumosa (0.9%), E. fasciculosa (0.9%), Pittosporum angustifolium (0.3%), Al. verticillata (0.1%)																	
E. leucoxylon, Cal. gracilis, Ac. retinodes, +5sp	341	89.5	5.9	1.6	18.0	492	60	0.93	9.9	109.36	54.24	199.07	0.53	5.76	6.09	3.02	11.08
E. leucoxylon ssp. (65.1%), Ac. retinodes (12.4%), Callitris gracilis (10.4%), E. fasciculosa (9.2%), E. largiflorens (1.9%), E. dumosa (0.5%), Ac. brachybotrya (0.3%), Ac. notabilis (0.1%)																	
E. leucoxylon/camaldulensis	314	40.0	3.7	1.5	9.0	364	60	1.00	5.7	22.22	11.02	40.44	0.68	2.02	2.47	1.23	4.50
E. leucoxylon ssp. (57.5%), E. camaldulensis var. (42.5%)																	
E. leucoxylon/camaldulensis, +1sp	375	48.6	4.1	1.8	24.0	237	36	1.00	11.8	154.41	76.59	281.08	0.36	6.76	6.44	3.20	11.73
E. leucoxylon ssp. (57.2%), E. camaldulensis var. (39.5%), E. diversifolia ssp. diversifolia (3.3%)																	
E. leucoxylon/cladocalyx/tricarpa, +2sp	487	106.5	6.7	2.2	20.9	917	36	1.00	12.4	192.87	95.66	351.08	0.53	8.55	9.21	4.57	16.76
E. cladocalyx (36.5%), E. leucoxylon ssp. (21.4%), E. tricarpa (16.0%), E. sideroxylon (15.6%), E. platypus (10.4%)																	
E. leucoxylon/fasciculosa, Ac. calamifolia, +3sp	572	129.8	7.7	2.6	11.8	535	60	0.33	3.7	17.16	8.51	31.24	0.91	1.12	1.45	0.72	2.64
Ac. calamifolia (48.3%), E. leucoxylon ssp. (21.1%), E. fasciculosa (12.3%), Ac. pycnantha (7.2%), Dodonaea viscosa ssp. (7.2%), Al. verticillata (3.9%)																	

REVEGETATION	SITE DETAIL				FIELD SURVEY					STANDING BIOMASS			ROOT	SEQUESTRATION			
NRM REGION SPECIES Proportion of site biomass by species	Rain [mm]	NCAT Max. Dry Matter [t/ha]	NCAT Forest Prod. Index	Bios Equil [t C/ha/yr]	Age [years]	Plant Density [trees/ha]	Observations	Proportion Trees	Height [m]	Dry Biomass [t/ha]	Carbon [t/ha]	CO_2e [t/ha]	Root/Shoot Ratio	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]
E. leucoxylon/fasciculosa, Ac. retinodes, +3sp	583	136.6	8.0	2.6	12.8	1016	60	0.95	7.0	70.12	34.78	127.65	0.66	4.71	5.47	2.71	9.95
E. fasciculosa (47.4%), E. leucoxylon ssp. (37.8%), Ac. retinodes (7.6%), Al. verticillata (3.4%), Ac. pycnantha (3.1%), Callitris gracilis (0.7%)																	
E. leucoxylon/gracilis/incrassata, +10sp	352	46.2	4.0	1.7	28.9	227	60	0.95	6.4	37.56	18.63	68.38	0.62	1.19	1.30	0.65	2.37
E. oleosa ssp. (23.0%), E. gracilis (21.4%), E. leucoxylon ssp. (18.8%), E. socialis ssp. (11.5%), E. incrassata (6.8%), E. fasciculosa (5.2%), E. leptophylla (3.9%), E. phenax ssp. (3.3%), Mel. lanceolata (2.3%), Al. verticillata (1.9%), Ac. calamifolia (1.0%), E. porosa (0.9%), E. diversifolia ssp. diversifolia (0.1%)																	
E. leucoxylon/largiflorens, +12sp	381	58.4	4.5	1.8	17.0	1537	60	0.82	5.9	83.47	41.40	151.94	0.63	4.16	4.92	2.44	8.96
E. leucoxylon ssp. (60.4%), E. largiflorens (21.8%), E. platypus (4.3%), E. fasciculosa (2.3%), Callitris gracilis (2.1%), Ac. argyrophylla (1.9%), E. leptophylla (1.8%), Mel. armillaris ssp. armillaris (1.6%), E. socialis ssp. (1.2%), E. oleosa ssp. (1.1%), E. camaldulensis var. (0.7%), E. brachycalyx (0.4%), Lepto. laevigatum (0.4%), Mel. lanceolata (0.1%)																	
E. leucoxylon/porosa/calycogona, +7sp	376	111.2	6.9	1.8	32.9	226	60	1.00	7.2	44.13	21.89	80.33	0.56	1.22	1.34	0.66	2.44
E. leucoxylon ssp. (36.1%), E. porosa (27.1%), E. calycogona ssp. (8.8%), Al. verticillata (8.6%), Callitris gracilis (6.0%), Mel. lanceolata (4.9%), E. gomphocephala (3.4%), E. torquata (2.6%), E. fasciculosa (1.9%), Mel. armillaris ssp. armillaris (0.6%)																	
Eucalyptus loxophleba ssp. lissophloia	318	40.1	3.7	1.5	8.0	1379	36	1.00	4.8	27.73	13.75	50.48	1.01	2.53	3.47	1.72	6.32
Eucalyptus loxophleba ssp. lissophloia	356	46.7	4.0	1.7	4.8	2144	247	1.00	3.7	12.99	6.44	23.65	1.79	1.61	2.69	1.33	4.89
E. microcarpa/brockwayii/calycogona, +8sp	381	54.9	4.4	1.8	32.9	273	60	0.97	7.9	75.20	37.30	136.89	0.49	2.23	2.28	1.13	4.16
E. brockwayi (54.8%), E. microcarpa (10.4%), E. cyanophylla (9.4%), E. occidentalis (8.6%), E. calycogona ssp. (6.6%), E. torquata (4.1%), E. dundasii (2.8%), Callitris gracilis (1.6%), E. incrassata (1.5%), Brachychiton populneus ssp. (0.1%), E. leucoxylon ssp. (0.1%)																	
Eucalyptus occidentalis	354	51.0	4.2	1.5	9.4	1075	36	1.00	6.7	37.26	18.48	67.83	0.58	3.04	3.96	1.97	7.22
Eucalyptus occidentalis	356	46.7	4.0	1.7	4.8	2205	254	1.00	4.5	24.95	12.38	45.42	1.14	3.56	5.16	2.56	9.39
Eucalyptus occidentalis	412	67.8	5.0	1.9	8.4	583	36	1.00	6.0	20.26	10.05	36.87	0.79	1.86	2.41	1.20	4.39
Eucalyptus occidentalis	437	80.3	5.5	1.8	10.0	692	36	1.00	14.3	179.46	89.01	326.67	0.33	16.91	17.95	8.90	32.67
Eucalyptus occidentalis	450	67.0	4.9	1.9	12.4	544	36	1.00	16.8	129.96	64.46	236.56	0.35	9.66	10.48	5.20	19.08
Eucalyptus occidentalis	463	66.9	4.9	2.1	8.4	592	36	1.00	7.1	36.88	18.29	67.13	0.43	3.58	4.39	2.18	7.99
Eucalyptus occidentalis	494	106.6	6.7	2.2	8.4	744	36	1.00	9.1	51.15	25.37	93.11	0.55	5.01	6.09	3.02	11.08
Eucalyptus occidentalis	512	77.1	5.4	2.3	7.4	636	36	1.00	9.4	55.60	27.58	101.21	0.45	6.31	7.51	3.73	13.68
E. occidentalis/leucoxylon, +3sp	367	43.1	3.9	1.7	19.0	330	60	1.00	9.7	41.77	20.72	76.04	0.67	1.92	2.20	1.09	4.01
E. occidentalis (41.5%), E. leucoxylon ssp. (37.3%), E. dundasii (9.5%), E. porosa (8.9%), E. astringens ssp. astringens (2.8%)																	
E. odorata/camaldulensis, +5sp	477	67.9	5.0	2.2	12.0	1241	60	0.90	6.7	62.48	30.99	113.74	0.93	4.24	5.21	2.59	9.49
E. odorata (48.8%), E. camaldulensis var. (22.0%), E. leucoxylon ssp. (12.5%), Ac. ligulata (6.8%), Ac. argyrophylla (4.0%), E. fasciculosa (3.7%), E. incrassata (2.1%)																	
E. odorata/leucoxylon, Ac. wattsiana, +1sp	465	56.1	4.4	2.1	17.8	1826	60	0.73	5.3	54.38	26.97	98.98	0.84	2.40	3.05	1.51	5.55
E. odorata (63.7%), E. leucoxylon ssp. pruinosa (31.2%), Ac. wattsiana (4.8%), Mel. acuminata ssp. acuminata (0.2%)																	
Eucalyptus oleosa ssp.	260	22.9	3.0	1.1	10.4	339	30	1.00	3.2	6.51	3.23	11.85	1.06	0.45	0.63	0.31	1.14
Eucalyptus oleosa ssp.	356	49.9	4.2	1.7	28.9	1046	36	1.00	5.0	35.16	17.44	64.01	1.10	0.95	1.22	0.60	2.22
Eucalyptus oleosa ssp.	357	49.9	4.2	1.7	28.9	1628	36	1.00	5.0	34.58	17.15	62.94	1.37	0.89	1.20	0.59	2.18
Eucalyptus oleosa ssp.	386	47.2	4.1	1.8	6.8	1072	30	1.00	3.0	12.63	6.26	22.98	1.57	1.27	1.86	0.92	3.39
E. oleosa/brachycalyx, +2sp	340	57.2	4.5	1.6	17.9	314	60	1.00	5.1	28.32	14.05	51.55	0.81	1.38	1.58	0.78	2.88
E. cladocalyx (46.0%), E. oleosa ssp. (27.4%), E. brachycalyx (18.3%), E. socialis ssp. (8.2%)																	
Eucalyptus polybractea	318	39.3	3.7	1.5	8.0	1270	36	1.00	4.2	28.97	14.37	52.74	0.97	2.66	3.63	1.80	6.60

