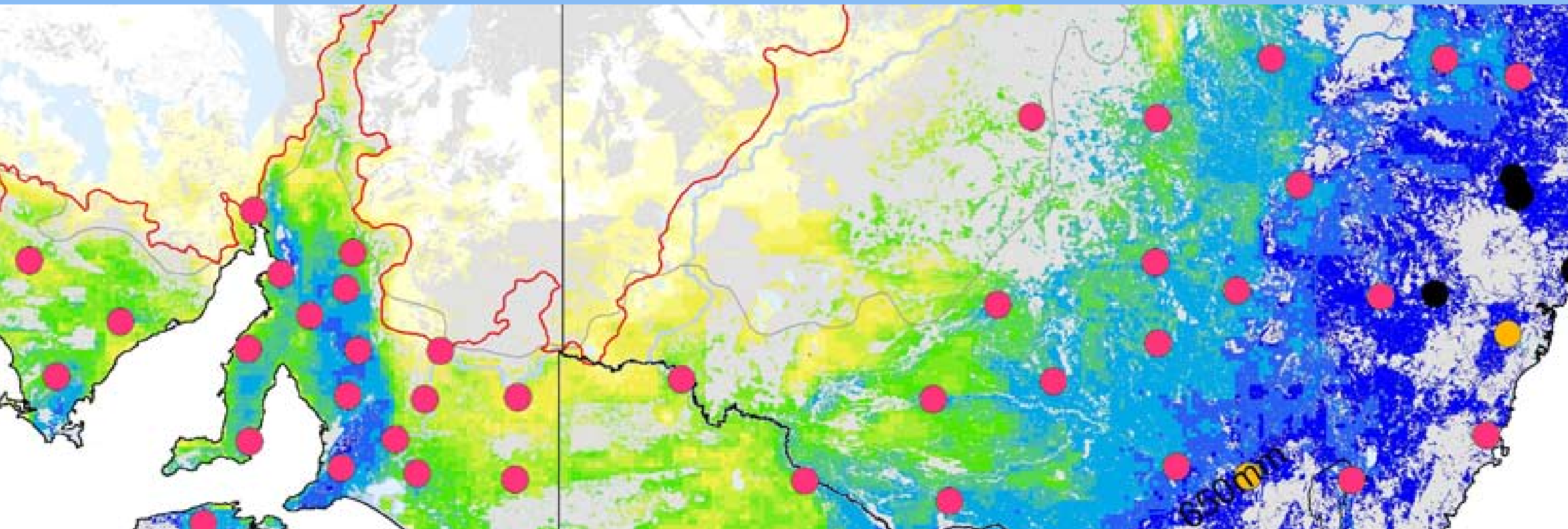
An Australian Government Initiative

Joint Venture Agroforestry Program
Rural Industries Research & Development Corporation
Forest & Wood Products Australia
Land & Water Australia

Regional Industry Potential for Woody Biomass Crops in Lower Rainfall Southern Australia

FLORASEARCH 3C

FUTURE FARM INDUSTRIES CRC
PROFITABLE PERENNIALS™ FOR AUSTRALIAN LANDSCAPES



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Regional Industry Potential for Woody Biomass Crops

in lower rainfall southern Australia

FloraSearch 3c

Edited by Trevor J. Hobbs

August 2009

RIRDC Publication No 09/045
RIRDC Project No UWA-98A

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ISBN 1 74151 848 2
ISSN 1440-6845

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Electronically published by RIRDC in August 2009
Print-on-demand by Union Offset Printing, Canberra at www.rirdc.gov.au
or phone 1300 634 313

Foreword

The dryland agricultural regions of southern Australia face many natural resource management challenges. Following a long history of widespread vegetation clearance for the development of annual crops and pastures these landscapes now experience significant environmental issues including dryland salinity, soil erosion and other losses of ecosystem function. Broadscale restoration of deep-rooted perennial vegetation to these landscapes can help to address many of these problems and provide opportunities for more sustainable and resilient farming systems in a world of diverse markets and variable climate.

The significance of carbon emissions has added to the potential importance of perennial woody crops which offer opportunities for mitigation and adaptation to changing conditions. Woody perennial systems can accumulate and store significant quantities of carbon in both living plant biomass and soil profiles and provide offsets as an alternative feedstock for energy and transport fuel production. A mosaic of land uses including tree crops driven by large-scale industrial markets, agricultural systems using annual and perennial crops, and biodiversity resources has an important role to play in Australian landscapes and sustainability of agricultural systems and rural communities.

Since 2002, the FloraSearch project has researched selection and development of new woody crop species to supply feedstock for large-scale markets, including wood products, renewable energy, carbon sequestration and fodder. FloraSearch 3 series of reports present the findings of the latest phase of this research, focussing on a suite of Australian native species and industries suited to new broadscale woody crops and their associated commercial industries. The results of this work are presented in three volumes, with the first providing in-depth information on the productive potential and agronomy of prospective new crops; the second enlarging on the domestication potential of 3 high priority species; and the third analysing regional industry potential for woody biomass crops in southern Australia (this report).

This project was funded by the Joint Venture Agroforestry Program (JVAP), which is supported by three R&D Corporations - Rural Industries Research and Development Corporation (RIRDC), Land and Water Australia (LWA), and Forest and Wood Products Research and Development Corporation[1] (FWPRDC). **The Murray-Darling Basin Commission (MDBC) also contributed to this project**. The R&D Corporations are funded principally by the Australian Government. **State and Australian Governments contribute funds to the MDBC**. Significant financial and in-kind contributions were also made by project partners in the Future Farm Industries Cooperative Research Centre: SA Department of Water, Land and Biodiversity Conservation; WA Department of Environment and Conservation; CSIRO; NSW Department of Primary Industries; and Department of Primary Industries Victoria.

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[1] Now: Forest & Wood Products Australia (FWPA)

This report is an addition to RIRDC's diverse range of over 1800 research publications. It forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems. The JVAP, under this program, is managed by RIRDC.

Most of RIRDC's publications are available for viewing, downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

Peter O'Brien
Managing Director
Rural Industries Research and Development Corporation

Acknowledgments

The editor acknowledges the Joint Venture Agroforestry Program (JVAP), Future Farm Industries Cooperative Research Centre (FFI CRC) and CRC for the Plant-based Management of Dryland Salinity for funding this project. We would also like to recognise the significant support of our parent organisations - SA Department of Water, Land and Biodiversity Conservation and WA Department of Environment and Conservation. Thanks to Avon Catchment Council and the Oil Mallee Association for their support of WA mallee biomass studies, and the Australian Government and the SA Centre for Natural Resource Management for their financial support for the Upper South East case study.

The input and helpful advice of project collaborators and interested supporters of the FloraSearch project is gratefully appreciated. This includes Rosemary Lott, Bruce Munday, Mike Ewing, Kevin Goss, Daniel Huxtable, Brendan George, Craig Neumann, David McKenna, Wayne O'Sullivan, Richard Giles, George Freischmidt, Graeme Olsen, Peter Georgaras, Don Cooper, Rob Sudmeyer, Col Stucley, Julian Morison, David Pannell, Richard Mazanec, Malem McLeod, Des Stackpole, Isla Grundy, Olivia Kemp, Peter Jessop, Peter Butler, Andrew Fisher and Joe Landsberg. We greatly appreciate the scientific research and administrative support of Merv Tucker, Gary Brennan, Julie Dean and Ligita Bligzna.

Thanks to John Bartle for his enthusiasm towards developing new woody crops in southern Australia and his dedication towards the development of oil mallee systems in Western Australia. Mike Bennell is a great supporter of the development of fodder shrub systems in Australia and we look forward further adoption of this industry type across vast regions of Australia. Thanks to Mike for his input into the FloraSearch woody developments in recent years and enthusiasm for lignocellulosic ethanol.

The editor also thanks Brett Bryan for his detailed commentary and formal review of this work, and Craig Neumann and David McKenna for detailed proofing of this report.

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Executive Summary

What the report is about

This report investigates the markets, economic drivers and spatial influences on developing commercial woody biomass crops in lower rainfall regions of southern Australia. This is done through surveillance of new markets and industries, detailed studies of production system economics, and spatial modelling and analysis for a range of industries and regions. It focuses on *Woody Bioenergy Crops for Lower Rainfall Regions of Southern Australia* and explores bioenergy opportunities for electricity generation and creation of liquid biofuels to replace fossil fuel consumption in Australia. A region specific spatio-economic analysis *Woody Crop Potential in the Upper South East Region of South Australia* identifies a region with significant potential for a wide range of woody crop industry types and investigates the feasibility of a range of industry types at high spatial resolution

Who is the report targeted at?

This report allows rural landholders, large scale biomass industries, government agencies and research managers to make informed decisions about appropriate species for new woody crop industry selections in the lower rainfall regions of southern Australia. It aims to influence decision makers at all levels involved in developing sustainable and productive agroforestry within Australian low rainfall farming systems.

Background

The over-arching goal of FloraSearch is the development of commercially viable, broad-scale woody perennial crops for low to medium rainfall agricultural areas of southern Australia. These crops need to suite integration with existing annual cropping and grazing systems providing a range of natural resource benefits, including improved dryland and stream salinity. They need to improve the resilience of agricultural systems in response to climate variability and form the foundation of new, large-scale rural industries.

The FloraSearch Stage 3 series of reports builds on earlier FloraSearch research that commenced in 2002 and identified a range of prospective species and industries suited to development as new woody crops. The current work provides a greater focus on species suited for further development and has refined methodologies that can be used to interrogate the feasibility of new woody crop industries at a range of scales. The research is supported by the Joint Venture Agroforestry Program and the Future Farm Industries Cooperative Research Centre and operates out of two key nodes based within SA and WA State Government departments.

FloraSearch Stage 3 presents the findings of the latest phase of this research and is reported in 3 volumes:

- **FloraSearch 3a - Developing species for woody biomass crops** (Hobbs *et al.* 2009a);
- **FloraSearch 3b - Domestication potential of high priority species (*Acacia saligna, Atriplex nummularia* and *Eucalyptus rudis*) for woody biomass crops** (Hobbs *et al.* 2009b); and
- **FloraSearch 3c - Regional industry potential for woody biomass crops** (this report, Hobbs 2009b).

Aims/objectives

The aims of FloraSearch Stage 3 are to:

- Assess the agronomic suitability of development species for cultivation in the wheat/sheep belt including adaptability and productive potential;

- Evaluate species with merit for progression as commercial crops (development species) and initial a process for the domestication and improvement of plant species with greatest potential (focus species); and

- Refine and adapt new industry evaluation methods, spatial analysis tools and to conduct scoping feasibility studies for new large-scale industries based on products from woody perennial production systems.

The objectives of the research described in this report are to explore potential market drivers and commodity values for large-scale woody crops in Australia; provide a better understanding factors affecting economic performance of woody crop production systems (e.g. the mallee belt system in WA); undertake economic and spatial analyses of potential bioenergy crops for southern Australia; and illustrate the ability of the regional industry potential analysis to evaluate a wider range of woody crop types and environmental benefits at a regional scale (e.g. Upper South East region of SA).

Methods used

Potential products and markets identified by our earlier work have been reviewed and re-prioritised based on new information on trends in expected market volumes and prices. This information has been extracted from the literature, online historical and current industry market data for both national and international markets, and through discussions with current biomass industry collaborators.

Mindful that potential biomass markets are not static, we have been scanning commodity markets, environmental drivers, industry and political trends, and technological advances for emerging markets and industries that could potentially utilise large volumes of industrial feedstocks from short-cycle woody crop systems or create market values for environmental services such as carbon sequestration in the lower rainfall regions of southern Australia.

Research into the integrated wood processing (IWP) model of crop production has been focussed in Western Australia for *Eucalyptus* spp. (mallees) to produce energy, charcoal and oils. We explore the feasibility of this system by detailed economic examinations of the influence of a range of productivity and production system variables on the likely annual equivalent returns for this woody crop system.

We have built on these economic analyses to encapsulate spatial factors affecting woody crop productivity and returns, through the application of *Regional Industry Potential Analysis* (RIPA) methodologies, which combine geographic information system (GIS) data with economic models to evaluate the potential commercial viability for a wider range of woody crop industries. This report highlights the full potential of this analytical technique through two case studies on the RIPA methodology which was first described in the FloraSearch Phase 1 report (Bennell *et al.* 2008) using early estimates of productivity and preliminary models to illustrate the concept. This work has progressed and is becoming a sophisticated tool, able to support the systematic regional evaluation of perennial crop options at a range of scales. It incorporates improved species knowledge (e.g. productivity estimates), industry developments, updated costs and returns and refinements in the modelling process.

The methodology has been recently adopted and modified to undertake other spatio-economic analyses for other industries and regions across Australia (e.g. JVAP *Regional opportunities for agroforestry* project, Polglase *et al.* 2008).

Results/key findings

Woody cropping systems in the lower rainfall regions of southern Australia provide numerous opportunities for commercial development of bioenergy, carbon sequestration, wood fibres and livestock production industries. These systems can also provide a wide range of environmental and community benefit across Australia. The scale of this potential is immense with over 57 million hectares in the lower rainfall regions of southern Australia currently used for cropping and grazing that could potentially be used to develop new sustainable woody crop industries. This study identifies industries that are more or less suitable to locations within dryland agricultural regions of southern Australia.

The *Factors Affecting the Economic Performance of Mallee Production Systems* section illustrates that there are numerous influences on the viability of woody crop production systems in Australia. Using oil mallee production systems in Western Australia we have shown the need to maximise productivity for commercial viability through better plant selections, and crop designs that can harvest excess water from the landscape. We are also aware of the need to balance woody crop production with other landuses, and that the goal is an optimal overall farming system that has components of new woody crops and existing industry types to be successful. Establishment, silvicultural, harvest and land management practices are highly important in optimising returns from these systems. Where additional (and often off-site) environmental benefits can be valued, these can potentially provide a new income stream to these new crop systems.

Case Study 1: Woody Bioenergy Crops for Lower Rainfall Regions of Southern Australia demonstrates there is immense potential to develop new woody bioenergy crops in southern Australia. Although prices of these new feedstocks are still tenuous, by comparing these product streams with internationally and Australian marketed commodities we can approximate likely feedstock values of woody biomass for these energy markets. The analyses do highlight the sensitivity of industry feasibility on commodity prices and production rates given the cost of growing, harvesting and transporting a currently low-valued product especially in remote and less productive landscapes.

Increasing energy (electricity, heat and transport liquid fuels) demands and prices, and emerging conversion and harvest technologies suggest that bioenergy crops will soon play an important role in Australian agricultural landscapes.