Appendix D - Productivity and Carbon Sequestration Studies

REVEGETATION	SITE DETAIL				FIELD SURVEY					STANDING BIOMASS			ROOT	SEQUESTRATION			
NRM REGION SPECIES Proportion of site biomass by species	Rain [mm]	NCAT Max. Dry Matter [t/ha]	NCAT Forest Prod. Index	Bios Equil [t C/ha/yr]	Age [years]	Plant Density [trees/ha]	Observations	Proportion Trees	Height [m]	Dry Biomass [t/ha]	Carbon [t/ha]	CO_2e [t/ha]	Root/Shoot Ratio	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]
Eucalyptus polybractea	356	46.7	4.0	1.7	4.8	2161	249	1.00	2.4	8.87	4.40	16.15	1.81	1.04	1.83	0.91	3.34
Eucalyptus porosa	386	47.2	4.1	1.8	6.7	1058	33	1.00	3.9	36.54	18.13	66.52	1.03	4.21	5.45	2.70	9.92
E. porosa, +2sp	423	117.5	7.1	2.0	33.0	2852	60	1.00	3.3	33.46	16.59	60.90	1.07	0.70	1.01	0.50	1.85
E. porosa (84.1%), E. fasciculosa (8.0%), E. leucoxylon ssp. (7.9%)																	
#E. porosa, Al. verticillata, M. armillaris, +26sp	348	50.8	4.2	1.7	15.4	293	581	0.54	3.3	18.23	9.04	33.18	0.50	0.99	1.19	0.59	2.16
E. porosa (49.7%), Mel. lanceolata (8.5%), Mel. armillaris ssp. (7.5%), Al. verticillata (6.6%), E. leucoxylon ssp. (5.0%), E. socialis ssp. (3.5%), Mel. uncinata (3.2%), E. cylindrocarpa (2.4%), E. leptophylla (2.2%), Chamaecytisus palmensis (1.9%), Ac. pycnantha (1.5%), Ac. calamifolia (1.4%), E. fasciculosa (1.2%), Senna artemisioides ssp. (1.0%), Dodonaea bursariifolia (0.9%), Ac. trineura (0.8%), Mel. halmaturorum (0.6%), E. cladocalyx (0.6%), Hakea francisiana (0.3%), Callitris gracilis (0.3%), Cal. glaucophylla (0.2%), E. phenax ssp. (0.2%), E. calycogona ssp. (0.2%), E. diversifolia ssp. diversifolia (0.1%), Pittosporum angustifolium (0.1%), E. oleosa ssp. (0.1%), E. incrassata (0.1%), Ac. spinescens (<0.1%), Westringia fruticosa (<0.1%)																	
E. porosa, Bursaria spinosa, +10sp	314	44.4	3.9	1.3	17.0	769	60	0.58	4.4	61.11	30.31	111.24	0.58	3.25	3.59	1.78	6.54
E. camaldulensis var. (34.9%), E. porosa (30.6%), E. leucoxylon ssp. (13.4%), E. dumosa (8.9%), Bursaria spinosa ssp. (5.6%), Ac. calamifolia (1.7%), E. incrassata (1.5%), Callitris gracilis (1.4%), E. fasciculosa (1.0%), Mel. lanceolata (0.9%), Al. verticillata (0.2%)																	
E. porosa/dumosa, +8sp	285	25.6	3.1	1.4	19.9	272	60	0.68	3.8	12.42	6.16	22.60	0.88	0.50	0.62	0.31	1.13
E. porosa (28.5%), Callitris gracilis (16.3%), E. dumosa (15.7%), E. socialis ssp. (11.4%), Mel. uncinata (10.5%), E. largiflorens (10.0%), E. incrassata (3.8%), E. calycogona ssp. (2.0%), E. cyanophylla (1.0%), Hakea leucoptera ssp. leucoptera (0.8%)																	
E. porosa/fasciculosa, Al. verticillata, +8sp	343	84.2	5.7	1.6	17.0	474	60	0.78	4.8	22.26	11.04	40.52	0.75	1.06	1.31	0.65	2.38
E. leucoxylon ssp. (28.4%), E. porosa (27.1%), E. fasciculosa (18.2%), Al. verticillata (12.6%), E. odorata (6.5%), Callitris verrucosa (5.1%), Ac. brachybotrya (0.7%), Ac. ligulata (0.7%), Ac. pycnantha (0.3%), Mel. lanceolata (0.2%), E. globulus ssp. globulus (0.2%)																	
E. porosa/gracilis/socialis, +3sp	322	43.8	3.9	1.5	14.0	1808	60	1.00	4.3	63.60	31.55	115.77	1.04	3.56	4.54	2.25	8.26
E. porosa (30.7%), E. socialis ssp. (19.6%), E. gracilis (16.9%), E. leptophylla (15.4%), E. incrassata (11.9%), E. dumosa (5.5%)																	
E. porosa/leucoxylon, +5sp	338	45.2	4.0	1.4	12.0	358	60	0.93	3.5	22.22	11.02	40.45	0.64	1.54	1.85	0.92	3.38
E. porosa (45.9%), E. leucoxylon ssp. (27.1%), E. platypus (9.6%), E. cladocalyx (9.6%), E. camaldulensis var. obtusa (6.5%), Ac. pycnantha (1.1%), Ac. calamifolia (0.2%)																	
#E. porosa/leuc./eremo., M. lanceolata, +26sp	347	52.1	4.3	1.6	15.6	265	189	0.69	5.7	46.77	23.20	85.14	0.47	2.78	2.99	1.48	5.44
E. porosa (39.3%), E. eremophila (15.1%), E. leucoxylon ssp. (7.4%), E. cylindrocarpa (5.9%), Mel. lanceolata (5.1%), Mel. armillaris ssp. (2.9%), E. socialis ssp. (2.8%), E. brockwayi (2.7%), E. astringens ssp. astringens (2.4%), E. odorata (1.9%), E. platypus (1.9%), E. fasciculosa (1.7%), E. calycogona ssp. (1.5%), Al. verticillata (1.3%), E. sporadica (1.2%), E. brachycalyx (1.1%), Callitris gracilis (1.0%), Mel. uncinata (1.0%), E. incrassata (0.7%), Ac. iteaphylla (0.7%), Ac. ligulata (0.6%), Ac. rigens (0.4%), E. phenax ssp. (0.3%), Ac. pycnantha (0.3%), Hakea carinata (0.3%), E. leptophylla (0.2%), Dodonaea viscosa ssp. cuneata (0.2%), Senna artemisioides ssp. (0.1%), Westringia eremicola (0.1%), Pittosporum angustifolium (<0.1%)																	
E. pterocarpa/kondininensis/brockwayi, +12sp	369	34.1	3.5	1.4	35.8	181	60	0.97	7.5	27.97	13.88	50.92	0.52	0.70	0.78	0.39	1.42
E. brockwayi (22.8%), E. pterocarpa (20.4%), E. salmonophloia (9.7%), E. melanoxylon (9.0%), E. diptera (7.8%), Callitris gracilis (6.3%), E. campaspe (6.1%), E. torquata (5.2%), E. calycogona ssp. (5.1%), E. kondininensis (4.1%), E. socialis ssp. (2.0%), E. flocktoniae (1.0%), E. forrestiana (0.6%), Ac. ligulata (0.1%), Ac. iteaphylla (0.1%)																	
Eucalyptus salmonaphloia	294	22.9	3.0	1.2	17.0	246	36	1.00	9.1	31.52	15.63	57.38	0.64	1.61	1.86	0.92	3.38
Eucalyptus salmonophoia	333	39.4	3.7	1.6	95.0	671	36	1.00	18.7	186.66	92.58	339.78	0.66	1.84	1.96	0.97	3.58
Eucalyptus socialis	260	22.9	3.0	1.1	14.4	552	30	1.00	3.8	24.13	11.97	43.92	0.95	1.31	1.67	0.83	3.05
Eucalyptus socialis	356	46.7	4.0	1.7	4.8	2135	246	1.00	1.5	6.35	3.15	11.55	2.21	0.62	1.31	0.65	2.39
#E. socialis/porosa/incrassata, +11sp	349	50.8	4.2	1.7	20.4	221	540	1.00	4.5	18.16	9.01	33.06	0.67	0.76	0.89	0.44	1.62
E. socialis ssp. (24.1%), E. porosa (15.9%), E. calycogona ssp. (12.5%), E. incrassata (10.5%), E. gracilis (9.2%), E. leptophylla (7.5%), E. cyanophylla (5.2%), E. oleosa ssp. (4.5%), E. phenax ssp. (4.5%), E. dumosa (4.2%), E. brachycalyx (1.5%), Callitris gracilis (0.4%), E. leucoxylon ssp. (0.1%), Myoporum platycarpum ssp. (<0.1%)																	
Melaleuca halmaturorum	419	119.3	7.2	2.0	9.7	2884	36	0.00	3.2	74.15	36.78	134.97	0.60	5.74	7.62	3.78	13.87
Melaleuca lanceolata	260	22.9	3.0	1.1	12.5	297	30	0.00	2.2	6.03	2.99	10.98	0.69	0.35	0.48	0.24	0.88
Melaleuca lanceolata, +7sp	376	116.1	7.1	1.4	16.9	622	36	0.72	4.8	54.84	27.20	99.82	0.57	2.76	3.24	1.61	5.90
E. leptophylla (32.6%), Mel. lanceolata (32.3%), E. incrassata (14.5%), E. phenax ssp. (12.4%), Mel. acuminata ssp. acuminata (2.7%), Al. verticillata (2.2%), E. platypus (1.9%), E. fasciculosa (1.3%)																	
Senna artemisioides ssp. coriacea	260	22.9	3.0	1.1	13.4	878	30	0.00	1.7	4.02	1.99	7.31	1.79	0.17	0.30	0.15	0.55

Appendix D - Productivity and Carbon Sequestration Studies

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NRM REGION SPECIES Proportion of site biomass by species	Rain [mm]	NCAT Max. Dry Matter [t/ha]	NCAT Forest Prod. Index	Bios Equil [t C/ha/yr]	Age [years]	Plant Density [trees/ha]	Observations	Proportion Trees	Height [m]	Dry Biomass [t/ha]	Carbon [t/ha]	CO_2e [t/ha]	Root/Shoot Ratio	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]
South East																	
Acacia mearnsii	492	76.8	5.4	2.3	12.5	1595	32	1.00	9.9	166.71	82.69	303.47	0.53	11.99	13.33	6.61	24.26
Ac. mearnsii/melanoxylon, E. viminalis, +3sp	578	92.5	6.0	2.6	11.9	2320	60	0.97	8.6	185.96	92.24	338.51	0.63	13.53	15.66	7.77	28.50
Ac. mearnsii (55.0%), Ac. melanoxylon (19.7%), E. viminalis ssp. cygnetensis (14.0%), E. leucoxylon ssp. (7.3%), E. fasciculosa (4.0%), Al. verticillata (0.2%)																	
Allocasuarina verticillata	478	98.1	6.3	2.2	14.8	854	36	1.00	7.4	59.23	29.38	107.83	0.66	3.27	4.01	1.99	7.29
Allocasuarina verticillata	493	77.1	5.4	2.3	10.9	376	30	1.00	8.6	92.61	45.94	168.58	0.44	7.99	8.51	4.22	15.49
Atriplex nummularia	463	111.4	6.9	1.9	3.0	651	30	0.00	1.6	6.34	3.14	11.54	1.26	1.43	2.15	1.06	3.91
Corymbia maculata	492	77.4	5.4	2.3	6.9	526	28	1.00	10.2	62.32	30.91	113.44	0.40	7.85	9.10	4.51	16.56
Corymbia maculata	493	77.1	5.4	2.3	10.8	405	25	1.00	9.0	51.57	25.58	93.87	0.43	4.40	4.79	2.38	8.72
Eucalyptus camaldulensis var.	458	69.9	5.1	1.9	10.7	430	33	1.00	11.4	113.76	56.42	207.08	0.38	10.35	10.59	5.25	19.27
Eucalyptus camaldulensis var.	494	77.9	5.4	2.3	9.9	950	30	1.00	8.2	64.43	31.96	117.28	0.44	5.38	6.52	3.23	11.87
Eucalyptus cladocalyx	459	68.6	5.0	1.9	6.7	540	30	1.00	6.4	29.68	14.72	54.02	0.52	3.56	4.43	2.20	8.07
Eucalyptus cladocalyx	459	71.9	5.1	1.9	6.7	366	30	1.00	5.0	17.35	8.61	31.58	0.47	2.13	2.59	1.29	4.72
Eucalyptus cladocalyx	460	65.1	4.8	1.9	6.7	756	33	1.00	5.6	28.70	14.24	52.24	0.72	3.50	4.28	2.12	7.79
Eucalyptus cladocalyx	460	64.8	4.8	1.9	10.7	374	30	1.00	14.9	142.23	70.54	258.90	0.35	12.73	13.26	6.58	24.14
Eucalyptus cladocalyx	460	65.1	4.8	1.9	14.0	747	36	1.00	10.2	104.72	51.94	190.62	0.44	6.64	7.50	3.72	13.65
E. cladocalyx, Corymbia maculata, +3sp	566	98.7	6.3	2.4	12.9	353	60	0.95	9.0	106.51	52.83	193.89	0.39	7.86	8.27	4.10	15.06
E. cladocalyx (64.4%), Corymbia maculata (23.7%), E. diversifolia ssp. diversifolia (6.3%), Casuarina cunninghamiana (3.7%), Ac. pycnantha (1.8%)																	
E. diversifolia/incrassata, +4sp	461	64.8	4.8	1.9	17.0	605	60	0.98	5.5	66.01	32.74	120.16	0.71	3.43	3.89	1.93	7.08
E. diversifolia ssp. diversifolia (78.7%), E. incrassata (10.5%), E. platypus (5.0%), E. leucoxylon ssp. (4.0%), Al. verticillata (1.3%), E. leptophylla (0.5%)																	
E. fasciculosa/leucoxylon, +8sp	470	38.2	3.7	2.2	10.7	2069	60	0.90	4.9	71.59	35.51	130.31	0.80	5.35	6.71	3.33	12.21
E. fasciculosa (38.0%), E. leucoxylon ssp. (27.8%), Dodonaea viscosa ssp. (11.5%), Ac. pycnantha (6.6%), E. leptophylla (5.5%), E. incrassata (5.0%), Ac. longifolia ssp. sophorae (2.4%), Al. verticillata (1.6%), E. diversifolia ssp. diversifolia (1.2%), Mel. lanceolata (0.4%)																	
E. fasciculosa/ovata/odorata, +9sp	600	92.5	6.0	2.6	18.8	770	60	0.93	7.4	142.84	70.85	260.01	0.46	7.04	7.58	3.76	13.80
E. fasciculosa (28.9%), E. ovata var. (24.0%), E. odorata (20.4%), E. cornuta (12.8%), Mel. lanceolata (10.5%), Al. verticillata (1.9%), Casuarina obesa (0.7%), Banksia marginata (0.3%), E. leucoxylon ssp. leucoxylon (0.2%), Hakea macraeana (0.1%), Lepto. coriaceum (0.1%), Senna artemisioides ssp. (0.1%)																	
Eucalyptus globulus ssp.	458	64.5	4.8	1.9	10.7	784	33	1.00	12.5	123.74	61.37	225.24	0.41	10.84	11.52	5.71	20.97
Eucalyptus globulus ssp.	494	77.9	5.4	2.3	6.8	934	30	1.00	11.1	125.67	62.33	228.77	0.39	15.98	18.35	9.10	33.41
Eucalyptus globulus ssp. globulus	607	98.1	6.3	2.7	4.9	1140	24	1.00	18.6	287.18	142.44	522.75	0.36	53.50	58.25	28.89	106.04
Eucalyptus globulus/camaldulensis	442	62.8	4.7	1.8	15.6	341	36	1.00	16.0	139.33	69.11	253.62	0.31	8.71	8.93	4.43	16.26
E. globulus ssp. globulus (56.8%), E. camaldulensis var. (43.2%)																	
Eucalyptus grandis	492	77.4	5.4	2.3	6.8	822	30	1.00	10.6	101.50	50.34	184.76	0.45	12.77	14.82	7.35	26.98
Eucalyptus leucoxylon ssp.	494	78.0	5.4	2.3	10.7	1057	33	1.00	8.6	104.20	51.68	189.68	0.47	8.64	9.71	4.82	17.68
E. leucoxylon, Ac. mearnsii/pycnantha, + 6sp	507	81.8	5.6	2.3	14.8	4052	60	0.83	7.2	204.64	101.50	372.52	0.61	11.72	13.84	6.86	25.19
E. leucoxylon ssp. (32.3%), Ac. mearnsii (30.6%), E. fasciculosa (12.5%), E. ovata var. (12.0%), Ac. pycnantha (12.0%), Mel. lanceolata (0.5%), Callistemon rugulosus (0.1%), E. gracilis (0.1%), E. incrassata (<0.1%)																	
E. leucoxylon, Ag. flexuosa, +9sp	488	69.3	5.0	2.0	11.7	639	60	0.82	4.3	26.04	12.92	47.40	0.77	1.77	2.22	1.10	4.04
E. leucoxylon ssp. (56.4%), Agonis flexuosa (14.3%), E. diversifolia ssp. divers. (7.0%), Mel. lanceolata (5.7%), E. fasciculosa (4.3%), Al. verticillata (4.3%), E. incrassata (3.2%), E. rugosa (2.3%), E. forrestiana (2.1%), Mel. halmaturorum (0.3%), Mel. alternifolia (0.2%)																	

Appendix D - Productivity and Carbon Sequestration Studies

REVEGETATION	SITE DETAIL				FIELD SURVEY					STANDING BIOMASS			ROOT	SEQUESTRATION			
NRM REGION SPECIES Proportion of site biomass by species	Rain [mm]	NCAT Max. Dry Matter [t/ha]	NCAT Forest Prod. Index	Bios Equil [t C/ha/yr]	Age [years]	Plant Density [trees/ha]	Observations	Proportion Trees	Height [m]	Dry Biomass [t/ha]	Carbon [t/ha]	CO_2e [t/ha]	Root/Shoot Ratio	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]
E. leucoxylon, Al. verticillata, +7sp	490	78.0	5.4	2.0	12.8	914	60	0.65	5.5	100.37	49.79	182.71	0.53	7.40	7.87	3.90	14.33
E. leucoxylon ssp. (39.7%), Al. verticillata (24.5%), Ac. pycnantha (14.0%), E. fasciculosa (11.0%), Dodonaea viscosa ssp. (8.1%), E. diversifolia ssp. diversifolia (1.3%), Ac. murrayana (0.6%), Mel. lanceolata (0.4%), Al. muelleriana ssp. (0.3%)																	
E. leucoxylon/baxteri, +12sp	514	63.6	4.8	2.1	19.3	1792	60	0.55	4.8	100.24	49.72	182.47	0.62	4.50	5.18	2.57	9.43
E. leucoxylon ssp. leucoxylon (24.0%), E. baxteri (21.1%), E. viminalis ssp. cygnetensis (15.7%), Ac. pycnantha (10.5%), E. camaldulensis var. camaldulensis (10.1%), Ac. baileyana (6.4%), Lepto. continentale (4.6%), Ac. brachybotrya (2.5%), E. fasciculosa (1.7%), Al. verticillata (1.5%), Ac. mearnsii (1.0%), E. incrassata (0.7%), Mel. decussata (0.2%), Al. muelleriana ssp. muelleriana (0.1%)																	
E. leucoxylon/camaldulensis, +6sp	525	83.6	5.7	2.4	12.8	5936	50	0.82	6.1	129.27	64.12	235.32	0.84	7.67	10.07	4.99	18.32
E. leucoxylon ssp. (57.7%), E. camaldulensis var. (25.2%), Ac. pycnantha (12.8%), Mel. decussata (1.5%), E. gracilis (1.4%), Ac. mearnsii (0.9%), Mel. lanceolata (0.3%), E. incrassata (0.2%)																	
E. leucoxylon/fasciculosa, +4sp	525	116.8	7.1	2.2	15.9	3421	60	0.97	7.4	222.02	110.12	404.16	0.49	12.22	13.98	6.93	25.45
E. leucoxylon ssp. (78.2%), E. fasciculosa (19.5%), Ac. mearnsii (1.2%), Ac. pycnantha (0.5%), E. viminalis ssp. cygnetensis (0.5%), Al. verticillata (0.1%)																	
E. leucoxylon/fasciculosa, Ac. pycnantha, +12sp	466	71.6	5.1	2.1	10.8	2112	60	0.55	3.8	44.08	21.87	80.25	0.84	3.19	4.09	2.03	7.44
E. leucoxylon ssp. (30.9%), Ac. pycnantha (22.1%), E. fasciculosa (21.2%), Ac. microcarpa (5.8%), Al. verticillata (5.6%), Mel. lanceolata (4.7%), E. leptophylla (3.2%), E. largiflorens (1.9%), E. platypus (1.8%), E. gracilis (1.7%), Mel. gibbosa (0.5%), Mel. uncinata (0.3%), E. incrassata (0.3%), E. porosa (0.1%), Callistemon rugulosus (0.1%)																	
E. leucoxylon/viminalis, +5sp	535	74.5	5.3	2.4	10.9	5702	60	0.82	5.9	277.84	137.81	505.75	0.51	22.96	25.54	12.67	46.48
E. viminalis ssp. cygnetensis (45.1%), E. leucoxylon ssp. (27.7%), Ac. pycnantha (24.5%), E. camaldulensis var. (2.5%), Callitris gracilis (0.1%), Al. verticillata (0.1%), Ac. paradoxa (<0.1%)																	
Eucalyptus occidentalis	459	71.9	5.1	1.9	6.7	570	32	1.00	8.2	39.44	19.56	71.79	0.46	5.06	5.89	2.92	10.72
Eucalyptus occidentalis	459	68.6	5.0	1.9	6.7	482	30	1.00	10.2	57.65	28.60	104.95	0.34	7.45	8.62	4.27	15.68
Eucalyptus occidentalis	460	64.2	4.8	1.9	5.7	639	34	1.00	9.8	90.56	44.92	164.85	0.40	14.44	15.87	7.87	28.89
Eucalyptus occidentalis	494	77.9	5.4	2.3	9.9	1165	30	1.00	10.5	140.16	69.52	255.13	0.37	12.30	14.18	7.04	25.82
E. occidentalis/camaldulensis, +5sp.	525	79.8	5.5	2.4	14.3	766	60	1.00	10.1	171.35	84.99	311.92	0.43	11.50	11.95	5.93	21.75
E. occidentalis (50.2%), E. camaldulensis var. (22.1%), E. globulus ssp. globulus (14.7%), E. viminalis ssp. cygnetensis (6.1%), E. petiolaris (4.6%), E. incrassata (1.2%), E. leucoxylon ssp. (1.1%)																	
E. occidentalis/megacornuta, +1sp	456	60.5	4.6	1.9	15.0	726	60	1.00	8.4	126.95	62.97	231.09	0.49	7.60	8.48	4.21	15.44
E. occidentalis (47.4%), E. megacornuta (45.8%), E. tereticornis (6.8%)																	
E. odorata/incrassata, Ac. pycnantha, +8sp	446	61.1	4.7	1.8	19.0	2044	60	0.93	5.4	98.80	49.00	179.85	0.63	4.32	5.20	2.58	9.46
E. odorata (35.4%), E. viminalis ssp. cygnetensis (17.5%), Ac. pycnantha (17.2%), E. arenacea (10.5%), E. porosa (6.9%), E. incrassata (4.2%), Ac. retinodes (4.1%), E. diversifolia ssp. divers. (1.8%), Ac. microcarpa (1.3%), E. leucoxylon ssp. (0.9%), E. leptophylla (0.2%)																	
E. ovata/camaldulensis/leucoxylon, +3sp	593	91.3	6.0	2.6	18.3	802	60	0.65	9.1	236.47	117.29	430.45	0.35	12.52	12.89	6.40	23.47
E. ovata var. (65.3%), E. camaldulensis var. (23.9%), E. leucoxylon ssp. (6.1%), Mel. lanceolata (2.3%), E. occidentalis (2.3%), Callistemon rugulosus (<0.1%)																	
Eucalyptus saligna	492	76.6	5.3	2.3	6.8	821	30	1.00	9.1	79.76	39.56	145.19	0.52	9.83	11.65	5.78	21.20
Eucalyptus viminalis ssp.	460	64.8	4.8	1.9	5.7	480	33	1.00	10.0	70.44	34.94	128.23	0.43	11.65	12.34	6.12	22.46
Eucalyptus viminalis ssp. cygnetensis	460	64.8	4.8	1.9	9.0	519	36	1.00	12.9	132.00	65.47	240.28	0.38	13.68	14.72	7.30	26.80
Eucalyptus viminalis ssp. cygnetensis	494	79.3	5.5	2.0	9.9	679	30	1.00	11.1	131.16	65.05	238.75	0.37	11.91	13.27	6.58	24.16
E. viminalis/camaldulensis, Al. verticillata, +8sp	440	76.4	5.3	1.8	10.9	331	60	0.92	7.5	63.95	31.72	116.41	0.49	5.56	5.87	2.91	10.69
E. viminalis ssp. cygnetensis (34.5%), E. camaldulensis var. (21.0%), Al. verticillata (17.9%), E. leucoxylon ssp. (11.6%), E. arenacea (8.1%), Ac. pycnantha (2.8%), E. cladocalyx (1.4%), E. porosa (1.3%), E. diversifolia ssp. diversifolia (0.9%), Ac. notabilis (0.3%), Leptospermum coriaceum (0.2%)																	
E. viminalis/leucoxylon, +8sp	445	62.6	4.7	1.8	19.0	1266	60	0.97	8.3	250.37	124.18	455.76	0.45	12.20	13.17	6.53	23.98
E. viminalis ssp. cygnetensis (41.4%), E. leucoxylon ssp. (19.7%), E. arenacea (9.6%), E. porosa (8.8%), E. odorata (8.1%), E. obliqua (4.1%), Ac. pycnantha (3.6%), Ac. retinodes (3.5%), E. diversifolia ssp. diversifolia (0.8%), E. incrassata (0.4%)																	

[#]Moorlands Case Study site.

Appendix D - Productivity and Carbon Sequestration Studies

Table 48. Observed above-ground biomass and carbon sequestration from remnant vegetation sites in agricultural regions of South Australia.