Case Study 2: Woody Crop Potential in the Upper South East Region of South Australia identifies a region with significant potential for a wide range of woody crop industry types. This case study is in a region that borders a higher rainfall zone with existing woodfibre industries (pulp, paper, particleboard production, woodchip export) and where there is existing interest in and use of fodder shrubs for livestock and timber for firewood. New bioenergy industries and potential carbon sequestration markets offer opportunities for landholders in this region and are likely to provide significant symbiotic (and perhaps competitive) economic returns to current cereal cropping and livestock grazing enterprises in the region. This study also explores the environmental benefits of woody crop systems and revegetation in the region. It has been used to identify specific districts that would most benefit from these new industry options.

Implications for relevant stakeholders

This research provides a solid base for development of several Australian species for woody crop production in the lower rainfall regions of southern Australia. It is work that is strongly supported by the Future Farm Industries Cooperative Research Centre, Joint Venture Agroforestry Program, several State Government departments, farm forestry researchers and several industry groups. We are developing new research and development opportunities by engaging further support of research and development corporations and new industry partners in Australia. The successful development of these new crop species can greatly diversify and improve agricultural landuse in many low-rainfall parts of southern Australia.

The *Regional Industry Potential Analysis* methodology has been recently adopted and modified to undertake other spatio-economic analyses for other industries and regions across Australia (e.g. JVAP *Regional opportunities for agroforestry* project, Polglase *et al.* 2008) and used to inform analyses for the Garnaut Climate Change Review (Garnaut 2008, Chapter 22 Transforming Rural Land Use).

Recommendations

Many short-cycle woody crops and biomass industries complement existing farm enterprises, while the analyses presented in this report show that some can be profitable across vast regions of southern Australia. Indeed, the potential economic returns from several of these industry types in some regions can be comparable to those from existing land uses. The current and potential profitability and sustainability of perennial woody crops can therefore provide landholders with alternatives into the future.

Further investment in research is required to progress the understanding of the spatial variability and economic influences on industry development in Australia. There is need to better understand processes to optimise productivity through better species selection, plant improvement, landuse planning, agronomic designs and effective water use in the landscape. Future work should strongly focus on more detailed studies such as variations in productivity and yields to enhance plant improvement processes and bring forth new candidates for domestication. Further agronomic and crop management research is also required to optimise productivity rates and sustainability of the new crops. Spatial variation in landscape productivity of both existing annual crops and new woody crops must also be further evaluated so that regional and whole-of-farm profitability can be optimised for agricultural landscapes facing the challenges of variable climates and dynamic markets and policy directions.

1. Introduction

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Overview

The clearing of native vegetation systems for agricultural use has altered the natural hydrology, soils and ecology of many landscapes in southern Australia. These changes have led to the emergence of many natural resource management issues, including increased rates of landscape salinisation, reduced groundwater and stream quality, soil erosion, depleted environmental carbon stores and the loss of biodiversity. The targeted re-establishment of woody perennial plants in the 250-650mm winter dominated rainfall zone (Fig. 1) could help alleviate the scale of these detrimental effects (Bartle *et al.* 2007). To do this on the scale required, woody perennials must be economically viable and must either provide a commercial alternative to, or complement, current land uses (Bennell *et al.* 2008, Stirzaker *et al.* 2002). More recently the recognition of carbon emissions and the consequences of climate change have emerged as a critical world and national issue. This has led to great public interest in the emerging opportunity to re-establish woody perennial plants into our agricultural landscapes to both sequester carbon dioxide and adapt to a changing environment.

While natural resources management (NRM) benefits have been a public motivation for revegetation in all its forms, this benefit is often only realised in the long term. For private landowners, a rational analysis of the immediate NRM benefits of revegetation on landscape productivity and health will seldom support any significant investment in revegetation. To provide public, and longer-term, natural resource management benefits from revegetation requires public investments and support to develop of commercially viable woody crops that are both attractive to farmers and have a complementary role in agricultural systems and broader environmental services (Bartle 1991, Bartle and Shea 2002, Bryan *et al.* 2005, Ward *et al.* 2005, Bryan *et al.* 2008, Pannell 2008).

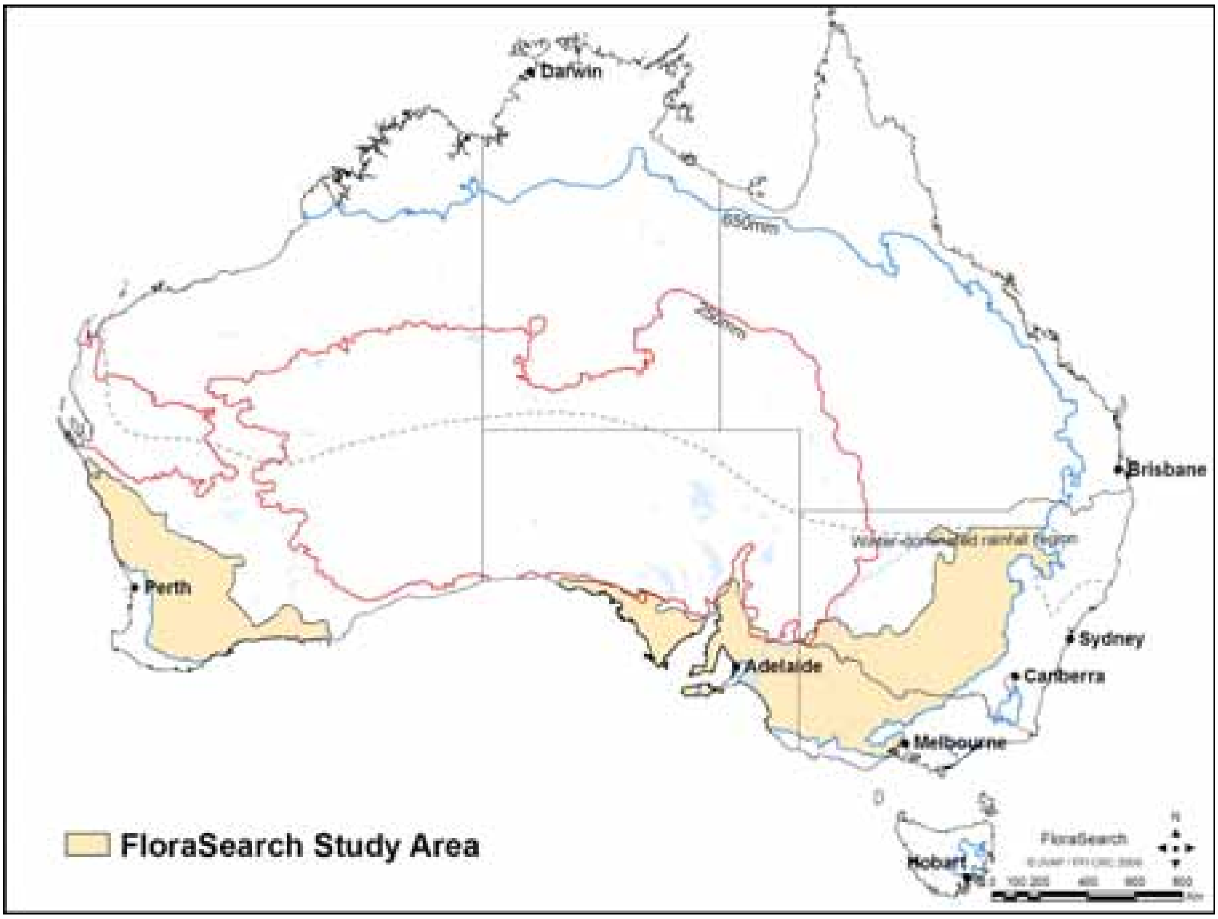
Commercial sawlog and pulpwood forestry in southern Australia is mainly limited to higher rainfall regions (650 - 1000mm mean annual rainfall). These industries are typically based on long-cycle rotations (>20 years) to grow large diameter logs which are transported to centralised processing facilities (Zorzetto and Chudleigh 1999). In medium to lower rainfall regions sawlog harvest cycles are even longer (Harwood *et al.* 2005) due to reduced water availability and slower growth rates. Recent rainfall trends and climate change predictions suggest that these long-cycle systems are likely to become progressively less viable in these regions.

To develop an alternative to long cycle species a significant investments has been made in developing short cycle native species as woody crop options in lower rainfall regions. Investigations into the use of oil-bearing mallee species for woody crops indicate significant potential for development of these new crops in the wheatbelt regions of Australia (Bartle and Shea 2002, Bartle *et al.* 2007). In the 1990’s extensive research and development work on ‘oil mallee’ species commenced in Western Australia and was oriented towards the development of new industries based on commercial integrated wood processing systems yielding Eucalyptus oils, charcoal and bioenergy (Bartle and Shea 2002, Enecon 2001). An expanded focus of this work and diversification of potential industries led to the development of ‘WA Search’ (Olsen *et al.* 2004) and later the ‘FloraSearch Stage 1’ (Bennell *et al.* 2008) projects to systematically screen other Australian native flora for their potential as new woody crops. With the support of the Cooperative Research Centre (CRC) for Plant-based Management of Dryland Salinity and the Joint Venture Agroforestry Program (JVAP) these two project teams joined forces in 2004 under the banner of the ‘FloraSearch Stage 2’ project to further progress woody crop research and development across southern Australia. Building on the strengths and results of this alliance of researchers the work was further supported by the CRC (now Future Farm Industries CRC) and JVAP in 2006 as ‘FloraSearch Stage 3’.

The FloraSearch project has made significant advances in developing novel crop options for the dryland agricultural region of southern Australia (Fig. 1). It integrates scientific advances in the biology of native plant species with agriculture and economics to demonstrate that woody crops have potential within the wheat/sheep regions. It begins the process of generating confidence that the best available information on biomass production for a range of products including carbon, bioenergy, extractives, fodder and wood products is available to landowners and businesses with aspirations in this area. New woody crop research and development, evolving out of FloraSearch ideas and information, will progress from within the Future Farm Industries Cooperative Research Centre and guide future woody biomass crop and industry development.

Fig. 1. The FloraSearch study area (shaded) contains the low rainfall winter cereal growing areas of southern Australia.

Bounded by the low rainfall limit of cropping, winter-dominated rainfall areas, and the 650mm annual rainfall isohyet.



Prior research and development – WA Search and FloraSearch Stage 1 and 2

Development of a mallee industry in WA was commenced by CALM in 1992 with the objective to create a new large-scale industry based on a tree crop that would be profitable for farmers as well as being a major part of their capability to control salinity (Bartle and Reeves 1992). The mallee development was the motivation and model for the Search Project. It demonstrated that novel 'short-cycle' crop types might be feasible. This work reached the conclusion that any new crop large enough to provide land management benefits will be locked into bulk production of a relatively low-value commodity, with efficiency of production, security of supply and achievement of quality standards being the most important determinants of market success.

This led to the Search project being undertaken with support of the National Heritage Trust in 1998 followed by the JVAP funded work in eastern Australia which commenced in 2002. FloraSearch Stage 1 (Bennell *et al.* 2008), which focused on eastern Australia, concluded in June 2004 having achieved its goals of:

- Selecting suitable target products such as pulp and paper, reconstituted fibreboard, bioenergy and fodder.
- Identifying and commencing the testing of species with the potential to be productive in short-cycle crop systems, and to supply these industries within the FloraSearch region.
- Developing a spatial analytical system suitable for regional analysis of current and potential industry based on these products and species.

The work being undertaken in eastern and western Australia was ultimately brought together under one project (FloraSearch Stage 2) supported by JVAP and the CRC - Plant Based Management of Dryland Salinity. This project provided an update and expansion of earlier FloraSearch work as the project evolved from an initial context and screening phase (Stage 1) to a more targeted and development phase (Stage 2).

This then led into FloraSearch Stage 2, which reported in mid 2006 (Hobbs *et al.* 2008c) having completed its goals of:

- A systematic survey of the native woody perennial flora of southern Australia's wheat-sheep zones, including selection and testing of species suitable for products identified in the FloraSearch stage 1 and WA Search project. This included establishment of a common database of attribute information of prospective native species for eastern and western nodes.

  Assessed the suitability of development species for cultivation and providing a short list of species with merit as commercial crops (development species) or the subject of domestication in the next phase including plant improvement (focus species). The current highest priority species (or "Focus Species") include the fodder shrub Old Man Saltbush (*Atriplex nummularia*) for southern Australia, and Orange Wattle (*Acacia saligna*) for Western Australia. The next highest priority (or "Development Species") included: *Acacia decurrens; Acacia lasiocalyx; Acacia mearnsii; Acacia retinodes var. retinodes; Anthocercis littorea; Casuarina obesa*; *Codonocarpus cotinifolius; Eucalyptus cladocalyx; Eucalyptus globulus spp. bicostata; Eucalyptus horistes; Eucalyptus loxophleba ssp. lissophloia; Eucalyptus occidentalis; Eucalyptus ovata; Eucalyptus polybractea; Eucalyptus rudis; Eucalyptus viminalis ssp. cygnetensis* and *Viminaria juncea.*

- Further developing spatial analysis tools to consider opportunities at the regional scale for new large-scale industries based on products from woody perennial production systems. This work progressed, becoming a sophisticated tool able to support the systematic regional evaluation of perennial crop options. The analyses presented showed that many industries are profitable across vast regions of southern Australia.

- Establishment of field trials in WA, SA, Victoria and NSW to evaluate development species (a component of a collaborative CRC project).

It is the final stage (Stage 3) of this work being reported here and the report reflects major developments in project structure, emerging issues in dealing with climate variability and evolutions in some product areas. This report should be read in conjunction with the earlier FloraSearch Stage 1 and 2 project reports (Bennell *et al.* 2008, Hobbs and Bennell 2008, Hobbs 2008a, Hobbs *et al.* 2008c), WA Search (Olsen *et al.* 2004) and Acacia Search (Maslin and MacDonald 2004).

FloraSearch Stage 3 - Report Structure

The FloraSearch Stage 3 report is presented in 3 sections (described below) due to the overall length of the material and to allow separation by topic to assist in ease of access to information by the reader. There have been several authors who have contributed to this report often with a focus on a particular aspect of the research or a particular regional view. To reflect this contribution the report sections are provided as chapters with the principal contributors nominated as authors.

FloraSearch 3a - Developing Species for Woody Biomass Crops

This section describes the detailed evaluation and development of species identified in FloraSearch Stage 2. Data on the performance of development species from CRC evaluation trials, WA mallee plantings and other trials have been collated to provide up to date information on allometrics and productivities for key species. Species selected for ongoing development (focus species) have been the subject of comprehensive reviews and summaries of these reviews and the first stage result from plant improvement trial are reported.

FloraSearch 3b – Reviews of High Priority Species for Woody Biomass Crops

Key focus species, Koojong or Orange Wattle (*Acacia saligna*), Oldman Saltbush (*Atriplex nummularia*) and Flooded Gum (*Eucalyptus rudis*) have been identified for plant improvement and further development. These species have been the subject of comprehensive species and domestication review and are reported in the FloraSearch 3b report.