REMNANT VEGETATION	SITE DETAIL				FIELD SURVEY					STANDING BIOMASS			ROOT	SEQUESTRATION			
NRM REGION SPECIES Proportion of site biomass by species	Rain [mm]	NCAT – Max. Dry Matter [t/ha]	NCAT Forest Prod. Index	Bios Equil [t C/ha/yr]	Estimated Age * [years]	Plant Density [trees/ha]	Observations	Proportion Trees	Height [m]	Dry Biomass [t/ha]	Carbon [t/ha]	CO_2e [t/ha]	Root/Shoot Ratio	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]
Adelaide & Mt Lofty Ranges																	
Al. verticillata, E. leucoxylon, Ac. pycnantha, +4sp	650	150.8	8.6	2.9	82.0	1141	60	0.87	7.8	364.39	180.74	663.30	0.32	4.86	4.44	2.20	8.09
E. leucoxylon ssp. (71.9%), E. ovata var. (10.9%), Al. verticillata (5.6%), E. camaldulensis var. camaldulensis (4.3%), Callitris gracilis (4.0%), Ac. pycnantha (2.1%), Banksia marginata (1.3%)																	
E. camaldulensis, +2sp	727	82.4	5.6	3.0	34.0	928	60	0.97	11.2	190.05	94.27	345.96	0.43	5.23	5.59	2.77	10.18
E. camaldulensis var. camaldulensis (95.0%), Banksia marginata (3.7%), Ac. melanoxylon (1.3%)																	
E. camaldulensis, Ac. retinodes	843	108.0	6.7	3.6	28.0	1720	30	0.97	12.9	474.98	235.59	864.61	0.35	16.40	16.96	8.41	30.88
E. camaldulensis var. camaldulensis (99.7%), Ac. retinodes (0.3%)																	
E. camaldulensis, Al. verticillata, +3sp	595	138.4	8.1	2.8	99.0	1117	60	0.88	8.7	510.79	253.35	929.81	0.20	6.25	5.16	2.56	9.39
E. camaldulensis var. camaldulensis (83.4%), Al. verticillata (13.1%), Ac. pycnantha (2.0%), Callitris gracilis (1.3%), Banksia marginata (0.2%)																	
E. camaldulensis/leucoxylon, +1sp	615	81.1	5.5	2.8	23.6	1991	60	1.00	9.1	319.89	158.67	582.30	0.39	12.45	13.55	6.72	24.66
E. camaldulensis var. (68.4%), E. leucoxylon ssp. (30.0%), Callitris gracilis (1.5%)																	
E. camaldulensis/viminalis, Ac. retinodes	843	108.0	6.7	3.6	12.9	741	30	1.00	13.4	191.78	95.12	349.10	0.33	14.08	14.89	7.39	27.11
E. camaldulensis var. (82.9%), Ac. retinodes (10.6%), E. viminalis ssp. (6.6%)																	
E. camald./viminalis/leuco., Ac. pycnantha, +2sp	633	125.9	7.5	2.8	146.0	441	59	0.95	9.5	301.92	149.75	549.60	0.25	2.36	2.07	1.03	3.76
E. viminalis ssp. viminalis (29.9%), E. leucoxylon ssp. (23.6%), E. viminalis ssp. cygnetensis (22.7%), E. camaldulensis var. camaldulensis (12.3%), Ac. pycnantha (8.3%), Exocarpos cupressiformis (3.2%)																	
E. fasciculosa/goniocalyx, Ac. pycnantha, +2sp	727	88.8	5.9	3.0	120.0	1002	60	0.93	7.6	528.88	262.33	962.74	0.22	5.19	4.41	2.19	8.02
E. goniocalyx ssp. goniocalyx (56.6%), E. camaldulensis var. camaldulensis (28.2%), E. fasciculosa (10.8%), Ac. pycnantha (2.9%), Al. verticillata (1.4%)																	
E. incrassata, Ac. pycnantha	442	103.7	6.5	2.0	30.0	346	36	0.92	5.5	22.88	11.35	41.66	0.63	0.65	0.76	0.38	1.39
E. incrassata (98.3%), Ac. pycnantha (1.7%)																	
Eucalyptus leucoxylon ssp.	458	112.2	6.9	2.1	101.0	80	36	1.00	12.9	69.08	34.26	125.74	0.23	0.73	0.68	0.34	1.24
E. leucoxylon/odorata, +2sp	456	111.7	6.9	2.1	120.0	172	36	0.78	7.9	117.65	58.35	214.16	0.21	1.09	0.98	0.49	1.78
E. leucoxylon ssp. (78.5%), E. odorata (21.0%), Ac. pycnantha (0.4%), Ac. paradoxa (<0.1%)																	
E. leucoxylon/ovata, Al. verticillata, +5sp	645	91.0	6.0	2.7	35.0	1644	60	0.83	6.6	137.53	68.21	250.35	0.47	3.58	3.93	1.95	7.15
Al. verticillata (34.9%), E. leucoxylon ssp. (34.5%), E. ovata var. (18.1%), Ac. pycnantha (10.0%), E. camaldulensis var. camaldulensis (0.8%), Ac. paradoxa (0.7%), Dodonaea viscosa ssp. (0.7%), Hakea leucoptera ssp. leucoptera (0.2%)																	
E. leucoxylon/viminalis, Ac. pycnantha, +3sp	623	142.6	8.2	2.6	95.0	292	60	0.88	9.1	174.38	86.49	317.44	0.32	1.93	1.84	0.91	3.34
E. leucoxylon ssp. (55.8%), E. viminalis ssp. (34.9%), Al. verticillata (8.2%), Ac. pycnantha (1.0%), Hakea rugosa (0.1%), Pinus radiata (<0.1%)																	
E. obliqua/camaldulensis, Cal. glaucophylla, +5sp	594	86.2	5.8	2.5	149.0	918	60	0.92	11.8	784.13	388.93	1427.37	0.22	6.11	5.26	2.61	9.58
E. obliqua (53.9%), E. viminalis ssp. viminalis (23.1%), E. camaldulensis var. camaldulensis (19.4%), Cal. glaucophylla (1.6%), E. goniocalyx ssp. goniocalyx (1.5%), Exocarpos cupressiformis (0.4%), Ac. paradoxa (0.2%), Dodonaea viscosa ssp. (<0.1%)																	
E. odorata, S. artemisioides, +6sp	421	61.9	4.6	1.9	88.0	1052	60	0.45	4.5	129.03	64.00	234.88	0.48	1.41	1.47	0.73	2.67
E. odorata (52.9%), E. socialis ssp. (31.8%), Callitris gracilis (12.0%), Pittosporum angustifolium (2.0%), Senna artemisioides ssp. (0.7%), Exocarpos cupressiformis (0.3%), Ac. notabilis (0.2%), Olearia decurrens (<0.1%)																	

Appendix D - Productivity and Carbon Sequestration Studies

REMNANT VEGETATION	SITE DETAIL				FIELD SURVEY					STANDING BIOMASS			ROOT	SEQUESTRATION			
NRM REGION SPECIES Proportion of site biomass by species	Rain [mm]	NCAT – Max. Dry Matter [t/ha]	NCAT Forest Prod. Index	Bios Equil [t C/ha/yr]	Estimated Age * [years]	Plant Density [trees/ha]	Observations	Proportion Trees	Height [m]	Dry Biomass [t/ha]	Carbon [t/ha]	CO_2e [t/ha]	Root/Shoot Ratio	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]
E. odorata/leucoxylon	506	70.2	5.1	2.3	168.0	61	30	1.00	11.6	119.14	59.09	216.87	0.27	0.80	0.71	0.35	1.29
E. odorata (92.3%), E. leucoxylon ssp. (7.7%)																	
E. odorata/leucoxylon	512	109.0	6.8	2.3	97.0	65	36	1.00	12.0	59.16	29.34	107.69	0.30	0.65	0.61	0.30	1.11
E. odorata (62.9%), E. leucoxylon ssp. (37.1%)																	
Eucalyptus viminalis ssp.	624	93.1	6.1	2.8	67.0	365	20	1.00	11.8	258.60	128.27	470.74	0.26	4.04	3.86	1.91	7.03
Northern & Yorke																	
E. brachycalyx/oleosa, +5sp	383	51.8	4.3	1.8	31.0	1186	36	0.31	4.7	75.24	37.32	136.96	0.70	2.10	2.43	1.20	4.42
E. brachycalyx (45.3%), Mel. lanceolata (21.5%), E. oleosa ssp. (18.3%), E. gracilis (10.8%), Mel. acuminata ssp. acuminata (2.3%), Santalum acuminatum (1.5%), Beyeria lechenaultii (0.3%)																	
E. gracilis/brachycalyx, +1sp	334	41.4	3.8	1.4	45.0	224	36	0.97	7.1	39.98	19.83	72.77	0.45	0.80	0.89	0.44	1.62
E. brachycalyx (61.3%), E. gracilis (37.7%), Exocarpos aphyllus (1.0%)																	
E. gracilis/oleosa, +4sp	351	40.6	3.8	1.7	80.0	215	36	0.92	7.2	59.93	29.72	109.09	0.30	0.74	0.75	0.37	1.36
E. gracilis (74.9%), E. oleosa ssp. (23.3%), Mel. lanceolata (1.4%), Ac. sp. (0.3%), Pittosporum angustifolium (0.1%), Santalum acuminatum (<0.1%)																	
E. incrassata/socialis	335	95.3	6.2	1.6	35.0	431	36	1.00	5.7	36.94	18.32	67.25	0.60	0.90	1.06	0.52	1.92
E. incrassata (85.6%), E. socialis ssp. (14.4%)																	
E. incrassata/socialis, +3sp	333	45.5	4.0	1.6	57.0	81	36	0.83	4.7	11.96	5.93	21.77	0.44	0.19	0.21	0.10	0.38
E. incrassata (53.5%), E. socialis ssp. (27.4%), E. oleosa ssp. (8.7%), Mel. lanceolata (6.5%), Mel. acuminata ssp. acuminata (3.9%)																	
E. incrassata/socialis, Callitris verrucosa	391	49.8	4.2	1.8	46.0	292	36	0.83	5.6	43.56	21.60	79.29	0.49	0.85	0.95	0.47	1.72
Callitris verrucosa (46.8%), E. incrassata (32.0%), E. socialis ssp. (21.2%)																	
E. incrassata/socialis/dumosa, +4sp	452	56.3	4.5	1.9	38.0	787	36	0.83	6.0	79.36	39.36	144.46	0.67	1.89	2.09	1.04	3.80
E. incrassata (41.2%), E. leptophylla (18.1%), E. dumosa (15.3%), E. socialis ssp. (13.6%), E. calycogona ssp. (5.9%), Mel. uncinata (5.7%), E. gracilis (0.2%)																	
Eucalyptus leucoxylon ssp.	473	105.5	6.6	1.9	120.0	51	30	1.00	10.7	53.46	26.51	97.31	0.35	0.48	0.45	0.22	0.81
E. leucoxylon, +1sp	495	116.5	7.1	2.2	225.0	93	30	1.00	15.4	292.06	144.86	531.64	0.22	1.55	1.30	0.64	2.36
E. leucoxylon ssp. pruinosa (59.0%), E. leucoxylon ssp. (40.8%), Olea europaea ssp. (0.2%)																	
E. leucoxylon, Ac. paradoxa/pycn., +1sp	573	72.4	5.1	2.5	160.0	880	60	0.35	4.7	226.91	112.55	413.04	0.31	1.57	1.42	0.70	2.58
E. leucoxylon ssp. pruinosa (98.4%), Ac. paradoxa (0.9%), Ac. pycnantha (0.7%), Al. verticillata (0.1%)																	
Eucalyptus odorata	487	118.4	7.2	2.2	105.0	45	36	1.00	11.6	44.22	21.93	80.49	0.25	0.45	0.42	0.21	0.77
Eucalyptus odorata	522	114.6	7.0	2.4	159.0	35	30	1.00	10.0	50.76	25.18	92.40	0.25	0.35	0.32	0.16	0.58
E. odorata/leucoxylon	430	106.0	6.6	2.0	153.0	37	30	1.00	10.9	59.90	29.71	109.04	0.30	0.43	0.39	0.19	0.71
E. odorata (92.1%), E. leucoxylon ssp. pruinosa (7.9%)																	
E. socialis/incrassata, +3sp	337	45.8	4.0	1.6	41.0	349	36	0.56	4.4	34.58	17.15	62.95	0.60	0.74	0.84	0.42	1.54
E. socialis ssp. (56.7%), E. incrassata (27.8%), Mel. lanceolata (9.7%), E. brachycalyx (3.1%), Mel. acuminata ssp. acuminata (2.7%)																	

Appendix D - Productivity and Carbon Sequestration Studies

REMNANT VEGETATION	SITE DETAIL				FIELD SURVEY					STANDING BIOMASS			ROOT	SEQUESTRATION			
NRM REGION SPECIES Proportion of site biomass by species	Rain [mm]	NCAT – Max. Dry Matter [t/ha]	NCAT Forest Prod. Index	Bios Equil [t C/ha/yr]	Estimated Age * [years]	Plant Density [trees/ha]	Observations	Proportion Trees	Height [m]	Dry Biomass [t/ha]	Carbon [t/ha]	CO_2e [t/ha]	Root/Shoot Ratio	Stem Volume MAI [m^3/ha/yr]	Dry Biomass [t/ha/yr]	Carbon [t/ha/yr]	CO_2e [t/ha/yr]
SA Murray-Darling Basin																	
Callitris gracilis	399	74.0	5.2	1.5	36.0	1273	36	1.00	9.9	238.29	118.19	433.76	0.33	6.01	6.62	3.28	12.05
#E. brachycalyx/porosa, Callitris gracilis, +4sp	345	49.3	4.1	1.6	81.0	256	60	0.98	8.6	82.21	40.77	149.64	0.43	0.99	1.01	0.50	1.85
E. brachycalyx (58.5%), Callitris gracilis (22.3%), E. porosa (9.4%), E. incrassata (4.7%), E. socialis ssp. (4.1%), Mel. armillaris ssp. (0.5%), Mel. acuminata ssp. acuminata (0.4%)																	
E. diversifolia/incrassata, +1sp	455	67.0	4.9	1.9	24.0	1788	60	0.98	4.4	64.11	31.80	116.70	1.00	2.10	2.67	1.32	4.86
E. diversifolia ssp. diversifolia (84.3%), E. incrassata (15.5%), Ac. pycnantha (0.2%)																	
E. goniocalyx/leucoxylon, +5sp	473	70.3	5.0	2.2	75.0	1818	60	0.88	6.5	205.11	101.74	373.37	0.53	2.53	2.73	1.36	4.98
E. leucoxylon ssp. pruinosa (65.3%), E. goniocalyx ssp. goniocalyx (27.8%), E. odorata (5.0%), Ac. pycnantha (1.2%), Exocarpos cupressiformis (0.4%), Xanthorrhoea quadrangulata (0.4%), Bursaria spinosa ssp. spinosa (<0.1%)																	
South East																	
E. fasciculosa/baxteri, +1sp	582	92.6	6.0	2.4	40.0	842	60	0.98	8.1	154.19	76.48	280.67	0.44	3.58	3.85	1.91	7.02
E. fasciculosa (65.6%), E. baxteri (34.2%), Banksia ornata (0.2%)																	

*based on diameters of largest tress (top 17% of sampled plants). #Moorlands Case Study site.

APPENDIX E - SA SOIL MAPPING CLASSES USED IN SPATIAL MODELLING

Table 49. Summary of soil classes and nominal assigned values used in developing models of carbon sequestration.

Soil Texture	Clay Content	
Class	Range	Nom. Value
Sand	< 5%	3%
Loamy sand	5 - 10%	8%
Sandy loam	10 -20%	15%
Loam	20 - 30%	25%
Clay loam	30 - 35%	33%
Clay	> 35%	45%
Inherent Fertility	**Clay Content**	**Clay Index**
Class	**Range**	**Nom. Value**
High to very high	> 35%	100
Moderate	20 - 35%	80
Moderately low	5 -20%	60
Low	1 - 5%	40
Very low	< 1%	13
Waterholding Capacity	**Rootzone AWHC (mm)**	
Class	**Range**	**Nom. Value**
High	> 100	110
Moderate	70 - 100	85
Moderately low	40 - 70	55
Low	20 - 40	30
Very low	< 20	10
Depth	**Depth to Rock or Hardpan (cm)**	
Class	**Range**	**Nom. Value**
Deep	> 150	200
Moderately Deep	100 - 150	125
Medium	50 - 100	75
Moderately Shallow	25 - 50	38
Shallow	10 - 25	18
Very Shallow	< 10	5
Dryland agriculture potential (Class C)	**Hardy perrenial crops Rootzone Depth (cm)**	
Class	**Range**	**Nom. Value**
Very deep	> 100	110
Deep	80 - 100	90
Moderately deep	60 - 80	70
Medium	50 - 60	55
Medium to shallow	40 - 50	45
Moderately shallow	30 - 40	35
Shallow	20 - 30	25
Very Shallow	< 20	10

APPENDIX F - IMPROVING NATIONAL CARBON ACCOUNTING MODELS: MOORLANDS CASE STUDY

Introduction

The Carbon Farming Initiative (CFI) is a carbon mitigation and sequestration scheme designed to allow farmers and land managers to earn carbon credits by storing carbon or reducing greenhouse gas emissions from their enterprises. These credits can then be sold to people and businesses wishing to offset their emissions. Under the scheme projects that remove carbon dioxide from the atmosphere by sequestering carbon in living biomass are eligible. To enable the take up of this category within the scheme The Department of the Environment (DOTE) and the Department of Agriculture (DOA) are working with industry to develop methods that can be used to assess and predict the carbon sequestered by reforestation.

At present, the Reforestation Modelling Tool (RMT) is the dominant methodology approved by the Domestic Offsets Integrity Committee (DOIC) to predict carbon sequestration by reforestation activities under the CFI scheme. Because the RMT is a simplified version of the National Carbon Accounting Toolbox (NCAT) it has been built on much the same data and contains many of the same limitations found in its predecessor (Hobbs *et al.* 2010). To help alleviate these problems both CSIRO and DEWNR have undertaken projects to improve the carbon assessment methods within revegetation sites and recalibrate FullCAM models for revegetation activities (Paul *et al.* 2012).

In a collaborative effort to improve on-ground carbon assessments, recalibrate the FullCAM model and improve RMT predictions of carbon sequestration from revegetation DEWNR and CSIRO combined resources and expertise to intensively examine several sites in the southern Murray-Darling Basin region of South Australia. DEWNR carried out extensive pre-sampling measurement work on two sites destined for destructive sampling as well as two other nearby sites (a windbreak and a patch of remnant scrub) that would later be used for comparisons. CSIRO used this pre-sampling data to select plots for destructive sampling within the two main blocks. Then a combined team from DEWNR and CSIRO carried out the above-ground destructive sampling and root excavation work at both sites, with subsamples taken away and processed by CSIRO to establish wood densities and moisture content.

The Moorlands sites are the only South Australian sites included in CSIRO's program of intensive sampling designed to improve the underlying data available to the FullCAM model. As such, the Moorlands sites provided an opportunity to compare results from the DEWNR simple measurement approach, based on generic allometrics and described in earlier sections, with the intensive CSIRO approach and the default estimates obtained from the RMT and NCAT at the time. Data collected by both DEWNR and CSIRO has been made available to DOTE and should help to improve the outputs of FullCAM based models such as the RMT and NCAT.

Location

Four sites (2 block plantings, 1 windbreak & 1 patch of remnant vegetation) were chosen in the vicinity of Moorlands (~48km SE of Murray Bridge, SA; Lat/Long 35.3332°S 139.6352°E). All sites are in close proximity to each other (<3.5km apart) and situated in similar positions in the landscape. The area receives an average of 365mm of rain a year, with more rain usually expected from May to October than in the warmer months. Typically the landscape in the area is fairly flat with large open areas suitable for cultivation interspersed with occasional very low sand dunes.

Soils vary across the area but are generally well drained. The dunes are deep sand over sandy clay loam or clay while the interdune areas are sandy clay loams over clay sometimes with calcrete structures forming 60 to 75cm from the surface. These soils are fairly low in fertility with acidic surface sands that become alkaline at depth. Owing to their sandy nature there is little organic matter present in these soils, even in the surface soil. Soil pits exposed at each of the two block sites using an excavator revealed little obstruction to root penetration other than a slight strengthening at depth. More detailed soil descriptions and analysis of the soil at the two block sites have been included in Appendix F - Improving National Carbon Accounting Models: Moorlands Case Study.

Block 1991 is a 2.8ha site located along a dune crest that was chosen for destructive sampling. A soil pit dug at this site revealed that an erosion event had deposited about 50 cm of loose water repellent sand over the top of the existing dune sand. The site was planted in 1991 with a mixture of Eucalypt Mallee species and is very open with a low plant density of 220 plants/ha. Block1991 has little understory other than a few perennial herbs and grasses, and little in the way of litter to protect the soil surface (Figure 34).

Block 1996 is a 2ha site located along a smaller dune crest that was also chosen for destructive sampling. A soil pit at this site revealed relatively undisturbed, loose, water repellent, sandy loam soil. The site was planted in 1996 with a mixture of tree and shrub species and is also fairly open with a low plant density of 290 plants/ha. Block1996 has an understory of planted shrub species along with a few perennial herbs and grasses. Again there was little in the way of litter covering the soil surface (Figure 35).

The Windbreak 1996 site is less than a hectare located along an almost flat dune. The site was not chosen for destructive sampling but had the same mixture of tree and shrub species that were planted at Block 1996 in the same year. The soil is also similar to Block1996 but the site has a slightly higher plant density of 320 plants/ha. Windbreak 1996 has a similar understory to Block1996 and little in the way of litter (Figure 36).

No destructive sampling was carried out at the Remnant site. The remnant is a 40 hectare patch of indigenous vegetation that covers a wide sandy rise. The site contained a mixture of tree and shrub species on soil similar to Block1996. This natural patch of vegetation has a plant density of 250plants/ha, a sparse understory of shrubs, perennial herbs, grasses and a sparse thin layer of litter (Figure 37).

Figure 34. Block1991: Multi-species Eucalypt Mallee plantings.

Figure 35. Block1996: Multi-species Environmental plantings.

Figure 36. Windbreak 1996: Multi-species Environmental plantings.

Figure 37. Remnant vegetation at Moorlands.

Assessments of Carbon in Plants

Calibration of FullCAM and Reforestation Modelling Tool

As part of CSIRO's larger program to improve the reliability of the Reforestation Modelling Tool (RMT) for DOTE (Paul *et al.* 2012), and in collaboration with DEWNR staff, two sites were selected at Moorlands to provide calibration data for Environmental Plantings and Mallee models used FullCAM and RMT. The targeted plantings had management regimes consistent with their local district and were successfully established within CSIRO's desired time frame of 7 to 22 years of age. Block 1991 and Block 1996 underwent detailed measurements, plot-based destructive sampling and root zone excavations. An additional site (Windbreak 1996) was also measured in this manner but without destructive sampling or excavations.

<u>Precision Sampling Method</u>

DEWNR staff carried out the initial whole of site measurements for Block 1991, Block 1996 and Windbreak 1996 along similar lines to CSIRO's Precision Sampling Methodology (PSM, Paul *et al.* 2011). The PSM called for a broad, non-destructive inventory of all plants (trees and shrubs) across the chosen sites. At all three sites the spatial location and basal stem diameters of every individual was recorded. From this survey a data base of individual diameters was established that represented a proxy for biomass across each site. An estimate of the basal area (BA) of the full planting could then be calculated.

The second stage of the process was to select a smaller subset of 4 plots within each site (i.e. Block 1991, Block 1996) for destructive sampling that had a plantation basal area within each plot that matched as closely as possible the basal area of the entire site. The size class distribution of stems was calculated for each site along with the plant density rate (plants/ha). A standard spatial GIS Shape-file was produced containing each tree's location along with their accompanying basal area calculation. These calculations were then entered into CSIRO's customised PSM software to optimize the location of the sampling plots so that each plot was representative of the whole site. The software selects sub-sets of plots randomly and repeatedly tests them until a sampling plan is found where the average plant spacing and basal area statistics are in agreement. This process was repeated several times to generate a number of sets of equivalently fitting solutions that were then checked for spatial representativeness (Paul *et al.* 2012). One of the best fit solutions was chosen at random for destructive harvest at each site.

The main advantage of the PSM approach was that it provided confidence that the estimated biomass obtained during the direct harvest of the 4 sample plots was representative of the site as a whole. A disadvantage of this method was that it required non-destructive measurements to be taken of every individual plant at each site to provide the broad scale baseline data on spatial variability of biomass across each site (Paul *et al.* 2012).

<u>Destructive Sampling</u>

Four 25x25m plots were marked out at each site (i.e. Block 1991, Block 1996). All living and dead individuals in each plot were harvested at 10 cm above ground level and weighed whole to obtain direct measures of above-ground fresh-weight biomass (Figure 38). Within the sample plots dead trees and shrubs were gathered together and bulk-weighed (Figure 39).

For the sampled plants, the following measurements were taken at the time of harvest:

- Total fresh mass
- Height
- Stem diameters at 10, 30, 50 and 130 cm height (Figure 38).

Sub-samples of stemwood and branches/leaves were taken, weighed and oven-dried at 70°C until a stable dry weight was reached to determine the moisture content of sub-samples. For analysis, the quadratic mean of individual diameter measurements were calculated to yield a single stem equivalent diameter.

A combined 128 living trees were destructively sampled at Block 1991 and Block 1996. Fifty mallee trees were destructively sampled from Block 1991, representing 10 of the 14 species present and 78 trees and shrubs were sampled from Block 1996 accounting 16 of the 29 species on site (Table 51).

Figure 38. DEWNR and CSIRO staff undertaking measurements to determine allometric relationships between stem diameter and carbon content at Moorlands.

Figure 39. CSIRO weighing equipment used at the Moorlands revegetation sites to measure the green biomass of destructively sampled eucalypt mallees, trees and shrubs.

Table 50. Summary of species recorded in Block plantings within the Moorlands Case Study.

Block 1991 Species	All Plants at Site	Above-ground Samples	Below-ground Samples
Eucalyptus socialis	90	8	4
Eucalyptus incrassata	82	10	5
Eucalyptus leptophylla	68	8	2
Eucalyptus cyanophylla	57	3	1
Eucalyptus porosa	51	2	
Eucalyptus calycogona	45	7	1
Eucalyptus phenax ssp.	42	7	
Eucalyptus dumosa	39	1	1
Eucalyptus oleosa ssp.	29	1	
Eucalyptus gracilis	26	3	2
Eucalyptus brachycalyx	8		
Eucalyptus leucoxylon	1		
Myoporum platycarpum	1		
Callitris gracilis	1		
Total records	**540**	**50**	**16**
No. of species	**14**	**10**	**7**

Block 1996 Species	All Plants at Site	Above-ground Samples	Below-ground Samples
Eucalyptus porosa	191	31	11
Allocasuarina verticillata	59	7	1
Dodonaea bursariifolia	51	4	2
Melaleuca lanceolata	35	5	3
Senna artemisioides	32	2	
Melaleuca uncinata	27	2	
Eucalyptus socialis ssp.	27	2	
Acacia calamifolia	26	6	1
Melaleuca armillaris	25	5	2
Eucalyptus leucoxylon	24	4	2
Eucalyptus leptophylla	17	3	1
Chamaecytisus palmensis	8		
Acacia pycnantha	7		
Callitris gracilis	7	1	
Eucalyptus fasciculosa	7	3	2
Melaleuca halmaturorum	6	1	
Acacia spinescens	5		
Eucalyptus diversifolia	4	1	
Hakea francisiana	4		
Callitris glaucophylla	4		
Eucalyptus cylindrocarpa	3		
Westringia fruticosa	2		
Eucalyptus calycogona	2		
Pittosporum angustifolium	2		
Eucalyptus incrassata	2		
Eucalyptus cladocalyx	1		
Eucalyptus oleosa ssp.	1	1	
Eucalyptus phenax ssp.	1		
Acacia trineura	1		
Total records	**581**	**78**	**25**
No. of species	**29**	**16**	**9**

Table 51. Destructively sampled plants from the Moorlands Case Study.

Moorlands Species	Count	Height (m) Min.	Max.
Acacia calamifolia	6	1.3	2.15
Allocasuarina verticillata	7	2.2	5.2
Callitris gracilis	1	2.0	2.0
Dodonaea bursariifolia	4	0.5	2.2
Eucalyptus calycogona	6	4.9	7.5
Eucalyptus cyanophylla	4	2.2	5
Eucalyptus diversifolia	1	0.5	0.5
Eucalyptus dumosa	1	2.1	2.1
Eucalyptus fasciculosa	3	1.9	3.9
Eucalyptus gracilis	4	5.0	9.3
Eucalyptus incrassata	11	1.8	5.1
Eucalyptus leptophylla	11	2.2	5.1
Eucalyptus leucoxylon	4	3.2	7.0
Eucalyptus oleosa ssp.	2	1.2	3.3
Eucalyptus phenax ssp.	5	1.8	4.8
Eucalyptus porosa	33	1.2	9.7
Eucalyptus socialis ssp.	10	3.4	7.8
Melaleuca armillaris ssp.	5	2.5	3.1
Melaleuca halmaturorum	1	2.1	2.1
Melaleuca lanceolata	5	2.0	3.3
Melaleuca uncinata	2	2.3	2.3
Senna artemisioides ssp.	2	1.8	2.0
Summary	**128**	**0.5**	**9.7**

<u>Root Sampling</u>

At both Block 1991 and Block 1996 portions within each harvested plot were then excavated to extract the roots and obtain a below-ground measure of biomass (Figure 40). The standard CSIRO method was to simply excavate a 10x10m plot within each of the larger plots harvested to assess aboveground biomass at each site. At Moorlands a different approach was taken and the area to be excavated was centred on individually selected plants within each harvested plot. The area to be excavated around each plant was defined as half the row width and half the distance to the next plants along the row. Thus the total area excavated varied depending on plant density, spacing and species mix, with 5 to 6 plants from each plot included in each excavated area leading to a larger total area being excavated. Using a large excavator, all roots were extracted from within boundaries of each subplot to a depth where the significant vertical roots ended. Working section by section, the excavator removed bucketful's of the loose sandy soil one at a time, spilling them onto the ground so all the coarse roots could be picked out by hand. Sub-samples of roots were taken and oven-dried for 10 days at 70°C to determine the dry weight to fresh weight ratios (Figure 41).