FloraSearch 3c - Regional Industry Potential for Woody Biomass Crops

This report concentrates on biomass industry development issues and approaches to help identify the spatial scale and economic potential of new woody biomass crops in the wheat-sheep zone of southern Australia. Feasibility investigations and development of markets has become a critical part of FloraSearch and related projects, and the need to analyse the scale and potential of existing and new industries that could utilise supply of feedstock from dryland production in the wheat/sheep belt is a key part of the project mix. The results of various approaches to market and business analysis by this and related projects are presented in this report.

This report investigates the markets, economic drivers and spatial influences on developing commercial woody biomass crops in lower rainfall regions of southern Australia. This is done through surveillance of new markets and industries and detailed studies of production system economics and spatial modelling and analysis for a range of industries and regions. It focuses on *Woody Bioenergy Crops for Lower Rainfall Regions of Southern Australia* and explores bioenergy opportunities for electricity generation and creation of liquid biofuels to replace fossil fuel consumption in Australia. A region specific spatio-economic analysis *Case Study 2: Woody Crop Potential in the Upper South East*

Region of South Australia identifies a region with significant potential for a wide range of woody crop industry types and investigates the feasibility of a range of industry types at high spatial resolution.

2. Prioritisation of Regional Woody Crop Industries

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Drivers and Market Opportunities

Key drivers for the development of new woody crops

While the mitigation of dryland salinity using commercially-viable perennial plants was the primary NRM driver for our early work on developing new woody crops, the issue of climate change has recently added extra impetus. Woody crops can sequester carbon and create long-lived carbon pools in the form of soil carbon and plant biomass, both above and below ground. Furthermore, harvested biomass is a renewable resource, suitable for use as an industrial or bioenergy feedstock, which in economies with emission controls will not be subject to any carbon emissions penalty. The potential sale of sequestered carbon and the potential enhanced demand for emissions-free renewable feedstocks could provide an early extra revenue source for woody crops. This revenue accrues progressively improving the cash flow and profitability of woody crops. From the growers perspective carbon benefits might greatly exceed NRM benefits as a driver for adoption.

Hence woody production systems can yield multiple benefits for landowners including economic diversification from new products (harvested biomass, carbon sequestration) together with social and environmental outcomes. Adaptable woody species selected through the species survey described in Stage 1 and 2 of the FloraSearch project (Bennell *et al.* 2008, Hobbs and Bennell 2008, Hobbs 2008a, Hobbs *et al.* 2008c) provide robust and reliable crop options in landscapes with variable soils and climates. The integration of perennial plants into our farming systems provides productive opportunities to buffer seasonal and annual variations in rainfall that cannot be reliably utilised by annual crops alone. By increasing the mix of functional plant types in the productive landscape we can improve risk management and long-term economic sustainability. Landscape and farm-scale benefits include decreasing recharge and thus the threat of salinisation, reducing wind erosion, and providing shelter for stock. Reforestation is also a means of restoring catchment water quality, the protection of land from salinity and erosion, the enhancement of remnant biodiversity, and opportunities for rural development.

Farm forestry industries for lower rainfall regions

The competitiveness of conventional long cycle forestry is quite sharply confined by rainfall. There is potential to extend conventional forestry into lower rainfall regions, especially with some modification in site selection, species selection and planting design, but the long production cycle of these crops restricts their profitability to wetter areas peripheral to the main wheatbelt regions. In this region options based on species more tolerant of lower rainfall such as Sugar Gum are gaining some traction but scale is limited. Consequently, FloraSearch has focused on short production cycle woody crops that current economic analyses indicate could be viable across the wheatbelt. These would utilise new agroforestry systems and include short-cycle woody crops based on belts or blocks of coppice and phase crops. These crops will produce a large-scale commodity product having a low value per unit weight product and this has directed FloraSearch towards highly productive agroforestry systems and large-scale industrial approaches to product harvest and handling.

Engagement with industries that market wood based products and can utilise this new source of feedstock is an important part of the project. The potential markets and products can best be considered in 3 broad categories:

1. Existing larger scale markets that are largely commodity based, e.g. pulp and export wood chip that are well developed and have been operating for a significant period;

2. Existing smaller scale and ‘niche’ markets that are generally developed but operate on a smaller scale; and

3. Emerging markets that are still developing with supply and demand channels not well established (e.g. carbon sequestration and biofuels).

Forestry products are the largest user of woody feedstocks and early FloraSearch market evaluation considered this market to provide the most likely demand. Pulpwood production and composite board products have a huge demand for feedstock currently met from high rainfall forestry operations but opportunities exist to gain access to this market. Farm forestry could supplement existing supplies or provide resources to new mill developments.

Options have recently broadened in scope, with products related to climate change mitigation and adaptation becoming more significant particularly as a significant amount of research and development funding is being invested to bring new technology online.

The principles of producing heat, electricity and transport fuels from woody biomass are well known from early in the twentieth century and have returned to the forefront of industrial research as an alternative to fossil energy supply. Biomass as an alternative feedstock for energy and transport fuel production provides benefits in offsetting carbon release to the environment i.e. it is a renewable energy source and provides a positive multiplier of energy gained in the product over the energy that goes into producing it. Providing greater security for fuel supplies by reducing the dependence on offshore suppliers of raw materials is also considered to be strategically important, particularly in the USA. The availability of clean second-generation transport fuels is still constrained by the need to develop economically competitive industrial scale processes and this is the subject of huge investment, particularly in North America and Europe. It is forecast to be five to ten years before a large-scale industrial plant becomes available for diesel and ethanol production from woody biomass.

Strong entrepreneurial interest, stimulated by the growing commitment to reduced carbon emissions restructuring of the energy sector, is emerging in large-scale processing of biomass from woody crops grown in the wheat/sheep agricultural regions of southern Australia. Carbon sequestration in farm-forestry based projects and the substitution of fossil fuel emissions using biomass combustion provide a real and immediate opportunity to reduce net greenhouse gas emissions. Large scale planting of tree crops is already occurring in NSW where there is a legislative framework in place to support carbon cropping. Delivery contracts for carbon will have to be underpinned by solid science and auditable accounting procedures to ensure delivery. At this stage, the carbon sequestration potential of many species and woody crops productions systems are poorly understood. We need to identify the best species and options for dryland farming systems if they are to contribute to future carbon sequestration markets. Introduction of an Australian emissions trading scheme is likely in 2010, and is expected to allow carbon sequestration in trees and possibly agricultural soils, to be counted as an offset against fossil fuel emissions. Similarly, there will be a national renewable energy target of 20% by 2020 that will promote the adoption of alternative energy sources including those sourced from biomass. Recent factors in bioenergy development include: the successful conclusion of Verve Energy’s IWP (Integrated Wood Processing) demonstration in WA; investment by Willmott Forests in second-generation ethanol R&D in NSW and several developers looking in detail at the potential for exporting wood fuel pellets to Europe and Japan.

Biosequestration thus forms a major component in both national and state climate change policies in reducing net greenhouse gas emissions. For landholders, carbon investment provides a very real prospect of financing revegetation to increase farm sustainability (Harper *et al.* 2007, Shea *et al.* 1998). Bioenergy from woody crop residues offer a direct means of reducing carbon dioxide levels and has been pursued in several projects including the Narrogin IWP plant (Enecon 2001) based on mallee residues.

The potential of forage production from woody species has been highlighted during the FloraSearch project. The potential of shrub based forage systems is gaining acceptance as a means of providing options that Provide a feed base made up of a functional mixture of plant species including shrub options that: are resilient to prolonged dry periods and provide feed in periods of seasonal shortfall; integrate into a productive livestock enterprise based on current pasture options but are of a sufficient scale to have a positive impact on land management issues; and provide the opportunity to include a plant in a mixed assemblage that provide compounds of medicinal value, or compounds that have favourable effects on gut health.

Woody crop production systems

Future research will provide improved plant production systems and in the future harvest methods to meet emerging markets. However, the question remains as to where to place these new systems in highly variable landscapes and how to optimise returns taking into account the land resource, existing land-uses and new crop options. Economic evaluation of new crop opportunities also requires reliable estimates of productivity (harvestable yield and carbon accumulation in plant biomass and soil profiles) and this will be related to regional and local variation in site conditions. Economic analysis needs to include all of the direct tangible costs and benefits discounted to present values over a long enough block of time to see whether large initial costs are exceeded by later revenues. This can be applied to alternative uses for the land in question such that the best option can be selected, thereby dealing with the issue of land opportunity cost. These scenarios can be evaluated using software tools, such as ‘Imagine’ (Abadi *et al.* 2005, Cooper *et al.* 2005) to explore optimal combinations of woody crops and annual cropping/grazing systems at the enterprise level.

The challenge of optimising landowner returns whilst adopting new crop options is a fundamental issue. Through a better understanding of the optimal productive arrangement of annual and woody crops in a farming enterprise issues of competition with woody crop options can be avoided and reduce opportunity costs to existing landuses. It is crucial to compare economic returns of new systems with those from existing annual crops/pastures so that the most profitable option is applied at any point.

Mallees are being extensively planted into belts through cropping areas particularly in WA. An investigation of the economics of belts in crop systems (Cooper *et al.* 2005) showed that for the mallee crop to break even with conventional annual plant agriculture belt designs would need to efficiently exploit lateral flows of surface and shallow surface water to achieve sufficient yield. However, we must be vigilant of the delicate balance between annual crop leakage of water that benefits neighbouring woody crop belts and the potential reduction in annual crop performance in areas adjacent to belts and windbreaks (Jones and Sudmeyer 2002, Bennell and Cleugh 2002, Cleugh 2003). There appears to be considerable potential to manipulate water sources and sinks to capture extra water to achieve a 20% yield increase. Lateral flows of shallow subsurface water can be captured by belts or on the surface by grade banks and diverted to belts or small block plantings.

Climate change and carbon sequestration

On March 11, 2008 the Australian Government ratified Kyoto Protocol for greenhouse emissions and their commitment to the global greenhouse treaty becomes effective on June 9, 2008 (DCC 2008a). The Australian Government also delivered its ‘Initial Report’ under the Kyoto Protocol earlier than required to the United Nations, which details how Australia intends to measure its emission reductions (DCC 2008b). A key part of this initial process is the development of a national carbon accounting system in measuring emissions from land use, land-use change and forestry.

In February 2008 the Australian Prime Minister, Kevin Rudd, tabled in Parliament a report which projected Australian annual emissions at 559m tonnes over 2008-12, the equivalent of its Kyoto target of 108 per cent of 1990 levels, and that recent projections suggest that Australia would miss its Kyoto target by 5.5m tonnes due to the inactivity of the previous Coalition Australian government.

Following the release of the May 2008 Federal Budget the Australia government announced $2.3 billion in funding to tackle climate change through initiatives across government over four years. This includes a $1 billion commitment to encourage solar hot water, solar panels and energy efficiency schemes, the introduction of household "green loans", and funding for a better access to Government environment initiatives. $260 million also has been allocated to Australian businesses to reduce their impact on the environment largely through the Clean Business Australia initiative (AusIndustry 2008).

The Clean Business Australia initiative includes:

- A $75 million Re-Tooling for Climate Change competitive grants program, which will complement other measures by supporting Australian manufacturers to improve their production processes, reduce their energy use and cut carbon emissions.

- A $90 million Green Building Fund, which will offer assistance for energy-efficient retro-fitting of existing buildings and support for training initiatives to improve the skills of building operators.

- A $75 million Climate Ready competitive grants program, which will encourage Australian businesses to develop and commercialise products, processes and services that save energy and water, reduce pollution and use waste products in innovative ways.

Other budget initiatives include:

- $130.0 million to Australia’s Farming Future to deliver the Climate Change and Productivity Program, the Climate Change and Adaptation Partnerships Program, and the Climate Change Adjustment Program;

- $15.5 million to administer the 20 per cent renewable energy target by 2020 - a target which is due to start increasing in 2009; and

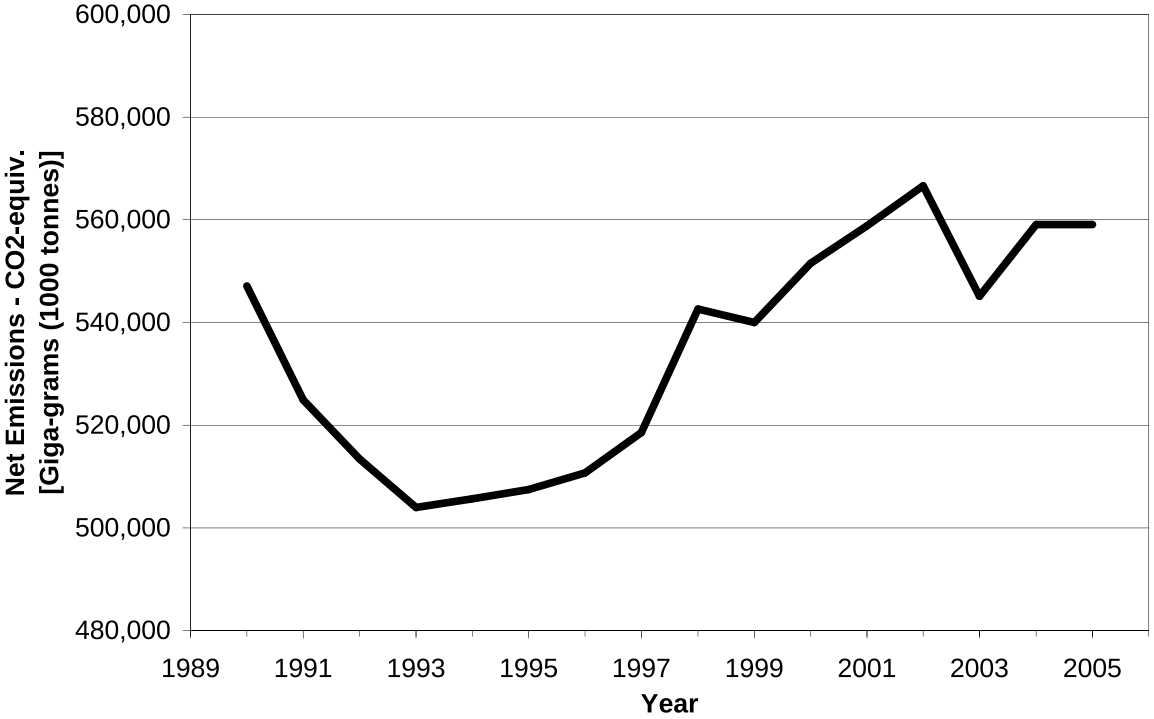
- $8.0 million for Australia’s forestry industry to better prepare for climate change by the development of a Forestry Adaptation Plan and an assessment of capacity for forests to sequester carbon.

Table 1. Kyoto Accounting - Australian carbon dioxide equivalent emissions by sector in 2005.

Sector	Giga-grams (1,000 Tonnes)
Total Kyoto	**559074**
Energy	**391019**
Fuel Combustion	359792
Fugitive Emissions From Fuels	31228
Industrial Processes	**29463**
Mineral Products	5641
Chemical Industry	938
Metal Production	12791
Consumption of Halocarbons and Sulphur Hexafluoride	4773
Other	5321
Solvent and Other Product Use	**0**
Other	0
Agriculture	**87889**
Enteric Fermentation	58678
Manure Management	3434
Rice Cultivation	216
Agricultural Soils	16558
Prescribed Burning of Savannas	8650
Field Burning of Agricultural Residues	352
Land Use, Land-Use Change and Forestry KP	**33667**
Afforestation and reforestation	-19609
Land use change (deforestation)	53276
Waste	**17037**
Solid Waste Disposal on Land	14742
Wastewater Handling	2266
Waste Incineration	28

Source: Australian Greenhouse Office (2008).

Fig. 2. Kyoto Accounting - Net Australian carbon dioxide equivalent emissions since 1990.



Source: Australian Greenhouse Office (2008).

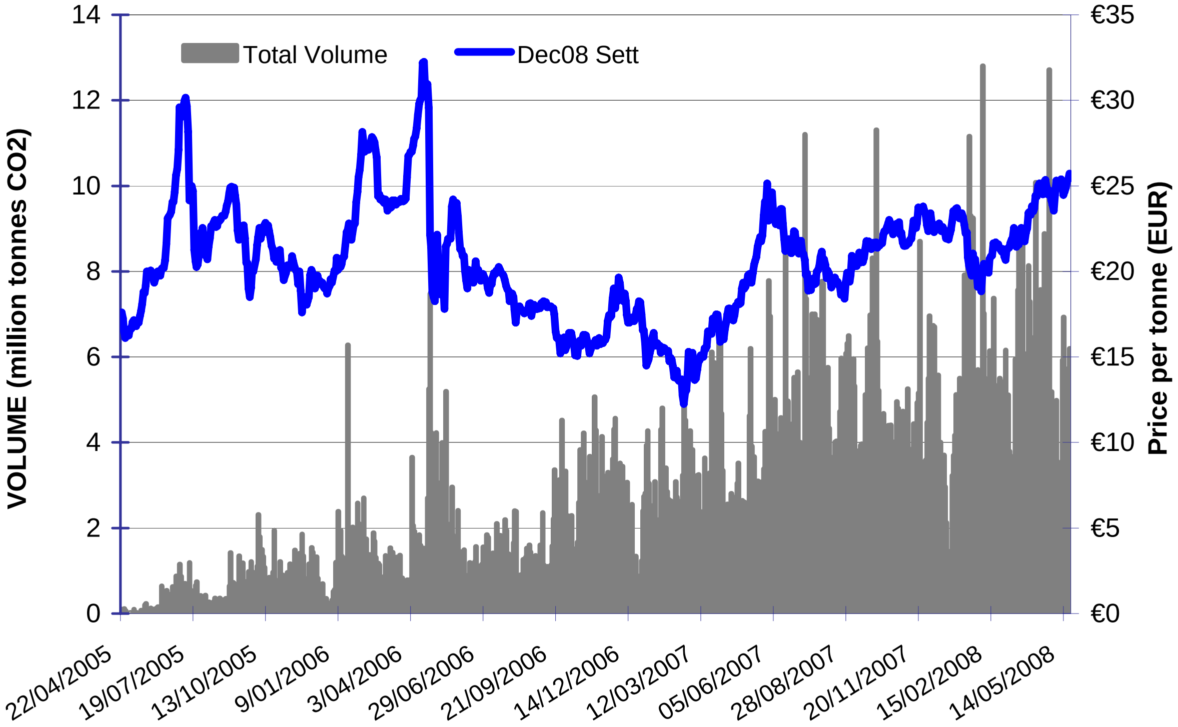
The potential for carbon trading has become a significant factor in evaluating the economics of long-term perennial vegetation as permanent sinks but there is also increasing interest in the carbon stores held in harvested perennial crop systems such as classical forestry and other shorter rotation agroforestry crops. European emissions trading have been active since early 2005 and have since traded well over 2,000 million tonnes of CO_2 equivalents (ECX 2008, Fig. 3). Current December 2008 ECX Futures (ECX 2008, 21/05/2008) are priced at €25.73/t CO_2-e (Fig. 3). However, spot price trades (non-futures) values have been highly variable in recent years and was below €5.00/t CO_2-e for all of 2007 with a strong rebound in April 2008 (ICE 2008).

In Australia, the carbon trading market has yet to fully take off, but NSW has mandated carbon emissions controls and other state governments and private corporations are already gearing up for carbon trading. The NSW Greenhouse Gas Abatement Scheme (NGGAS) certificate price (NGAC) was A$11.50 per tCO2-e of greenhouse shortfall in July 2007. NSW government projections expect the price to raise to A$15.50 by 1 January 2013, however, spot price NGAC trades in the last 2 months have been stable at just under A$7.00 (NSW GGAS 2008).

The National Emissions Trading Taskforce, a joint state and territory initiative to create an Australian emission trading schemes was particularly active in 2007 (then without Federal Government support). With change in Australia Federal Government in late 2007 the concept has now been adopted by the Australian Government. In early 2008, the Australian Prime Minister, Kevin Rudd confirmed the intent to establishing a national emissions trading scheme by 2010 in Australia (DCC 2008b) and setting a 20 per cent target for renewable energy use by 2020 to drive demand for use of renewable energy sources such as solar and wind.

If future Australian emission trading values approximate those of the current European system it is likely that carbon sequestration with woody biomass or offset using renewable biomass energy will be economically viable for revegetation in some landscapes and regions Additionally, commercial woody crops may also include the average standing biomass of these crops as a carbon sequestration value, or even the long term carbon stored in the roots and accumulated soil carbon of these crops, as a contributor to the economic value of these perennial farming systems.

Fig. 3. The European Carbon Exchange (ECX) settlement price and volumes in recent times.



Source: ECX (2008).

Natural resource management

The natural resources of lower rainfall regions of southern Australia provide the backbone of a diverse range of ecosystems, agricultural pursuits, industries and communities. However, many regions are significantly affected by the natural resource management issues of dryland salinity, soil stability and fertility, altered hydrological balances, water quality and ecosystem fragmentation or degradation. The loss of perennial vegetation cover has contributed substantially to these natural resource management issues and it is well recognised that there is a role for agroforestry, perennial farming systems and habitat re-creation to alleviate some of these problems. Woody crop industries can provide both environmental services and economic opportunities through the development of commercial revegetation in southern Australia.

In Australia, approximately 57 million hectares of land are currently used for annual cropping and modified pastures and >200 million hectares of livestock grazing on semi-natural pastures (BRS 2004). There is huge potential for the greater use of sustainable and resilient woody biomass crops. Leakage of water from the current cropping/grazing farming systems contribute significantly to groundwater recharge in many areas. In some regions this recharge and rising water tables is undesired as it can promote salinisation processes. Plantations of woody crops on these landscapes would virtually eliminate recharge, greatly reduce the progression of dryland salinity, reduce wind erosion risk and provide additional biodiversity benefits. Additional benefits would also be gained from atmospheric carbon dioxide sequestration. The ability of woody crop system to sequester atmospheric carbon dioxide to help ameliorate this climate change driver is now being recognised widely in the community. There is currently strong international and Australian support to minimise atmospheric carbon dioxide and many emission and carbon trading schemes are being developed that support the use of perennial woody crops and revegetation for this purpose.

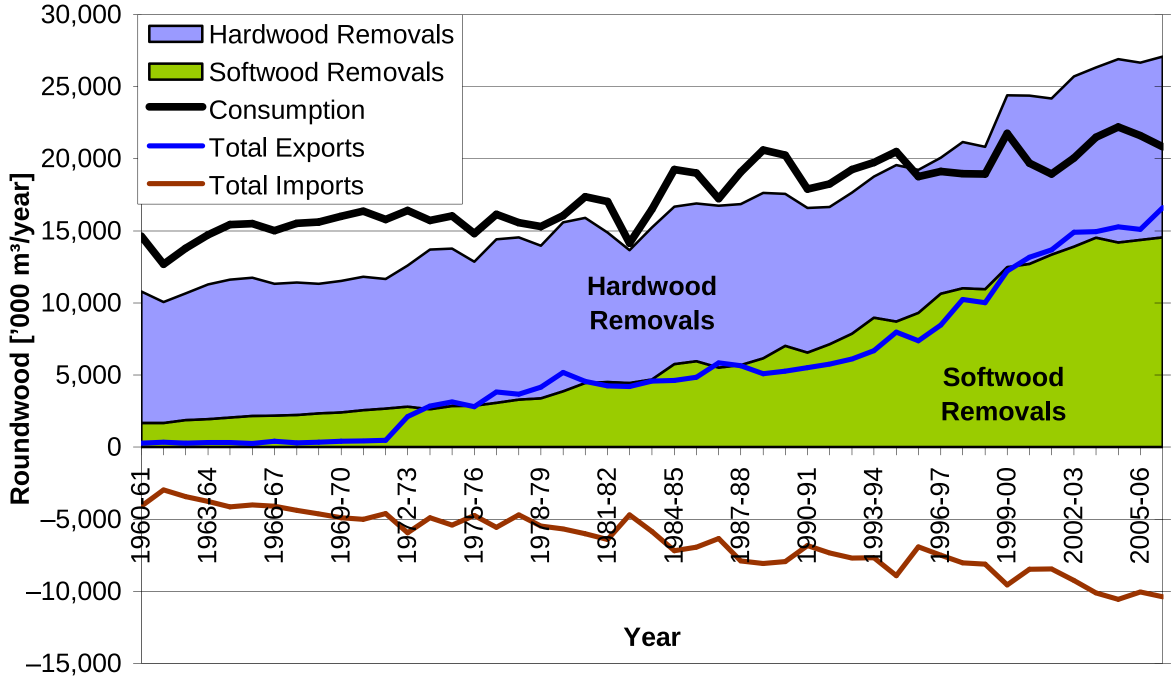
FloraSearch investigates opportunities for a diverse range of woody biomass industries that can potentially service the region. Some industry types, such as fodder shrubs for livestock, pulpwood and firewood, already exist in the region and could be significantly expanded with little or no new investment in industrial infrastructure. New industries based on bioenergy and *Eucalyptus* oil or combined in an Integrated Tree Processing plant (e.g. Narrogin WA oil mallee plant) has strong potential in the region but may require significant investment in new infrastructure to proceed. Measurement and ranking of the intensity and impact of natural resource management issues that influence landscape and environmental health, and woody crop commercial viability can be used to identify which regions and districts would most benefit from investments in woody perennial crops.

Wood fibre industries

The Australian Bureau of Agricultural and Resource Economics (ABARE) regularly produce summary statistics on the nature, volume and value of Australian wood production, imports and exports (ABARE 2004, 2007, 2008a). Australian forest industries consume around 21 million cubic metres of broad-leaved hardwood and coniferous softwood logs every year to produce lumber, paper products and panel products for Australian and export markets (see Fig. 4, Fig. 5, Table 2). Approximately 67% of this consumption is based on softwood coniferous forests (mainly Pinus spp.) with the remainder mainly based on hardwood Eucalyptus species. Additionally, the export of pulpwood chips consumes around 6 million tonnes of chips mainly from hardwood Eucalyptus species (4.9 million tonnes, see Fig. 6).

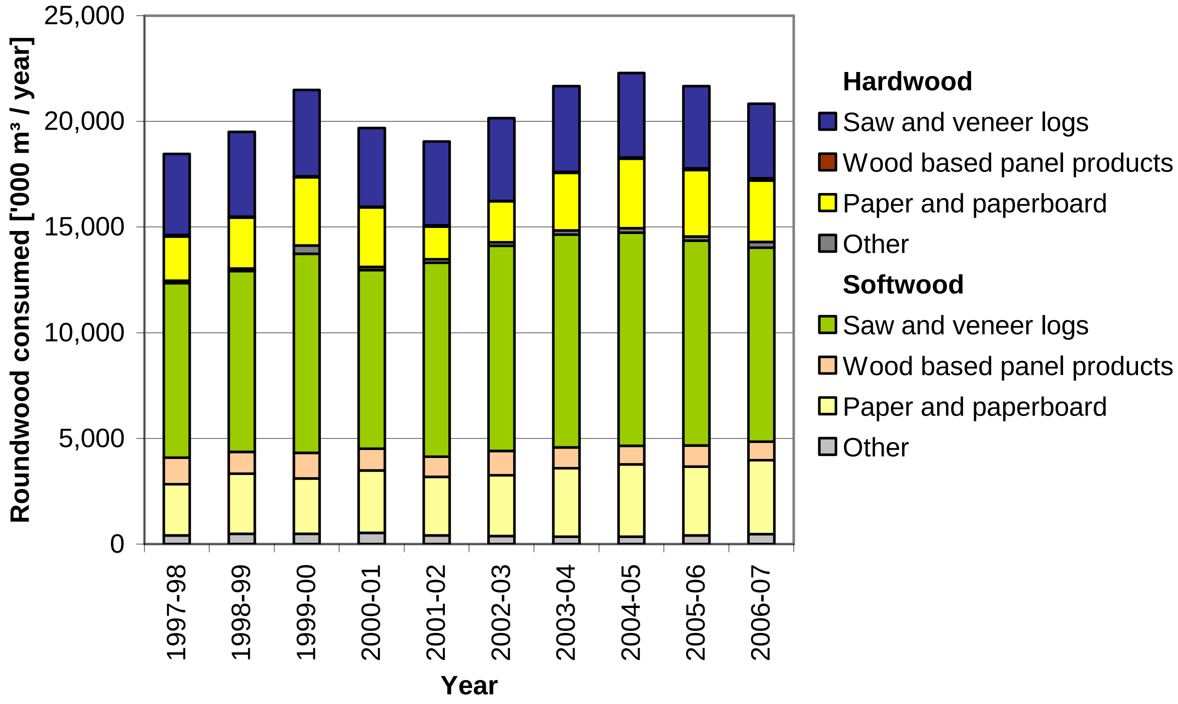
Focussing on the paper and paperboards, fibreboards and particleboards (part of the wood based panel products sector), and woodchip components of that data, we can provide an indication of the scale and value of those market sectors within the current Australian forestry industry. These markets provide opportunities for new industry development in low rainfall zones to supplement or expand capacity in existing industries and markets. The paper and paperboard manufacturing industries consume the largest share by value of wood fibre supply in Australia, followed by woodchip exports and secondary paper manufactures (e.g. boxes etc.). In 2006-07 Australian wood panels, paper and paperboard products consumed 3.0 million cubic metres of hardwood timber and 4.4 million cubic metres of softwood timber. Over the last 5 years the volume of hardwood logs consumed by Australian forest industries has grown by 55% and softwood logs by 9% (24% combined).