Figure 40. DEWNR and CSIRO researchers excavating the root zones of plants at Moorlands to develop a better understanding of the carbon stored in below-ground structures.

Figure 41. Excavated and sorted roots from a destructive sampling plot at Moorlands ready for weighing and subsampling. Subsamples were oven dried and reweighed to determine moisture content.

Site Specific Allometrics

At both sites, allometrics were derived for each key species and applied to the inventory of stem diameters. Root-to-shoot ratios were calculated for each site and the allometrics used to estimate the above and below-ground biomass components. The two destructively sampled sites had direct whole plot measures of above and below-ground biomass providing a test of any estimates based on the application of allometrics. More detailed descriptions of the methods used for direct and indirect sampling of biomass, and the development of site specific allometrics by CSIRO, are described in Paul *et al.* (2011) and Paul *et al.* (2012).

DEWNR Detailed Survey

To allow for the application of the allometric equations previously developed and described in earlier sections of this report (i.e. Allometric Models of Above-ground Biomass) the initial site survey included an extensive suite of measurements not usually carried out as part of CSIRO's PSM approach. To meet DEWNR's requirements at Block1991, Block1996 and Windbreak 1996 a more detailed set of plant measurements were made in addition to the spatial location and basal stem diameters required for CSIRO's initial PSM survey. This extra information included species, height, crown width, form, foliage density, distance to neighbouring plants, count of all stems and stem circumferences (>25mm diameter) at 2 heights. Observation heights for stem counts and circumferences were 0.5m and 1.3m for trees and mallees, and typically 0.1m for lower shrubs with only shrub stem counts made at 1.3m (if applicable).

DEWNR Rapid Surveys

Over the last six years DEWNR have developed a rapid survey method to accurately estimate above-ground biomass by non-destructively measuring a representative sub-sample of plants at a site. The method for mixed species sites involves 6 transects per site containing 10 plants per transect; 60 plants per site. Each transect is placed within a uniformly stratified grid segment that divides up the entire site into six equally sized parts. The transects are placed along continuous rows of plants avoiding edge rows and the end of rows. At each transect, individual species (>2m high) are recorded and plant measurements taken including; 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 0.1m for shrubs), and visual ranking of foliage density using reference photographs (8 classes). Foliage density classes are expressed as a percentage 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%). More detailed descriptions of non-destructive site assessment methods are described in section 4. Carbon Sequestration in Revegetation and Remnants.

At Moorlands only the Remnant site was surveyed using this method. As previously described the Block 1991, Block 1996 and Windbreak 1996 sites had every plant at each site measured intensively. This enabled a comparison of the DEWNR rapid survey method to the whole population of plants on these sites. To accomplish this the pre-measured sites were divided into six roughly equal parts, the edge plants excluded, and a random number generator used to select the starting point for a ten plant transect much like the normal DEWNR rapid survey method described earlier. Starting points were chosen using a random number generator to select transects that would not exceed the end of the blocks. For Block 1991 and Block 1996 this process was repeated nine times. Due to the small size of Windbreak 1996 the process was only carried out three times but this included almost all the internal plants at that site. Once the selections were made the allometrics described earlier were applied to estimate the above -ground biomass components. The results could then be compared within each site and with those generated by other modelling and destructive sampling.

DOTE CFI Reforestation Modelling Tool and NCAT FullCAM Model

Using the latest Carbon Farming Initiative Reforestation Modelling Tool (CFI RMT; available May 17th, 2012) the latitude, longitude and hectares planted for each of the three sites was fed into the planting window of the model. This information was initially taken directly from Paul *et al.* (2012) so the figures would be directly comparable. The planting date was then entered into the management window and 'mixed species environmental planting' and 'non-harvested regime, planting density: low (<=800 stems/ha)' selected. The results window was then activated to examine the models predictions. Following the exact methodology used in Hobbs *et al.* (2010) predictions from the 2005 NCAT version of FullCAM for each of the Moorlands sites was generated for comparison with the later models.

Comparisons of Carbon Assessment Methods

Assessment of above-ground biomass

On Block 1991 the CSIRO intensive sampling approach estimated 16.9 tonnes of total plant carbon per hectare (comprising of 9.9 tC/ha above ground and 7.1 tC/ha below ground) giving the site a carbon accumulation rate of 0.49 tC/ha/yr (Table 52). The CSIRO site specific and generic allometric model calculations were comparable with the destructively-sampled above-ground carbon, with -1% and +7% differences respectively. The estimates produced by the DEWNR allometric model (based on stemwood volume) produced a -16% difference in above-ground carbon when applied to the same plots as the CSIRO models. When applied to the entire site the DEWNR allometric model produced a -9% difference from the observed above-ground plot based figure. The DEWNR allometric model was also used to provide an estimate of above-ground carbon for nine simulations of the standard DEWNR sampling method producing an average result of -18% with a range between 9.3 and 6.3 tC/ha.

The data from Block 1996 was analysed in the same way as Block 1991 (Table 52). The CSIRO intensive sampling observed 14.1 tC/ha at (comprising of 8.5 tC/ha above ground and 5.6 tC/ha below ground) with a carbon accumulation rate of 0.94 tC/ha/yr. The CSIRO site specific allometric model calculated the closest biomass estimate to the observed above-ground carbon store of -2% difference, their generic model estimated a difference of +15%. When applied to the same plots the DEWNR allometric model produced a difference of +4% to the observed above-ground carbon store and, when applied to all trees on the site a difference of +6% was estimated. The DEWNR allometric model was again used to provide an estimate of above-ground carbon for the nine simulations of the standard DEWNR sampling method and produced an average result of +1% with a range between 4.7 and 3.7 tC/ha.

The narrow Windbreak 1996 site was not destructively sampled but the site was extensively measured with a full suite of data recorded for every significant plant at the site. The DEWNR allometric model was applied to the entire planting and also used to provide an estimate of above-ground carbon for three simulations of the standard DEWNR sampling method (see Table 52). There was a -7% difference between the above-ground estimates produced and the range of the three simulation estimates were between 11.4 and 11.5 tC/ha.

The RMT and NCAT models were applied, in the default mode, to the destructively sampled sites, Windbreak 1996 and a patch of Remnant vegetation growing in similar conditions nearby (see Table 52). Little difference can be observed between the individual site estimates these models produce. Both the RMT and NCAT produced above-ground plant biomass estimates reasonably close to that observed by destructive sampling at Block 1991 and Block 1996 but consistently underestimate both sites when below-ground elements are considered. When applied to the Remnant and Windbreak 1996 and compared to the estimates produced by the DEWNR allometric model the RMT and NCAT models grossly underestimate the biomass present on those sites.

Assessment of below-ground biomass

At Block1991 sixteen of the destructively sampled individuals were also excavated so their below-ground elements could be sampled. The selected plants included 7 of the 14 species present producing a below-ground biomass estimate of 7.1 tC/ha. Due to the higher plant density (plants/ha) and more diverse species planted at Block 1996, 25 individuals were sampled that accounted for 9 of the 25 species present at the site. The below-ground biomass at Block 1996 was estimated to be 5.6 tC/ha.

There was little difference between the plot total root to shoot (RS) ratio across sites (average = 0.69). However, it was found that RS ratio is influenced by the size and maturity of the individual plants. Regression models (Figure 7) show that below-ground (root) biomass is more reliably predicted using regressions with plant volume (height x crown area; R^2=0.88), above-ground biomass (R^2=0.83) or stemwood volume (R^2=0.83). Basal area is significantly correlated to root biomass (r2=0.68) but is a less reliable predictor.

Table 52. Comparisons of plot and site carbon estimates using different assessment techniques in the Moorlands Case Study.

		CSIRO plots				DEWNR Rapid Survey	All Plants on Site	DOTE Models at time of survey		DOTE Models at 100 years	
		Destructive Sampling	CSIRO Generic Allometric Model	CSIRO Species Specific Allometric Model	DEWNR Generic Allometric Model	DEWNR Generic Allometric Model	DEWNR Generic Allometric Model	NCAT	CFI RMT	NCAT	CFI RMT
Biomass Type by Site	Age (years)	(tonnes of elemental carbon per hectare, tC/ha)									
Whole Plant Biomass											
Block 1991 (Mallee)	21	16.9	15.0	14.3	13.8	13.6	15.0	13.7	13.3	27.0	26.1
Block 1996 (Mixed)	16	14.1	14.1	12.5	13.5	12.8	13.5	10.6	10.9	27.1	26.0
Windbreak 1996 (Mixed)	16					32.9	34.0	10.6	10.4	26.8	26.2
Remnant	~81*					58.5		25.1	24.6	26.0	27.7
Above-ground Plant Biomass (stems, branches, twigs & leaves)											
Block 1991 (Mallee)	21	9.9	10.6	9.8	8.3	8.1	9.0	10.4	10.1	20.9	19.8
Block 1996 (Mixed)	16	8.5	9.8	8.3	8.8	8.6	9.0	8.0	8.2	21.0	19.6
Windbreak 1996 (Mixed)	16					21.5	23.2	8.0	7.9	20.7	19.7
Remnant	~81*					40.8		19.4	19.0	20.2	21.4
Below-ground Plant Biomass (roots)											
Block 1991 (Mallee)	21	7.1	4.4	4.4	5.6	5.5	6.0	3.3	3.2	6.1	6.3
Block 1996 (Mixed)	16	5.6	4.2	4.2	4.7	4.1	4.5	2.6	2.7	6.1	6.4
Windbreak 1996 (Mixed)	16					11.4	10.8	2.6	2.6	6.1	6.5
Remnant	~81*					17.7		5.7	5.6	5.9	6.3

* Age estimated using basal diameters of ten largest trees in sample

Assessments of Soil Carbon

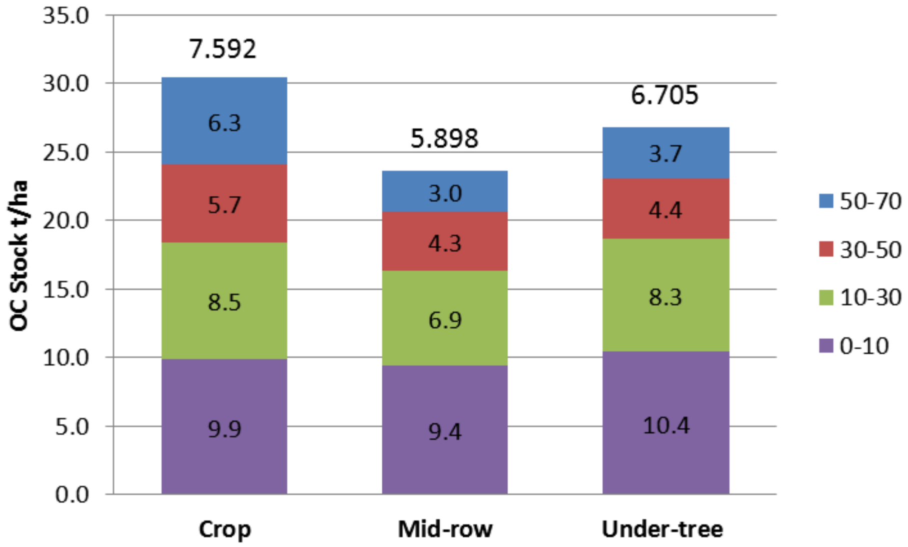
Soil samples were also collected to assess soil carbon at the same sites chosen for above and below-ground biomass assessment. The above-ground vegetation had been removed at the time of soil carbon sampling but the root zones had yet to be excavated. Each site contained 4 plots and five tree stumps were chosen from each plot to have soil samples taken next to them. Generally the chosen five stumps were divided into two lines to simplify access for the vehicle and trailer carrying the coring equipment, (1 line of 3 stumps and 1 line of 2 stumps). At each stump a core was taken approximately 1m from the stump for the "under-tree" sample and approximately 2.5m from the stump for the "mid-row" sample ("mid-row"). Due to the soil horizons present four depths were sampled from each core (i.e. 0-10cm, 10-30cm, 30-50cm, 50-70cm). Soil bulk density samples were taken in each plot to standardise soil carbon calculations. Soil samples collected within each plot were bulked for chemical analysis. A cropped paddock adjacent to each site was also sampled at the same depths following National Soil Carbon Research Programme (Sanderman *et al,* 2011) protocols and a separate descriptive core was taken at each plot (Schapel, 2012).

Some weak differences in soil organic carbon stocks (t/ha) were detected between the Block 1996 and Block 1991 sites (Table 53). But no significant differences were found between plots, sample position (crop, under-tree or mid-row) or the two sampled sites when the full range of recordings was tested (Figure 42). On average the mid-rows at each site contained slightly less soil carbon than the averages for under-tree or crop and the cropped area held the most soil carbon. Organic carbon also decreased significantly with the depth of sample but this was true across all sample points. This pattern was also true of soil density with a significant increase after the first ten centimetres but no significant differences between the locations sampled (Schapel, 2012).