Fig. 4. Historical volumes of roundwood harvested, consumed, exported and imported by forest industries in Australia (financial years ending 1961 to 2007).



Source: ABARE 2007

Fig. 5. Volumes of forestry roundwood consumed by Australian industry product groups in recent years.



Source: ABARE 2008a

Fig. 6. Australian hardwood and softwood export chip quantities.

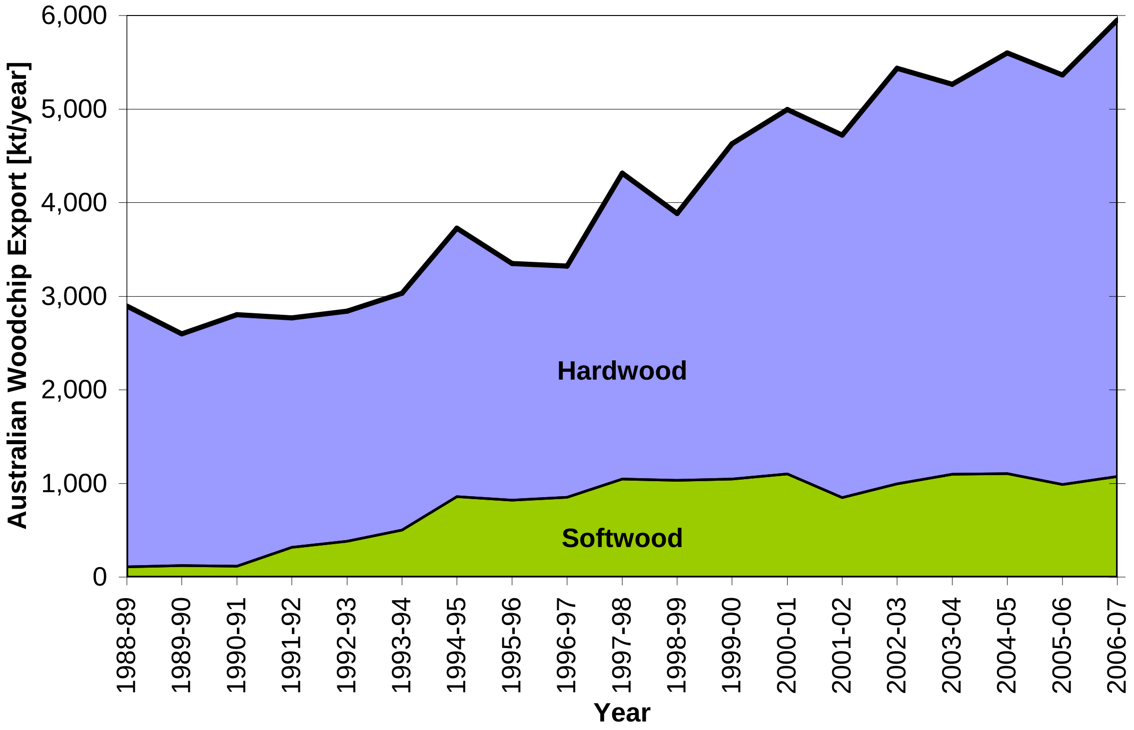
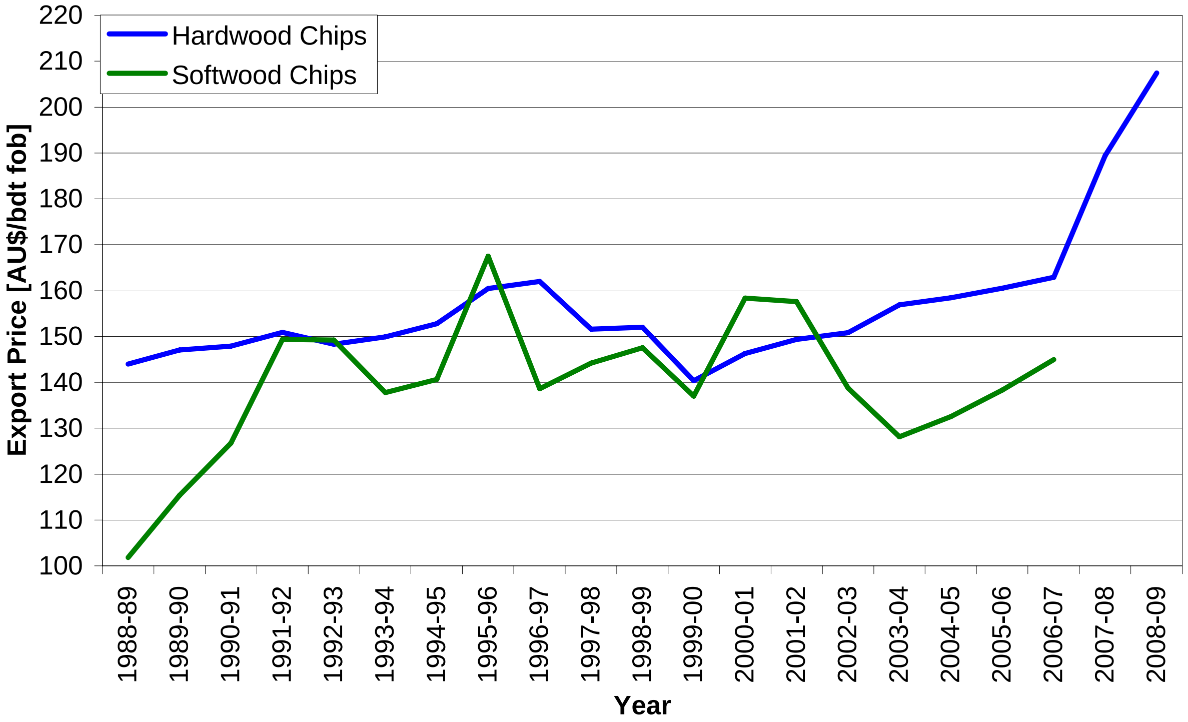


Fig. 7. Australian hardwood and softwood export chip prices.



Source: ABARE (2007), Great Southern Ltd (2008)

Table 2. Volumes of roundwood consumed by Australian forest industries in recent years.

Roundwood consumed ['000 m³/year]	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
Hardwood (broad-leaved)							
Saw and veneer logs	3734	3965	3920	4056	3998	3905	3519
Wood based panel products	18	54	19	55	63	75	114
Paper and paperboard	2830	1551	1931	2720	3288	3139	2904
Other	144	171	173	193	206	208	266
Total	**6726**	**5741**	**6043**	**7024**	**7555**	**7327**	**6803**
Softwood (coniferous)							
Saw and veneer logs	8457	9167	9713	10071	10082	9686	9177
Wood based panel products	1023	952	1143	990	889	1004	890
Paper and paperboard	2955	2771	2879	3244	3420	3243	3489
Other	528	415	377	343	347	415	472
Total	**12963**	**13305**	**14112**	**14648**	**14738**	**14348**	**14028**
Hardwood and Softwood							
Saw and veneer logs	12192	13132	13633	14127	14079	13591	12696
Wood based panel products	1042	1006	1162	1045	652	1079	1004
Paper and paperboard	5785	4322	4810	5964	6708	6383	6393
Other	672	586	550	537	553	623	738
Total	**19691**	**19046**	**20155**	**21673**	**21992**	**21676**	**20831**

Sources: ABARE 2004, 2008a

Table 3. Australian production, trade and consumption of fibre/particle panel products in recent years.

Volume ['000 m³/year]	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
Production							
Particleboard	904	965	1025	1048	944	1002	933
Medium density fibreboard	712	732	786	795	794	798	680
Total	**1617**	**1697**	**1811**	**1843**	**1738**	**1800**	**1613**
Imports							
Particleboard	44	70	93	60	65	37	77
Hardboard	8	7	8	13	22	30	44
Medium density fibreboard	88	81	77	47	28	52	21
Softboard and other fibreboards	33	20	16	8	12	14	14
Total	**174**	**179**	**194**	**128**	**127**	**133**	**156**
Exports							
Particleboard	98	100	54	32	14	14	18
Hardboard	7	10	8	12	8	7	6
Medium density fibreboard	389	403	405	357	365	352	260
Softboard and other fibreboards	14	11	27	18	15	11	5
Total	**508**	**524**	**495**	**419**	**401**	**385**	**289**
Consumption							
Particleboard	850	935	1063	1077	995	1025	992
Medium density fibreboard	411	411	458	485	457	497	441
Total	**1262**	**1346**	**1521**	**1561**	**1453**	**1522**	**1433**

Source: ABARE 2007

Table 4. Australian production, trade and consumption of paper products, and woodchip exports in recent years.

Quantity [kt/year]	**2000-01**	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**
Production							
Newsprint	465.0	395.0	412.0	422.0	443.0	415.0	411.0
Printing and writing paper	554.0	624.0	564.0	585.0	659.0	663.0	676.0
Household and sanitary	204.0	198.0	194.0	200.0	197.0	217.0	204.0
Packaging and industrial paper	1449.0	1679.0	1892.0	1956.0	1945.0	1926.0	1901.0
Total	**2672.0**	**2897.0**	**3061.0**	**3164.0**	**3244.0**	**3221.0**	**3192.0**
Imports							
Newsprint	283.9	224.2	273.3	303.5	314.0	324.5	262.5
Printing and writing paper	765.0	842.3	973.1	1101.9	1189.7	1140.1	1173.5
Household and sanitary	54.8	55.9	66.7	84.6	77.9	87.9	101.8
Packaging and industrial paper	306.2	212.9	152.7	159.5	184.1	190.8	258.4
Total	**1409.8**	**1335.4**	**1465.8**	**1649.5**	**1765.7**	**1743.4**	**1796.2**
Exports							
Newsprint	2.6	12.2	3.5	0.7	1.7	0.2	0.2
Printing and writing paper	79.3	297.1	200.2	160.3	174.9	147.0	131.7
Household and sanitary	24.6	43.4	55.1	36.2	37.1	31.6	32.5
Packaging and industrial paper	390.4	384.7	483.5	596.8	568.7	632.2	640.5
Total	**496.9**	**737.4**	**742.3**	**794.0**	**782.4**	**811.0**	**804.8**
Woodchip Exports							
Hardwood (broad-leaved)	3893.7	3872.1	4442.3	4165.1	4493.9	4374.4	4880.4
Softwood (coniferous)	1100.4	848.6	994.8	1098.8	1104.5	989.0	1072.0
Total	4994.1	4720.7	5437.1	5263.9	5598.3	5363.4	5952.4
Total consumption							
Newsprint	746.3	607.0	681.8	724.8	755.4	739.3	673.3
Printing and writing paper	1239.7	1169.3	1336.9	1526.5	1673.8	1656.1	1717.8
Household and sanitary	234.2	210.5	205.6	248.4	237.8	273.4	273.3
Packaging and industrial paper	1364.8	1507.2	1561.2	1518.7	1560.5	1484.6	1519.0
Total	**3584.9**	**3495.0**	**3784.5**	**4019.5**	**4227.3**	**4153.4**	**4183.4**
Consumption per person [kg/year]							
Newsprint	38.4	30.9	34.3	36.1	37.1	35.7	32.0
Printing and writing paper	63.9	59.5	67.3	76.0	82.3	80.0	81.8
Household and sanitary	12.1	10.7	10.3	12.4	11.7	13.2	13.0
Packaging and industrial paper	70.3	76.7	78.6	75.6	76.7	71.7	72.3
Total	**184.7**	**177.9**	**190.4**	**200.1**	**207.8**	**200.6**	**199.1**

Source: ABARE 2007

Table 5. Value of wood product exports and imports in Australia in recent years.

Exports Value [$m/year]	**2000-01**	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**
Roundwood	66.84	89.14	106.86	113.66	72.56	82.36	117.38
Sawnwood	62.46	70.48	70.42	74.10	101.59	120.96	145.30
Railway sleepers	9.03	6.57	4.40	4.21	3.99	3.70	4.63
Miscellaneous forest products	77.56	61.82	58.01	64.38	74.43	68.74	62.54
Veneer	8.56	8.87	7.53	8.30	6.02	6.53	5.80
Plywood	3.28	5.89	3.07	3.69	5.88	4.71	2.69
Particleboard	26.49	26.66	17.41	11.26	6.35	6.23	6.45
Hardboard	10.63	5.99	4.08	5.99	4.71	4.97	3.73
Medium density fibreboard	150.56	162.43	145.57	112.45	118.89	120.95	96.87
Softboard and other fibreboard	7.81	6.60	10.15	9.48	11.55	9.65	2.75
Paper and paperboard	459.31	612.92	630.16	634.89	626.86	601.08	650.50
Paper manufactures c	175.32	189.81	173.13	148.88	126.43	125.10	111.61
Wastepaper	39.83	55.62	49.87	52.66	96.74	140.13	175.05
Pulp	4.55	2.84	2.12	1.37	4.40	5.48	12.04
Woodchips	743.80	711.99	807.95	794.44	858.24	839.04	950.30
Exports Total	**1846.04**	**2017.63**	**2090.74**	**2039.75**	**2118.66**	**2139.61**	**2347.62**

Imports Value [$m/year]	**2000-01**	**2001-02**	**2002-03**	**2003-04**	**2004-05**	**2005-06**	**2006-07**
Roundwood	0.92	0.71	1.75	1.12	1.03	0.41	0.60
Sawnwood	427.67	442.51	504.68	501.89	492.03	419.38	418.38
Railway sleepers	0.00	0.00	0.00	0.10	0.00	0.00	0.00
Miscellaneous forest products	461.51	528.05	589.31	583.48	586.09	527.57	567.85
Veneer	22.91	22.28	25.96	23.06	24.35	24.91	31.48
Plywood	65.75	81.90	114.30	113.03	128.56	133.58	167.03
Particleboard	13.77	18.74	21.51	17.19	24.45	13.68	26.19
Hardboard	5.52	7.06	5.97	10.68	18.83	27.35	35.16
Medium density fibreboard	34.73	31.73	29.39	22.90	14.99	21.62	12.08
Softboard and other fibreboard	9.71	8.25	8.92	3.45	4.92	7.08	7.15
Paper and paperboard	2088.01	2029.77	2158.35	2136.70	2184.10	2187.03	2270.50
Paper manufactures	377.50	354.28	362.73	340.66	395.78	425.80	469.51
Wastepaper	8.84	4.56	8.00	4.69	2.32	1.46	2.26
Pulp	316.65	221.26	253.74	235.09	225.06	225.03	265.17
Pulpwood	1.43	1.20	1.54	1.41	2.00	2.10	1.48
Imports Total	**3834.91**	**3752.31**	**4086.17**	**3995.43**	**4104.50**	**4016.99**	**4274.84**