The NCAT model displays a soil carbon component and as it was applied in the default mode to the sites to provide estimates of carbon sequestered in the vegetation and estimates of the soil carbon sequestered in the top 30cm (Table 53). Little difference can be observed between the NCAT estimates produced for individual sites of the same age and the level of carbon stored in the soil consistently declines with the age of the revegetation in the plot after an initial short term increase. The NCAT soil carbon estimates for both Block 1991 and Block 1996 were more than double that observed by direct sampling.

Table 53. Observed and predicted soil organic carbon stocks in the 0-30cm soil profile at cropland, revegetation and remnant vegetation sites at Moorlands.

Site	Observed (tC/ha)	DOTE NCAT Model (tC/ha)
Cropland	18.4	-
Block 1991 (Mallee)	15.9	37.6
Block 1996 (Mixed)	18.2	40.1
Windbreak 1996	-	40.1
Remnant	-	26.5



Colours represent soil depths (cm). Average carbon stock is shown over the bars (from Schapel 2012).

Figure 42. Comparisons between soil organic carbon stock in cropland and revegetation (mid-row, under tree) at Moorlands.

Discussion

The Moorlands Case Study provided a rare opportunity to compare a variety of vegetation carbon assessment methodologies ranging from intensive measurements and sampling (e.g. Precision Sampling Methods & Destructive Plot Sampling) to intermediate intensity measurements (e.g. Rapid Surveys & Generic Allometrics) and the application of generic models (e.g. DOTE National Carbon Accounting Toolbox, Reforestation Modelling Tool). With decreasing effort carbon assessment methods become cheaper and perhaps less reliable. DEWNR Rapid Surveys and Generic Allometrics methods have always been intended to be a compromise between cost and accuracy so that reasonable carbon assessments could be made in lower to medium rainfall areas of the state, and in landscapes that are spatially variable. In lower productivity landscapes of mallees, shrublands and open woodlands the cost of the carbon assessment methodology should not exceed the value of the carbon sequestrated by revegetation.

While accurate, the time and resources required to assess carbon sequestered using the CSIRO precision sampling methods (Paul *et al.* 2012) at Moorlands (e.g. Block 1991 + Block 1996) would grossly exceed the carbon trading return of these medium-sized plantings. At Moorlands the highly intensive sampling method utilized a large labour crew for on-ground surveys and sampling (estimated >400 person hours), plus the expense of hiring an excavator and driver, bulk weighing equipment, extensive laboratory, analysis and reporting time. While the detailed surveys and destructive methods used by CSIRO and DEWNR in the Moorlands study were not intended to be a routine measurement protocol for carbon accounting purposes there are other approved or proposed CFI methodologies that include substantial destructive sampling (e.g. "Reforestation and Afforestation Methodology", CO_2 Australia). The destructive nature of these approaches are inherently problematic (especially in smaller plantings) as it requires a portion of the carbon crop to be sacrificed from the stock held by the landowner (i.e. decreasing asset values). While sampling within larger plantations may have minimal impact as they represent a smaller proportion of carbon estate, smaller plantings have the potential to be greatly reduced in value.

In contrast to destructive sampling, the measurement of a statistically representative number of individuals located by randomly or stratified selections, and the application of appropriate allometric equations to estimate carbon stocks, can often be completed within a few hours. The optimal survey design and number of samples is dependent on the inherent spatial and species variability of each site being assessed. The DEWNR generic allometric model utilises data collected from samples harvested across the state to robustly predict carbon stores from a set of simple measurements in situations where harvesting may not be a viable option. While none of the above methods can be declared the perfect "truth", the DEWNR generic allometrics for above-ground biomass were on average within 7% (range 4% to 16%) of destructive samples within the CSIRO plots. The reduction in accuracy using non-destructive techniques is supplanted by several financial and asset management advantages in carbon accounting.

Table 52 clearly demonstrates that the small increases in precision using "site specific allometrics" by destructively sampling at every site does not justify the additional cost to attain this data. The current CSIRO and DEWNR generic allometrics methods provide reliable and cost-effective estimates of carbon stored in individual plants across a range of species. The discrepancies between CSIRO and DEWNR site estimates of biomass using generic models are small and may be partially attributed to slight differences in the definition of the area occupied by surveyed plants from different edge buffer calculations (i.e. half-row width versus standard 5m buffer). While the differences are minor in this example, they do demonstrate the implications of different interpretations of area occupied by the vegetation. For example, if the plot area is calculated at 30x30m rather than 25x25m the resulting 30% decrease in plant density per unit of area will substantially reduce the assessed biomass on site when expressed on per hectare basis.

Table 52 also demonstrate the discrepancies that can be produced by measuring different groups of trees within a site. The DEWNR Generic Model was applied to the trees within the plots, a 60 plant sample selection and every plant in Block 1991 and 1996, because the trees chosen and the area they occupied differed the results also varied. In particular, it can be seen that the carbon estimate of above-ground biomass for "All Plants on Site" is generally larger than the DEWNR estimates for CSIRO plots and Rapid Surveys taken from the interior of the sites (i.e. no edge rows). This result may be partially influenced by the inclusion of plants on the outside edges of these narrow blocks that are generally larger due to the extra resources available from the surrounding paddock.

A study by Mokany *et al.* (2006) encouraged the use of vegetation-specific root: shoot ratios (RS ratio), suggesting there was a negative relationship between RS ratio and mean annual rainfall and mean annual temperature. It's also been suggested that some species will require unique allometrics, particularly those with resprouting root organs (like lignotubers) that are likely to increase in biomass at a much greater rate compared with above-ground biomass (Low & Lamont 1990). Given the strong relationship between above-ground and below-ground biomass at Block 1991 and Block 1996 (R^2 = 0.83), it is evident that the allometric model formulated to estimate the tonnage of carbon stored in the root material would be robust for both. The estimate of the below-ground carbon store was similar from both the site specific and generic models and generally under-estimated what was observed (Table 52). However, further research is required to explore how applicable this relationship might be across a variety of planting types, species mixes and different environments.

By any method, the extraction of roots is a laborious and expensive process that lacks absolute precision (Mokany *et al.* 2006). Deliberately large plots were excavated, centred on individual plants. While some roots exceeded the excavated space around each tree, the influence of the lost biomass is likely to be negligible with 68% of each tree's roots contained within a 2m radius (Macinnis-Ng *et al.* 2010). The method also capitalised on the friable nature of the sand, allowing the majority of the coarse and fine root material to be easily separated from the soil. The plot scale RS ratio was found to be 0.69 based on all the plants excavated at Block 1991 and 1996. While the RS ratio varied a great deal between plants it was collectively higher than those suggested in similar studies (Mokany *et al.* 2006 and Snowdon *et al.* 2000) possibly due to the large number of mallees with underground lignotubers in Moorlands samples (Figure 43).

For a landowner the least expensive method of obtaining a carbon sequestration estimate is from an established growth model or tool (e.g. National Carbon Accounting Toolbox - NCAT or Reforestation Modelling Tool - RMT). Cost savings are obvious when landholders are not burdened by the expense of having to measure or sample vegetation on site. Both NCAT and RMT are based on 3PG and FullCAM models and are available online. The simplicity of these tools allows landowner to input basic data to generate a carbon sequestration estimate. It has been previously noted these model predicts have tendency to under-predict carbon accumulation in mixed environmental plantings in South Australia (Hobbs *et al.* 2010).

Predicted carbon sequestration estimates using NCAT and RMT for Block 1991 and Block 1996 are presented in Table 52 and demonstrate the tendency of these tools to underestimate site carbon, particularly the below-ground component. Windbreak 1996 is an example of the tendency of these tools to underestimate site carbon. As the name suggests Windbreak 1996 is a narrow planting that has slightly better soil, a slightly higher plant density and an almost identical species mix to Block 1996. Both 1996 sites were planted in the same season within a kilometre of each other. Despite their similarities Windbreak 1996 has produced more than double the amount of biomass of Block 1996 a fact which not reflected in NCAT or RMT predictions.

Figure 43. An example of a large mallee root (lignotuber) of a 21 year old eucalypt mallee at a revegetation site at Moorlands.

The NCAT and RMT produce almost identical figures for both 1996 sites which highlight some of the problems Hobbs (*et al.* 2010) previously found with the NCAT FullCAM model predictions. Differences in plant density could not be adjusted readily in the default FullCAM model and the default estimates of site maximum dry biomass were found to be unreliable. This second problem is perhaps best demonstrated by the estimates returned for a remnant site in similar environmental conditions close to the other Moorlands sites. At this location the two FullCAM based models return estimates close to the ceiling value set by the maximum dry biomass figure within the models function however, this ceiling value is less than half the measured biomass at the remnant site (Table 52). In this case the maximum dry biomass figure is obviously set too low. Hobbs (*et al.* 2010) previously found that attempts to force the maximum value beyond the given NCAT maximum dry biomass figure only resulted in future predictions returning to the set ceiling value over time.

Table 54 displays the outputs from the NCAT and RMT models for Block 1991 under different planting regimes and time scales. In this case, the above-ground biomass estimates are reasonably close to that observed by destructive sampling at year 21 after planting. Based on the same FullCAM model as the older NCAT structure the RMT delivers similar estimates to its predecessor from a much simplified entry interface. While this makes it easier to use it removes the user's ability to make modifications that might enhance the models accuracy. It is also interesting to note the default multipliers used in the RMT outputs for *Eucalyptus globulus* and *Pinus radiata* produce extremely high carbon estimates, well beyond what the maximum dry biomass cap allows without a multiplier at this location (as indicated by the NCAT outputs).

Hobbs (*et al.* 2010) found that 'on average, NCAT significantly under-predicts dry matter production in the region' from the default outputs (~27% of observed production). Because of the high degree of scatter between NCAT predicted biomass production and the observed values found across the Southern Murray-Darling Basin it is risky to use a generic multiplier to correct this under prediction. Predictions for Block 1991 for instance would be significantly over estimated if a multiplier of 4 was applied as suggested by other data collected from across the region.

Table 54. Comparison of observed carbon stock and predicted carbon stock using DOTE NCAT and CFI RMT models and revegetation options at the Moorlands Block 1991 site.

Planting Type	Model Plant Density Class	Age (years)	CSIRO Plot Observed Above-ground Biomass (tC/ha)	NCAT FullCAM Model Above-ground Biomass	NCAT FullCAM Model Total Plant Biomass (tC/ha)	CFI RMT Model Total Plant Biomass (tC/ha)
Mixed Species Environmental Plantings	Low	21	9.86	10.40	13.68	13.28
	Normal			10.46	13.78	13.52
	High			15.92	20.73	13.78
	Direct					12.55
	Regeneration			9.93	13.06	
	Low	100		20.88	26.96	26.11
	Normal			21.00	27.13	26.05
	High			21.10	27.28	26.02
	Direct					25.96
	Regeneration			20.82	26.86	
Eucalyptus globulus	Low	21		9.42	11.78	111.49*
	Low	100		20.55	25.47	218.40*
Pinus radiata	Low	21		6.99	8.27	74.74*
	Low	100		19.76	23.34	216.48*

*RMT uses a default "site maximum above-ground biomass" multiplier of 8.5 for *Eucalyptus globulus* and 9.8 for *Pinus radiata*.

Total site carbon is a combination of the carbon data from plantings, soil and ground debris (litter) and as such perpetuates any inaccuracies that exist in the component data used to create it. This is probably best exemplified in the difference between the measured soil carbon figures and those given by the NCAT default run (Table 53). A discrepancy of this magnitude easily masks any small inaccuracies that might be found in the calculation of plant carbon figures in Table 54. Without further investigation it is difficult to say why the NCAT soil carbon figures are double those measured at the site for the same depth of soil but using such modelled figures can easily lead to an overestimation of total site carbon.

At present, the DOTE's NCAT and RMT models (including FullCAM, 3PG and FPI components) are poorly calibrated for environmental plantings, especially in low to medium rainfall regions of Australia. While some recent studies are partially addressing this issue (Paul *et al.* 2011, 2012), the NCAT and RMT models will continue to be insensitive to plant densities, have inappropriate soil fertility modifiers in lower to medium rainfall regions, and produce results that are often contrary to field measurement in South Australia (Hobbs *et al.* 2010). While information from sites like Moorlands will add to and improve these models over time, at present they are unreliable for estimating carbon sequestration from revegetation in South Australia.

Conclusions

The Carbon Farming Initiative requires an approach that accurately and efficiently measures carbon in environmental plantings for an economically viable carbon sequestration and trading industry. The most accurate methods that include extensive surveys and destructive sampling are costly and inappropriate in smaller plantings where the destructive sampling method substantially diminishes the carbon crop. The cost of carrying out destructive sampling at small sites can easily exceed the value of the carbon they sequester. The Moorlands case study also illustrates the inherent inaccuracies of currently available or CFI-approved models and tools. RMT tends to under predict carbon sequestration rates in a similar fashion to its NCAT predecessor. Caution still needs to be exercised when relying on forecasts of potential carbon sequestration from the RMT or other predictive models, especially in low to medium rainfall regions where background data is limited. Such models predictions may need to be adjusted based on limited and cost-effective survey data.