Source: ABARE 2007

Energy

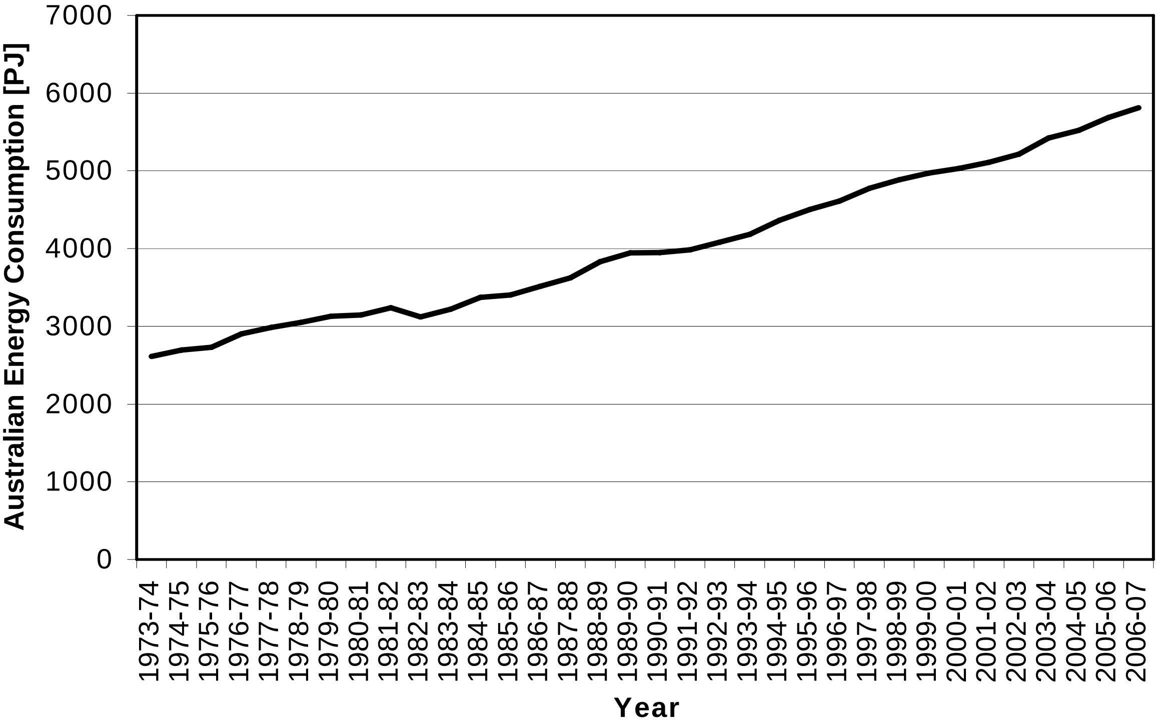
Australia's has significant resources of liquid petroleum, natural gas, coal and uranium and is a net energy exporter. Since 1986, it has been the world's largest exporter of coal and in the last 9 years has emerged as one of the largest exporters of liquefied natural gas (LNG) and uranium. However, Australia is a net importer of liquid fuels, including crude oil and refined petroleum products, such as petrol, diesel and fuel oil. The value of Australia's energy exports has grown by 5% annually since 1986 to around $38 billion in 2006-07; equally our energy imports have also grown in the same time and were worth $22 billion in 2006-07. Total domestic consumption of energy in Australia is consistently increasing and is expected to be 5,941 Petajoules for 2007-08 (see Fig. 8). Domestic energy consumption is dominated by coal for electricity generation and metal refineries. Liquid fuel industries also require significant amounts energy for petrochemical extraction, processing, refining and transport.

The value of most energy commodity exports and imports is expected to rise over the medium term to longer term as demonstrated by recent record thermal coal (A$139/t) and crude oil prices (US$130/barrel = A$125/barrel, 22/05/2008) in recent months.

Historically, firewood was a common source of fuel for many purposes, especially in household heating. It is still widely used for domestic heating but at lower levels than decades ago. In the last 10 years there have been significant improvements in wood fire heater efficiencies and pollution levels. We would expect the use of firewood will persist for warming homes, especially in rural and urban fringe areas, however, we can expect that firewood, briquettes and wood pellets will gain momentum and value as a replacement for expensive fossil fuels in the future.

More detailed discussions of bioenergy prices and markets are given in Section 4 '*Case Study 1: Woody Bioenergy Crops Woody Bioenergy Crops for Lower Rainfall Regions of Southern Australia*' of this report.

Fig. 8. Primary energy consumption across all energy sectors in Australia (1973 to 2007).



Source: ABARE (2008b).

Industrial carbon (coal, carbonised wood and charcoal)

The refining of metal oxides requires carbon as a reducing agent. Coke, a derivative of coal, is currently the major source of carbon used for metal refining. The steel industry in Australia consumes around 4.2 million tonnes of black coal for this purpose (ACA 2006). Australian exports of metallurgical coal are significant, at around 132 million tonnes per year and at a price of $114/tonne in 2007. This rate has been increasing in recent years (Table 6). High demand for coking coal for steel production is likely to drive the price up further and some forecasts suggest the price will be approach $280/tonne in the near future.

Table 6. Recent historical, and predicted, volumes and values of Australia metallurgical coal exports.

Recent Years	Unit	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
Volume	Mt	105.5	105.8	107.8	111.7	124.9	120.5	131.9
Value	A$m	7331	8688	7810	6671	10588	17003	15035
Unit value	A$/t	69.49	82.10	72.45	59.72	84.78	141.13	113.98

(Source: ABARE 2008)

The interest in the use of renewable sources of carbon for mineral processing is increasing. In Australia some mining companies have been exploring the potential of renewable carbon for metal refining. Coal is also used extensively in cement manufacture and uses about 0.9 million tonnes per year (ACA 2006). The current developed world traded market for wood charcoal is approximately 1 million tonnes/year (OMC 2006).

Steam treatment of charcoal is used to create the highly valued activated carbon. The special property of activated carbon is its ability to preferentially absorb chemicals, ions and odours. A property utilised widely for water treatment, gold recovery and in the food and beverage industries. The world market for activated carbon is around 700,000 tonnes/year (140,000 tonnes/year for water treatment alone) and is currently increasing by about 4-5% each year (OMC 2006). Australian markets for activated carbon (excluding gold refining) are approximately 3,000 tonnes/year and is conservatively worth an estimated $1,800/tonne.

The metallurgical industry faces increasing pressure to reduce emissions of greenhouse gases (GHG) from production of metals. The substitution of fossil carbon by renewable carbon from biomass has the potential to radically reduce the net carbon emissions from metallurgical processes. The high reactivity and low sulphur content of charcoal makes it an attractive metallurgical reductant. The extent of substitution that is technically possible depends on the process. For example, in blast furnace iron making, perhaps 20% of the fossil carbon in coke could be replaced by renewable carbon as an injectant, due to the need to maintain a strong and coherent coke bed in the furnace. On the other hand, in new technologies such as bath smelting (e.g. HIsmelt) which use granular carbon rather than lump size high strength coke, potentially all of the fossil carbon could be replaced by renewable carbon. It may also be possible to substitute charcoal for coal in other processes such as synthetic rutile production in rotary kilns where high reactivity is beneficial and the strength of the carbon is less critical. This opens up a large potential range of markets for wood carbons as reductants.

The economics of replacing coal by charcoal poses a significant challenge. Using a reported charcoal cost of A$435/t and a thermal coal price of A$100/t, it was estimated that the production cost of pig iron would increase by about A$234/t in completely changing from coal to charcoal, assuming that there were no significant increases in capital cost in making this change. This increase would represent an approximate doubling in the cost of pig iron. In order for charcoal to be competitive with coal the following potential advances would need to be developed: recognition of the value of carbon emission reduction and other potential environmental credits; development of more sophisticated charcoal production processes to utilize potential co-products such as bio-oil and waste heat; and the use of lower value woody biomass fractions for charcoal production.

There is potential to greatly reduce the charcoal cost and to increase the reactivity of the charcoal by using the twig and leaf fraction of mallee biomass. This raw material at ~$10 green tonne could be readily converted to charcoal at <$100/tonne and be much more competitive than coking coal at >$114/tonne.

Eucalyptus oil and other extractives

Eucalyptus oil

The increased cost of petrochemical-based solvents and adhesives resulting from sustained higher world oil prices, and the declining use of more carcinogenic adhesives and preservatives (eg. formaldehyde) used in composite wood manufacturing has resulted in an improvement of market potential and price of many biomass extractives in local and international sectors. ABARE (2004, 2008, see Table 7) reports on the high import and export value of wood and biomass extractives, and the stable demand for essential oils and the demonstrated increasing value trend of lacquers, gums and resins in Australian exports and imports.

The reported world market consumes around 3000 tonnes/year of Eucalyptus oil (mainly cineole), which is mainly produced in China, Portugal and India (OMC 2006). However, Australian production is ~7% (200 tonnes) of the world's production and is primarily destined for specialty fragrance markets. It appears there is a currently a high demand for oil volumes and production levels appear to be increasing. Good growing conditions in China in 2005 has put forecasts of Chinese *Eucalyptus globulus* oil production in 2006 at 4500 tonnes with an expectation of prices remaining stable (FDL 2006). The cineole component of Eucalyptus oil is well recognised for its degreasing and solvent properties. Large potential markets exist for this purpose after the implementation of measures to eliminate the use of the petrochemical based Trichloroethane, an ozone depleting chemical, during the

1990s. Other essential oils extracted from Eucalyptus leaves are very highly prized for their medicinal, antifouling and other properties which would attract premium prices in niche markets. In 2006, *Eucalyptus globulus* oil was valued at A$7.52/kg (George Uhe 2008; US$4.40/kg using US dollar exchange rate of 0.5850, RBA 29/03/2006), Eucalyptol (cineole 99.5%) at A$11.11/kg (US$6.50/kg) and Brazilian *Eucalyptus citriodora* oil at A$12.82/kg (US$7.50/kg).

In February 2008, *Eucalyptus globulus* oil was valued at A$6.76/kg (George Uhe 2008; US$6.40/kg using US dollar exchange rate of 0.9466, RBA 29/02/2008), Eucalyptol (cineole 99.5%) at A$8.66/kg (US$8.20/kg) and Brazilian *Eucalyptus citriodora* oil at A$12.09/kg (US$11.45/kg). The local prices were notably influenced by international exchange rates. However, specialised Eucalypt oil lines, such as Australian blue mallee, (see Fig. 9) can attract significantly higher trade values.

Other extractives

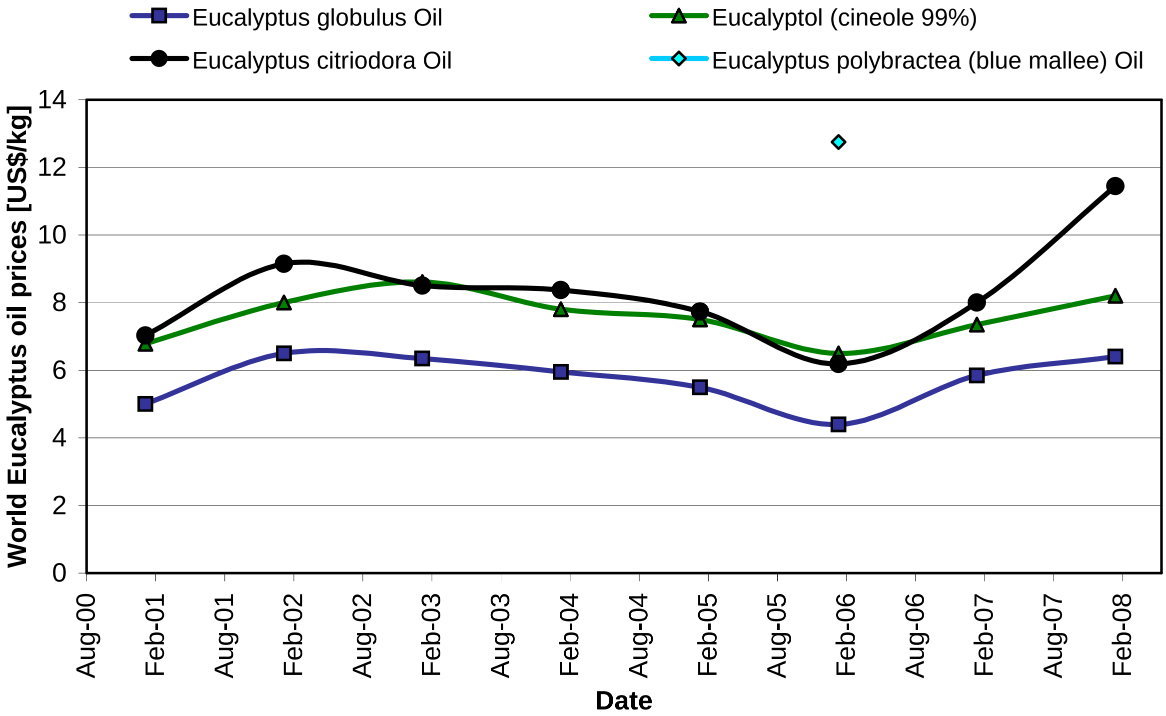
There are probably many chemicals that might be commercially extracted from large volume biomass feedstocks. The FloraSearch project recognises the potential economic importance of additional revenue that might accrue from being able to extract an additional product. One class of chemicals has emerged in recent years that occur in the leaves of many species of *Eucalyptus* called formylated phloroglucinols compounds (FPCs). One such compound called sideroxylonal has been shown to have potent anti-fouling properties when applied to the hulls of ships. One of the main mallee species used in WA *Eucalyptus loxophleba* spp. *lissophloia* has been shown to have the highest recorded content of sideroxylonal. Sideroxylonal content is strongly correlated with eucalyptus oil content. It is not steam extractable and would need a separate process but it appears that such a step could be readily incorporated into an integrated process.

Table 7. The value of extractives and other miscellaneous forest products.

Miscellaneous forest products value [$'000]	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
Exports							
Lac, gums, resins etc	1901	2348	1148	1918	9800	5149	1780
Eucalypt oils	1981	2175	1783	2965	2024	2293	1967
Rosins and wood tar	638	533	398	73	23	62	186
Fuelwood	1853	23	20	2003	32	9	18
Wood charcoal	1342	2068	2070	2655	3470	3587	1967
Imports							
Lac, gums and resins	6289	7998	8307	7288	10128	7977	9819
Essential oils	10839	10437	12750	11391	11066	10761	10111
Rosins and wood tar	251	151	97	87	34	100	87
Fuel wood	65	75	79	40	69	28	54
Wood charcoal	354	276	287	590	806	681	1651

Source: ABARE (2005a, 2007)

Fig. 9. Trends in world market prices of Eucalyptus oils in recent years.



Source: George Uhe (2008)

Fodder industries

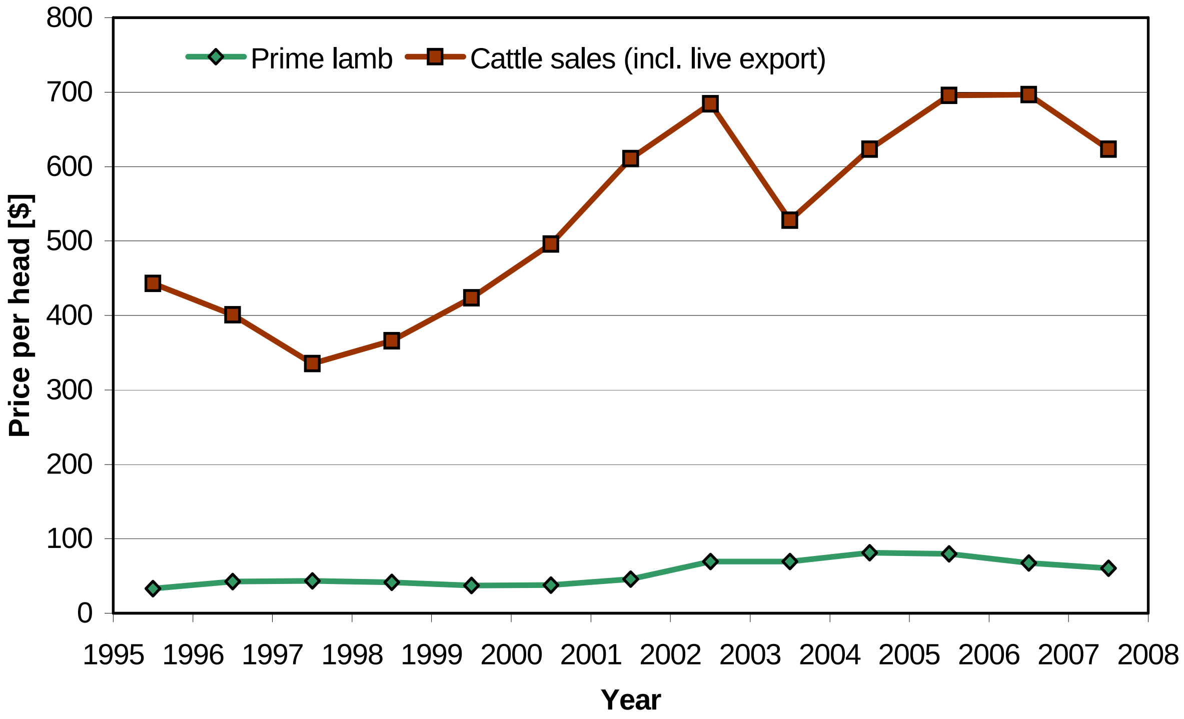
There are several broad segments of Australian fodder industries, including on-farm meat production, on-farm wool production, feedlot production of meat and livestock feed manufactures. All these segments required a primary resource of livestock fodder, which is presently based on predominantly annual crops of pasture and cereals. However, some herbaceous perennial plant species (predominantly lucerne) are widely utilised, and highly valued, for their provision of green feed or nutritious hay for dry season fodder in the paddock or as a feedlot resource.

On-farm meat and wool

Gross value of Australian farm production for livestock slaughtering and production was approximately $17.8 billion dollars in 2004-05 (MLA 2006), based on herds of 102.7 million sheep and lambs, and 27.7 million cattle and calves. The Australian red meat market has strengthened in recent years. The strong demand has generally driven up livestock and meat prices (Fig. 10).

The number of sheep currently shorn for wool in Australia (106 million head in 2004-2005, AWI 2006) has decreased by around 32% since 2000-01 (140 million head). Australian Wool Innovation forecasts the 2005-06 shearings will be approximately 106 million head producing around 456 million kilograms of greasy wool. An offset to the lower production values in recent years has been the increasing proportion of production of higher value low micron fine wools.

Fig. 10. The average sale value per head of prime lambs and cattle in Australia in recent years.



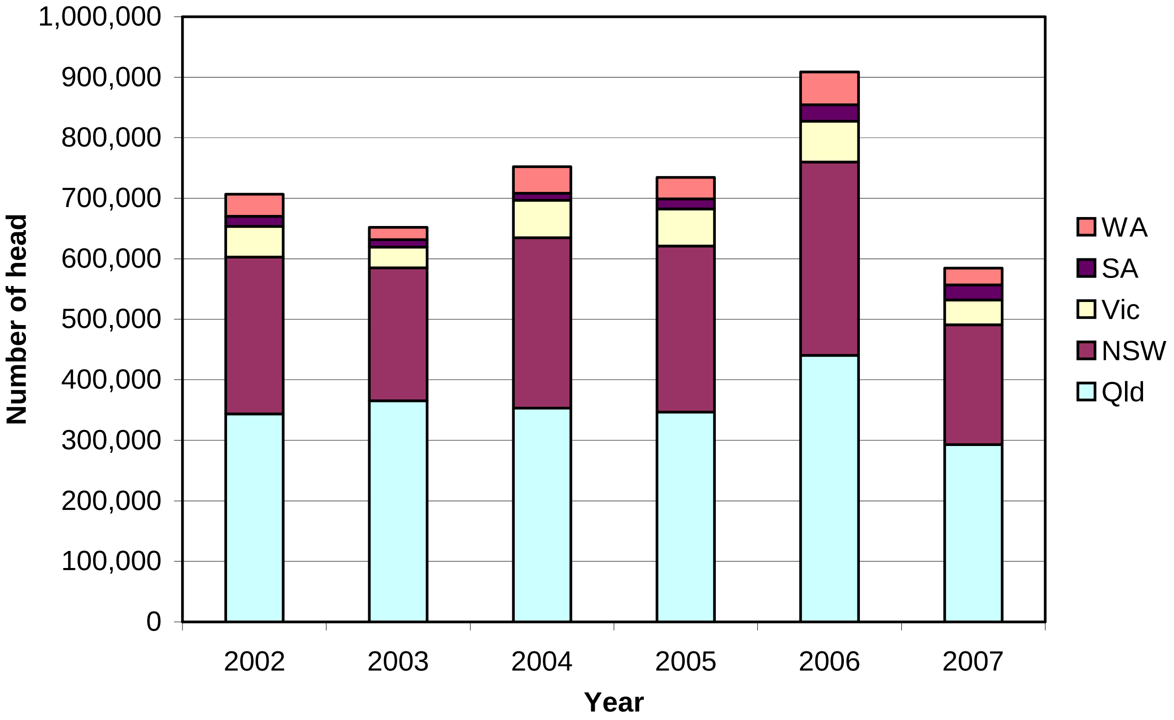
Source: ABARE (2007)

Australian feedlots and stockfeed manufacturers

The Australian Lot Feeders' Association reported (ALFA 2008) that the turn-off of lotfed cattle for 2007 was a record 2.40 million head. The feedlot holding of cattle in December 2007 was around 584,500 head (Fig. 11), at 51% of total capacity (1.15 million head).

The stockfeed manufacturing industry utilises a wide range of agricultural resources, including cereal grains, legume grains, oil seeds, protein meals, cereal milling co-products, hays and other fibre sources, to produces a variety of meals, fibres, supplementary pellets, ration and finishing pellets. Australia's annual consumption of manufactured stockfeed has doubled since 2003 (4.95 million tonnes) to about 10 million tonnes in 2005 (SFMCA 2006). The greatest consumption by volume of manufactured stockfeed is in the dairy (27.2%), poultry (27.1%), feedlot beef (24.6%) and pig (16.4%) industries. The demand and prices of these products is closely tied to local and export livestock markets.

Fig. 11. The number of head of livestock held in feedlots for the December period over recent years by state.



Source: ALFA 2008

Perennial shrub fodder sources

Lucerne is highly nutritious and widely used forage in southern Australian livestock industries. It is a relatively adaptable species suited to a variety of climates and soil types in Australia. Even with extensive breeding and selection programs lasting many years it still fails to perform as a dryland crop in some areas, especially in lower rainfall regions (<500mm) and on soils that are shallow, acidic, high in exchangeable aluminium or sodium salt, or with hostile subsoils. Many Australian chenopods palatable to livestock (eg. saltbushes, bluebushes) are suited to harsh and dry environments, as are many Australia Acacias, other Fabaceous genera, and other palatable native species. Many species from these groups have a long history of use as livestock fodder plants in relatively natural Australian rangelands. Over the years a few species have been planted specifically for use as fodder crops.

Oldman Saltbush (*Atriplex nummularia*) is the most widely used and valued of these native shrubs as it is easily propagated, fast growing, readily managed and grazing tolerant. Early Australia selections programs commenced around 50 years ago, with some small advances in nutritional status in the time. Over the last decade some further selections and clonal reproduction by private industry has been used to make more nutritious and better forms of Oldman Saltbush (e.g. “Eyre’s Green” cv Topline Nursery - crude protein [CP] of 14.4% dry matter, digestibility of 34% of dry matter, metabolisable energy [ME] 5.1 MJ/kg dry matter)). Interest also exists in several other Atriplex species (eg. *A. amnicola, A. cinerea, A. vescicaria*). Acacia species, although often palatable to livestock and with some species tolerant to grazing pressure, are generally lower in their nutritional value and harder to digest. Some populations of *Acacia saligna* from Western Australia have proven to be more nutritious (CP 14.4%, digestibility 34%, ME 5.1 MJ/kg), hardy and more easily established than most other Acacia species, although their taller form requires greater degree of crop management. These two species are discussed in detail in the ‘*FloraSearch 3b*’ (Hobbs *et al.* 2009b).

Oldman saltbush and the exotic Tagasaste or Lucerne Tree (*Chamaecytisus* spp.) has been widely used as fodder shrub crops over the last decade in southern Australia. Early research on Oldman Saltbush on saline affected landscapes has painted a poor picture of its nutritional status (Lefroy 2002) largely due to high salt loads in the foliage from these environments. However, the salt load in the foliage is much less significant on non-saline affected sites. Further, Oldman Saltbush provides a valuable green feed resource during summer and autumn, when other typically annual fodder species are desiccated. This seasonally increases the value of the saltbush fodder crop to a level similar to that of lucerne pastures or hay.

Australia-wide Industry Evaluations and Regional Opportunities

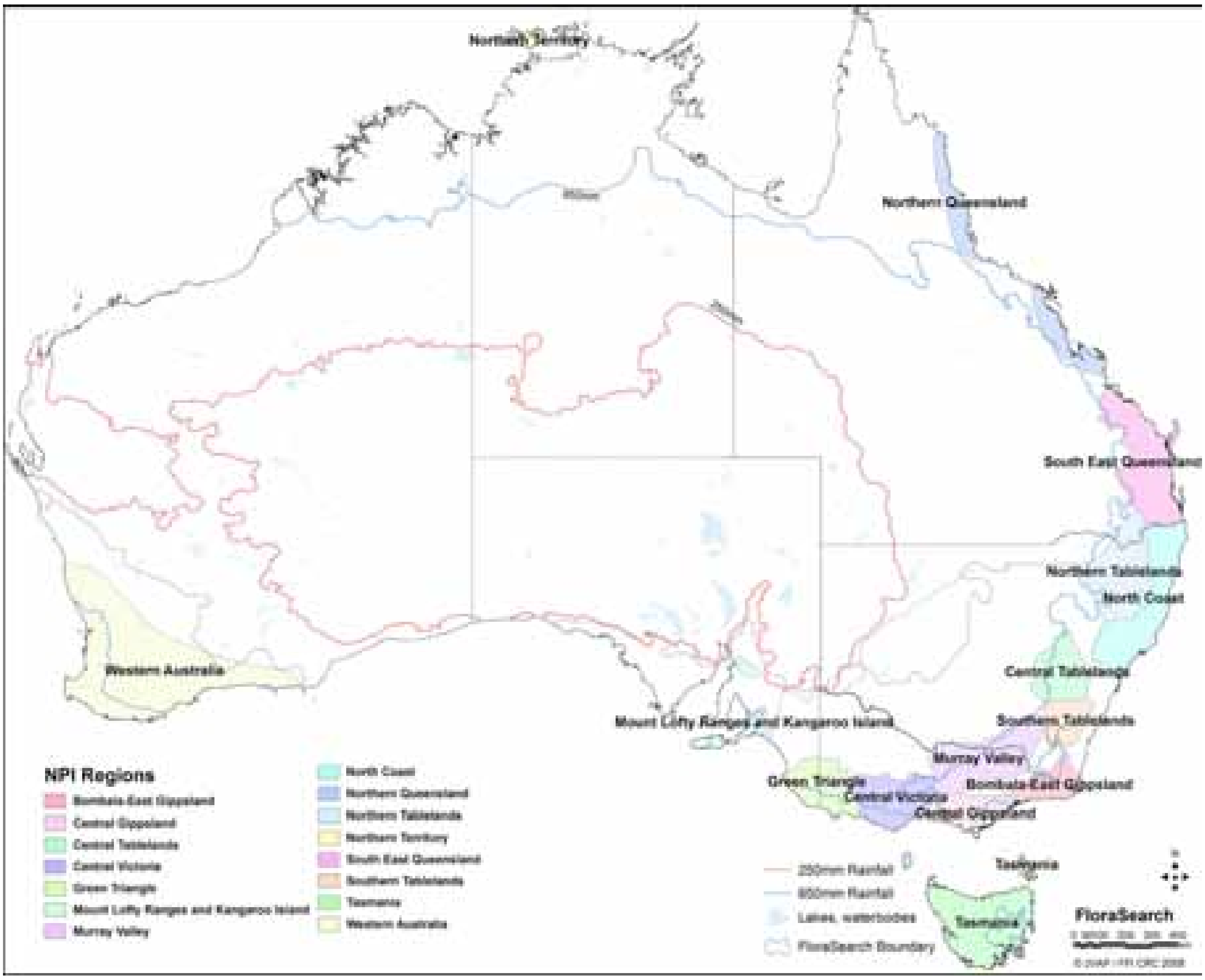
In 2007, the Joint Venture Agroforestry Program developed and engaged 2 national projects to investigate market opportunities and regional priorities for all major existing and emerging farm forestry types across all regions of Australia. The '*Agroforestry Industry Evaluation*' project has been led by Mark Kelly of URS Forestry and aimed to take stock of farm forestry development throughout Australia and identify market opportunities that provide scope for future development (URS Forestry 2008). The second study, '*Prioritisation of Regional Opportunities for Agroforestry Investment*' led by Phil Polglase of Ensis (a joint venture between CSIRO Australia and SCION New Zealand) aimed to identify priority regions in Australia based on spatial productivity and economic evaluations (Polglase *et al.* 2008). '*Regional Industry Potential Analysis*' methodologies developed by FloraSearch (Hobbs *et al.* 2008c) have been implemented through the CSIRO Scenario Planning and Investment Framework (SPIF) GIS Toolbox (Hawkins 2008, Polglase *et al.* 2008). Both these projects were conducted in partnership with the Future Farm Industries CRC/FloraSearch team (primarily Trevor Hobbs) and aimed to provide direction for farm forestry development into the markets likely to hold the greatest value for future investment and will inform the development of priorities for future investment in research and development by JVAP.