Current information clearly demonstrates a high degree of variation in carbon sequestration rates from plantations and revegetation activities in low to medium rainfall regions resulting from a variety of species, management practices and environmental factors (Hobbs *et al.* 2010). The Moorlands case study has demonstrated the robustness of generic allometric models to estimate carbon stocks in revegetation. The accuracy of these generic allometric models has increased substantially in recent years as more destructive data for lower rainfall species has been accumulated and analysed (e.g. this study, Paul *et al.* 2012). Measurement protocols must be highly attuned to spatial variation in productivity within revegetation sites and appropriate sampling designs and minimum sample sizes identified to ensure the representativeness of measurements taken (Paul *et al.* 2012).

Supplementary Data – Soil Reports

Moorlands 1991: Deep siliceous sand

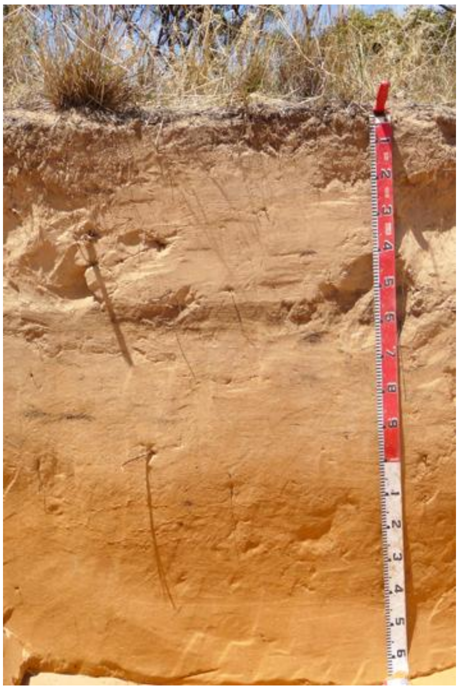
General Description: Deep, disturbed, sporadically bleached sandy soil

Subgroup *soil*:	H2–H3
Landform:	Disturbed linear dune
Substrate:	Siliceous sand.
Vegetation:	Woody native revegetation site (revegetated in 1991).

Type Site:	Site No:	MM167	1:50,000 sheet:	6827–3 (Moorlands)
	Hundred: Sherlock		Easting:	0375 868 (WGS84)
	Section:	-	Northing:	6088 629 (WGS84)
	Sampling date:	13/12/2011	Annual rainfall:	365 mm

The site is in on a duneslope. The site and surrounding area have been subjected to considerable wind erosion activity since clearing and settlement, with the described site overlain by 54 cm of deposited sand.

Soil Description:



Depth (cm)	*Description*
Overlying sand:	
0–13	Loose, water repellent, dark brown, loamy sand with single grain structure.
13–32	Light yellowish brown, loamy sand with single grain structure.
32–54	as above.
Buried soil:	
54–60	Dark brown, loamy sand with massive structure
60–75	Yellowish brown and orange brown, clayey sand with sporadic bleaching and massive structure.
75–102	as above
102–140	Dark brown, clayey sand with sporadic bleaching and massive structure.
140–170	Strong brown, clayey sand with sporadic bleaching and massive structure.
Classification:	Basic, Arenic, Yellow-Orthic Tenosol; medium, non-gravelly, sandy / sandy, deep.

Appendix F - Improving National Carbon Accounting Models: Moorlands Case Study

Summary of Properties

Drainage: Drainage is excessive (rapid).

Fertility: Inherent fertility is very low (as the sandy soil has limited capacity to retain and provide nutrients). This is evidenced by very low cation exchange capacity (which is approximated by the sum of cations). There is also little organic matter (which provides natural fertility), even in the surface soil, owing to disturbance and erosion, and the soil's low clay content. Maintenance and improvement of surface soil organic matter, residues and vegetative cover is extremely important for maintenance of fertility as well as protection against erosion.

pH: Surface soil pH is acidic; pH increases with depth to slightly alkaline levels.

Rooting depth: Root growth was observed to the base of the pit, with roots becoming few below 140 cm.

Barriers to Root Growth

Physical: There are no physical limitations to root growth to the base of the pit.

Chemical: Low fertility may limit root growth (e.g. low to very low phosphorus, sulfur and boron levels). Zinc and even manganese levels below the surface soil may also limit root growth with depth.

Water holding capacity: Estimate for perennial vegetation to 140 cm = 90 mm (moderate)
[(0.13x100)+(0.41x60)+(0.06x90)+(0.8x60)].

Seedling emergence: Good.

Workability: Good.

Erosion Potential

Water: Low.

Wind: Extreme – highly fragile. Permanent vegetation cover is essential to protect soil against erosion.

Laboratory Data

Depth cm	pH H_2O	pH $CaCl_2$	CO_3 %	EC 1:5 dS/m	ECe dS/m	Org.C %	Avail. P mg/kg	Avail. K mg/kg	Cl mg/kg	SO_4-S mg/kg	Boron mg/kg	Trace Elements mg/kg (DTPA)				Sum cations cmol (+)/kg	Exchangeable Cations cmol(+)/kg				Est. ESP
												Cu	Fe	Mn	Zn		Ca	Mg	Na	K	
Paddock	6.3	5.5	0	0.027	-	0.65	13	111	7.1	6.4	0.33	0.27	40.5	1.83	0.92	2.1	1.45	0.39	0.04	0.22	1.9
0–13	6.1	5.3	0	0.018	-	0.58	13	108	4.4	2.9	0.17	0.32	13.8	1.54	0.92	1.9	1.33	0.36	0.03	0.20	1.6
13–32	6.8	5.8	0	0.022	-	0.14	4	64	6.6	2.2	0.15	0.22	17.4	0.32	0.04	1.3	0.78	0.31	0.07	0.15	5.3
32–54	7.2	6.7	0	0.021	-	0.07	<2	85	4.9	2.2	0.15	0.64	8.30	0.56	0.33	1.5	0.92	0.32	0.07	0.18	4.7
54–60	7.5	6.5	0	0.052	-	0.25	<2	114	23.6	3.4	0.36	0.16	8.33	1.46	0.05	3.2	2.24	0.46	0.23	0.25	7.2
60–75	7.5	6.8	0	0.052	-	0.18	<2	86	32.1	5.9	0.29	0.23	8.77	0.28	0.06	2.9	2.06	0.37	0.25	0.19	8.7
75–102	7.0	6.5	0	0.064	-	0.06	<2	65	58.5	5.9	0.18	0.15	5.84	0.17	0.10	2.3	1.58	0.38	0.18	0.16	7.8
102–140	7.6	6.9	0	0.033	-	<0.05	<2	47	19.0	4.0	0.23	0.20	5.44	0.28	0.13	3.1	2.17	0.67	0.12	0.12	3.9
140–170	7.7	6.8	0	0.038	-	<0.05	<2	54	16.1	3.1	0.23	0.31	3.21	0.25	0.45	3.1	2.03	0.84	0.09	0.14	2.9

Note: Paddock sample bulked from 20 cores (0–10 cm) taken around the pit.

Sum of cations approximates the CEC (cation exchange capacity), a measure of the soil's capacity to store and release major nutrient elements.

ESP (exchangeable sodium percentage) is derived by dividing the exchangeable sodium value by the CEC, in this case estimated by the sum of cations.

Moorlands 1996: Bleached sand over sandy clay loam

General Description: ***Bleached sandy topsoil over light sandy clay loam subsoil with fine carbonate at depth***

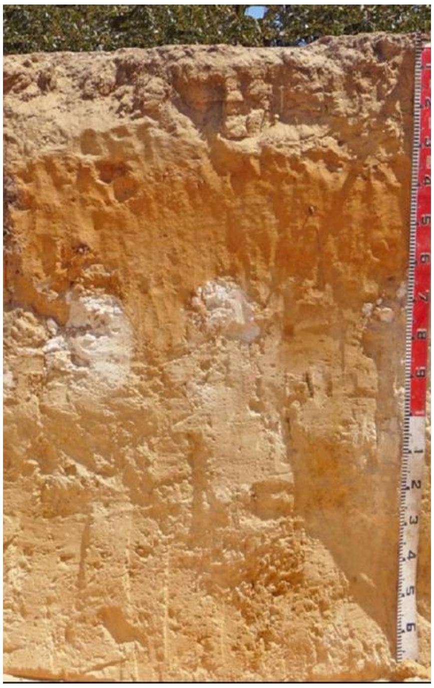
Subgroup *soil*: G2
Landform: Linear dune
Substrate: Sandy loam
Vegetation: Woody native revegetation site (revegetated in 1996)

Type Site:	Site No:	MM168	1:50,000 sheet:	6827-3 (Moorlands)
	Hundred: Sherlock		Easting:	0376 004 (WGS84)
	Section:	-	Northing:	6089 161 (WGS84)
	Sampling date:	13/12/2011	Annual rainfall:	365 mm

The site is in on a dunecrest. The site and surrounding area have been subjected to considerable wind erosion activity since clearing and settlement.

Soil Description:

Depth (cm)	*Description*
0–11	Loose, water repellent, dark brown, loamy sand with single grain structure.
11–25	Bleached loamy sand with single grain structure.
25–62	Light yellowish brown and strong brown, heavy sandy loam with sporadic bleaching and massive structure.
62–88	Light yellowish brown and strong brown, light sandy clay loam with sporadic bleaching, massive structure and >50% hard carbonate fragments (>60 mm diameter).
88–125	Very highly calcareous, light yellowish brown, light sandy clay loam with massive structure and 10–20% hard carbonate fragments (>60 mm diameter).
125–175	Very highly calcareous, light yellowish brown, heavy sandy loam with massive structure and 2–10% hard carbonate fragments (>60 mm diameter).



Classification: Bleached, Supracalcic, Yellow Kandosol; medium, non-gravelly, sandy / clay loamy, deep.

Appendix F - Improving National Carbon Accounting Models: Moorlands Case Study

Summary of Properties

Drainage: The soil profile is well drained.

Fertility: Inherent fertility is low, especially in the sandy topsoil where cation exchange capacity (which is approximated by the sum of cations) is very low. Capacity to retain nutrients increases with increasing soil texture and cation exchange capacity below 25 cm, and especially below 62 cm. However, phosphorus levels are extremely low below the surface soil. Organic matter levels are low owing to sandy texture and the disturbed nature of the site. Maintenance and improvement of surface soil organic matter, residues and vegetative cover is extremely important for maintenance of fertility as well as protection against erosion.

pH: Soil pH is acidic in the surface soil, neutral in the subsurface layer and alkaline in the subsoil.

Rooting depth: Root growth was observed to the base of the pit, with most roots in the top 25 cm.

Barriers to Root Growth

Physical: A minor physical limitation to root growth occurs at around 62 cm where the subsoil increases in strength.

Chemical: Low fertility may limit root growth (e.g. very low phosphorus levels). Low zinc levels may also limit root growth. Surface organic carbon level is low.

Water holding capacity: Estimate for perennial vegetation to 170 cm = 95 mm (moderate) [(0.11x100)+(0.14x80)+(1.45x100x0.5)].

Seedling emergence: Good.

Workability: Good.

Erosion Potential

Water: Low.

Wind: High. Residue retention and maintenance of surface cover are crucial for protection against erosion.

Laboratory Data

Depth cm	pH H_2O	pH $CaC1_2$	CO_3 %	EC 1:5 dS/m	ECe dS/m	Org.C %	Avail. P mg/kg	Avail. K mg/kg	Cl mg/kg	SO_4 -S mg/kg	Boron mg/kg	Trace Elements mg/kg (DTPA)				Sum cations cmol (+)/kg	Exchangeable Cations cmol(+)/kg				Est. ESP
												Cu	Fe	Mn	Zn		Ca	Mg	Na	K	
Paddock	6.1	5.2	0	0.045	-	0.82	9	127	7.8	6.2	0.31	0.45	28.6	3.10	0.24	3.6	2.78	0.56	0.04	0.25	1.1
0–11	6.3	5.4	0	0.085	-	0.80	12	137	13.4	8.7	0.28	0.62	28.1	3.64	0.41	3.6	2.70	0.55	0.04	0.27	1.1
11–25	7.0	6.3	0	0.087	-	0.26	<2	120	8.0	5.1	0.32	0.42	13.2	1.13	0.08	3.4	2.32	0.71	0.05	0.28	1.5
25–62	8.9	7.9	0.45	0.129	-	0.08	<2	195	24.7	6.5	0.86	0.28	9.73	0.34	0.14	8.2	6.31	1.23	0.19	0.50	2.3
62–88	9.0	8.1	4.51	0.138	-	0.14	<2	184	30.9	3.3	1.45	0.35	7.80	0.42	0.26	13.1	9.23	3.15	0.25	0.47	1,9
88–125	9.1	8.3	7.51	0.137	-	0.15	2	260	19.1	3.1	3.90	0.54	7.79	0.28	0.25	13.7	7.59	4.89	0.58	0.67	4.2
125–175	9.1	8.3	4.29	0.205	-	0.07	<2	324	10.9	2.5	5.96	0.24	7.31	0.25	0.10	11.8	5.43	4.04	1.54	0.81	13.0

Note: Paddock sample bulked from 20 cores (0–10 cm) taken around the pit.

Sum of cations approximates the CEC (cation exchange capacity), a measure of the soil's capacity to store and release major nutrient elements.

ESP (exchangeable sodium percentage) is derived by dividing the exchangeable sodium value by the CEC, in this case estimated by the sum of cations.

Government of South Australia

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