JVAP Agroforestry Industry Evaluation Project

Commencing in 2007, URS Forestry (funded by JVAP) in partnership with the Future Farm Industries CRC and FloraSearch researchers conducted the "*Agroforestry Industry Evaluation Project*" for all major existing and emerging farm forestry types across the whole of Australia. A report from this project '*Market Opportunities for Farm Forestry in Australia'* (URS Forestry 2008) provides an analysis of the range of markets that offer potential for farm forestry investment and the priorities by which these markets should be pursued. It is the culmination of significant market research, regional investigation and consultation across a wide range of stakeholders. It reports market opportunities for existing larger scale markets are ranked on a region by region basis (see Fig. 12). Opportunities in smaller scale or niche markets and emerging markets are ranked at the national level.

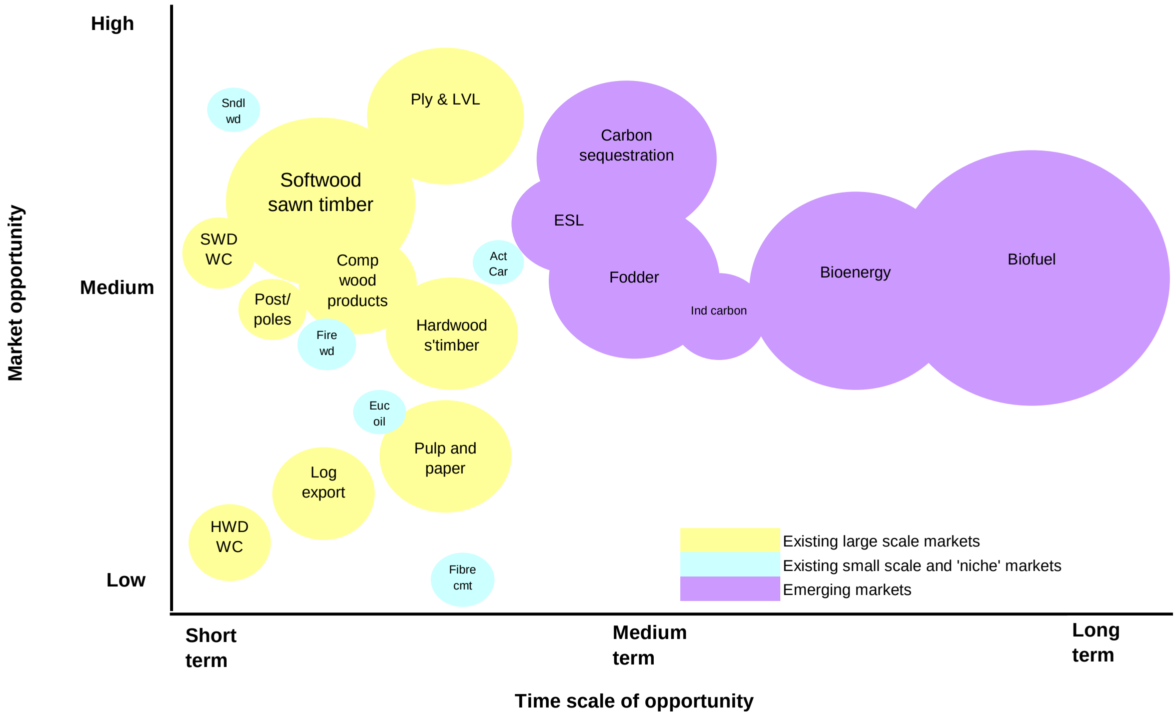
This analysis has suggested a wide range of market opportunities for farm forestry incorporating a number of products, regions and also timescales for development. Opportunities for each market type have been ranked based on current available information on existing industries. It must be noted there is potential for some emerging markets to provide very large scale opportunities in the future but at the present time have substantive risks due to relatively undeveloped nature of some of these markets. Fig. 13 attempts to capture the three main aspects of ranked market opportunity (y-axis), the term over which the opportunities exist (x-axis) and the potential scale of opportunity (relative size of the circle). It illustrates that while products such as bioenergy and biofuel are ranked as 'medium' market opportunities, below other products including sawn timber, plywood and LVL, the potential scale of opportunity in the future could be much larger. Further, the potential scale of opportunity for emerging products is likely to be relatively small in the short term but may improve in ranking as well as expand its scale over time.

Fig. 12. National plantation inventory (NPI) regions in Australia.



Source: Bureau of Rural Sciences (2007).

Fig. 13. Australia-wide farm forestry market opportunities by product, ranking and time scale in Australia as identified by URS Forestry in 2008.



URS Forestry analysis noted the relative size of market opportunities is also influenced by the scale of production required to support forest resources. This is well known for existing forest products but less so for emerging forest products. Table 8 illustrates the size of plantation estates in higher rainfall regions that would be typically required to support larger scale existing markets. There are two key strategies for smaller scale farm forestry enterprises to meet volumes required for each of these industry types: farm forestry growers can either look to supply marginal volumes to existing processors; and/or aggregate resources with other growers or other larger scale forestry investors in the region. This is less of an issue for smaller scale or ‘niche’ market opportunities but these opportunities are often constrained by size of market. While market opportunities have a strong influence on the attractiveness of farm forestry investment, adoption of farm forestry is influenced by a range of factors that can vary amongst investors. The most significant of these factors will be economic returns from the investment. The potential returns from farm forestry investments are part of the analysis conducted by Ensis/FloraSearch project ‘*Prioritisation of Regional Opportunities for Agroforestry Investment*’. Future investments will be influenced by the market opportunities identified by the URS Forestry (2008) report.

Table 8. Indicative scale required for high to medium rainfall zone competitive forest product processing facilities.

Product	Minimum input requirement (m^3 pa)	Indicative plantation estate required (ha)
Softwood sawn timber	600,000	27,273
Hardwood sawn timber	100,000	5,000
Veneer, plywood and LVL	200,000	9,091
Log export	150,000	6,818
Woodchip export	250,000	12,500
Kraft pulp mill	3,000,000	150,000
BCTMP pulp mill	500,000	25,000
MDF/particleboard	300,000	13,636

JVAP Prioritisation of Regional Opportunities for Agroforestry Investment Project

This project aimed at 'prospecting for regional opportunities and research needs for agroforestry systems in Australia' and at compareing regions and agroforestry systems for current and future prospects. The project combines spatial and economic models through a geographic information systems (GIS) to compare the likely economic returns from a range of farm forestry industry types at a coarse resolution (1km scale, Polglase *et al.* 2008) in an approach based on the '*Regional Industry Potential Analysis*' methodologies developed by FloraSearch (Bennell *et al.* 2008, Hobbs *et al.* 2008c).

The '*Prioritisation of Regional Opportunities for Agroforestry Investment*' project focussed on 10 agroforestry systems:

Sawlog systems	Short-rotation systems	Carbon plantings
1. Hardwood sawlogs	3. Pulpwood	7. Environmental plantings
2. Softwood sawlogs	4. Bioenergy	8. Hardwood plantations
	5. Integrated Tree Processing	9. Softwood plantations
	6. Fodder (in-situ)	10. Mallee plantings

A matrix of representative species growth models and regional scenarios for each industry type (where applicable) were developed to cover 5 climatic regions: 1/ Southern wet (>550 mm, S of 29°S); 2/ Southern dry (275-550 mm, S of 29°S); 3/ East coast tropics and sub-tropics (> 800 mm, N of 35°S, E of 144°E); 4/ Northern savannah and semi-arid (>275 mm, N of 29°S, excluding Region 3); and 5/ Arid (<275mm).

It evaluates likely economic returns for scenarios based on current economic and policy conditions and explores potential future markets (carbon sequestration, prospective industries using a fixed transport distance of 100 km to simulated new facility). It also explores discounted cash flow analyses to determine annual equivalent returns and '*Net Annual Forestry Return*' (NAFR) which includes a broad regional opportunity cost of existing agriculture into discounted cash flow analyses. NAFR is an indicator of new farm forestry returns that are competitive to existing landuse annual returns from cropping and grazing systems.

The study also explores environmental impacts of agroforestry on: (i) biodiversity, and (ii) rainfall interception to identify areas where profitability coincided with biodiversity need and least water impact. It also evaluates uncertainty and sensitivity (Monte Carlo) analyses to identify aspects of agroforestry to which profitability was sensitive.

This study concludes that:

(i) ***Agroforestry can be competitive*** with agriculture in some regions and for some forestry systems, as demonstrated by positive values of NAFR (i.e. the forestry system is more profitable than the preceding agriculture phase).

(ii) ***Pulpwood systems and hardwood sawlogs look promising*** in several regions, mainly because of the often fast rates of growth of hardwoods (and relatively short cycle time for pulpwood systems) and high price for hardwood sawn timber and pulpwood products.

(iii) ***Transport distances and product price are important*** in influencing profitability. This is well established but reinforces that large-scale expansion of agroforestry systems will be constrained by distance to existing processing or handling facilities or new ones will have to be built.

(iv) ***Northern Australia and the east coast shows promise*** for expansion of agroforestry systems and industries due to the often low profitability of agriculture and potential fast rates of growth.

(v) ***Dedicated bioenergy and integrated tree processing (ITP) systems are not profitable at present*** unless they are very close to processing facilities. This is due to the high cost of production (harvesting and transport) relative to low product price for wood energy (market failure at present).

(vi) ***Carbon farming looks promising*** due to the relatively low cost of production (no harvesting, transport) relative to a possibly high product price. This indicates that new forests can be grown in many locations and for multiple environmental outcomes such as biodiversity enhancement. For example:

- environmental carbon plantings could be profitable (given a suitable carbon price) and to deliver significant biodiversity enhancement, with least impact on water, across 13 million ha. These areas are roughly in south-east Qld, south-east Australia, south-west WA.
- the profitability of harvested forestry systems can be significantly improved if carbon is included as an additional, saleable, product.

(vii) ***Maximizing rates of forest growth*** remains one of the most important determinants of profitability and thus where agroforestry research can have the highest impact.

The Ensis study (Polglase *et al.* 2008) parallels many of the findings of FloraSearch's '*Regional Industry Potential Analysis*' (Bennell *et al.* 2008, Hobbs *et al.* 2008c). Some differences in conclusions are due to: 1/ CSIRO 3PG growth models that are dominated by long harvest cycle productivity data from higher rainfall regions and lower stocking densities than would be used in short cycle crops; 2/ an underlying assumption of the shape of very young age growth curves embedded in the 3PG model that underestimates early productivity rates; and 3/ the fixed transport distance of 100 km to simulated new facilities that demotes or masks the value of any industry type that utilises low value commodities (bioenergy and ITP biomass). Their discussions do recognise the limitation of 'fixed transport of 100km' issue and note that bioenergy and ITP are likely to be profitable when close to processing facilities.

Conclusions from JVAP "Regionals" projects

The '*Prioritisation of Regional Opportunities for Agroforestry Investment*' project also compares regional priority rankings derived from the URS Forestry (2008) and Ensis (CSIRO) (Polglase *et al.* 2008) approaches. There is much synergy between industry by region rankings resulting from the 2 approaches (see Table 9), but where differences occur it may suggest opportunities for change in that region. CSIRO rankings are largely based on potential economics but may not fully consider some production chain and market/policy implications known to URS Forestry. Where CSIRO rankings are higher than URS it may suggest potential to expand this industry in the region and may also require investment in upgrading infrastructure or production chains in the region. In contrast, where URS ranking are higher than CSIRO it may suggest regions that have been established for some time, supported by past infrastructure investment and local community may face decline in the future due to less competitive (and perhaps unsustainable) productivity rates in these regions.

Table 9. Comparison of URS Forestry and CSIRO rankings of existing industry opportunities in National Plantation Industry regions in Australia.

Region	Softwood		Hardwood		Wood-chip exports or pulpwood	
	URS	CSIRO	URS	CSIRO	URS	CSIRO
Central and North Queensland	L	L	M/H	M	M	L
SE Queensland	M	L	H	H	M	H
North Coast NSW	L	L	H	H	M	H
Northern/Central Tablelands	M/H	L	M	H	L	H
Murray Valley	H	L	L	H	H	H
Southern Tablelands	M	L	L	M	M/H	H
SE NSW	M	L	M/H	M	M	L
NW Victoria	L	L	L	L	L	L
Central and W Vic	H	L	H	M	M	L
Gippsland	H	L	H	M	H	M
Green Triangle	H	L	L	M	M	H
Mt Lofty and KI	M	L	L	L	L	L
SW WA	H	L	H	M	M	H
Tasmania	H	M	H	M	M	H
NT	L	L	M	L	L	L

From Polglase *et al.* (2008). Rank: L=low; M=Medium; H=High.

The implementation and expansion of '*Regional Industry Potential Analysis*' approach of FloraSearch (Bennell *et al.* 2008, Hobbs *et al.* 2008c, Hobbs *et al.* 2008) through the CSIRO Scenario Planning and Investment Framework (SPIF, Hawkins 2008, Polglase *et al.* 2008) provides a useful and more publicly accessible toolbox for regional prioritisation analysis. It will benefit, in the future, from further development of higher resolution datasets and better productivity models, especially in relation to mixed species plantings and short cycle woody crop systems.

These studies support the notion of substantive potential opportunities for further developing current industries based on wood fibres (pulpwood, fibreboards and composite wood) and fodder shrubs in Australia. Prospects are also high for carbon sequestration, bioenergy and biofuels in the future (see Fig. 13 and Table 9). Many of which can be substantially, or partially, sourced from farm forestry enterprises in medium to lower rainfall zones of Australia. There is also potential for governments to stimulate farm forestry investment through the development of markets for environmental services or government support of new structures to drive commercial investments in emerging markets such as bioenergy and biofuels.

Scale of Potential in Lower Rainfall Regions

The natural resources of lower rainfall regions of southern Australia provide the backbone of a diverse range of ecosystems, agricultural pursuits, industries and communities. The removal of native vegetation and development of annual agricultural systems in the agricultural districts of southern Australia has had widespread environmental impacts including dryland salinity, salinisation of waterways and soil erosion. Restoration of deep-rooted perennial vegetation can make a significant contribution to correcting this problem but it needs to be on a large scale to control salinity. There are many agricultural regions in southern Australia that are dominated by annual cropping and livestock grazing of annual pastures. The recognition of carbon emissions as an important issue has added to the potential importance of perennial woody crops by offering opportunities for mitigation of emissions and adaptation to changing conditions. Consequently, the development of a mosaic of land uses including tree crops driven by large-scale industrial markets, agricultural systems utilising annual and herbaceous perennial crops, and biodiversity resources has an important role to play in Australian landscapes and the sustainability of agricultural systems and rural communities.

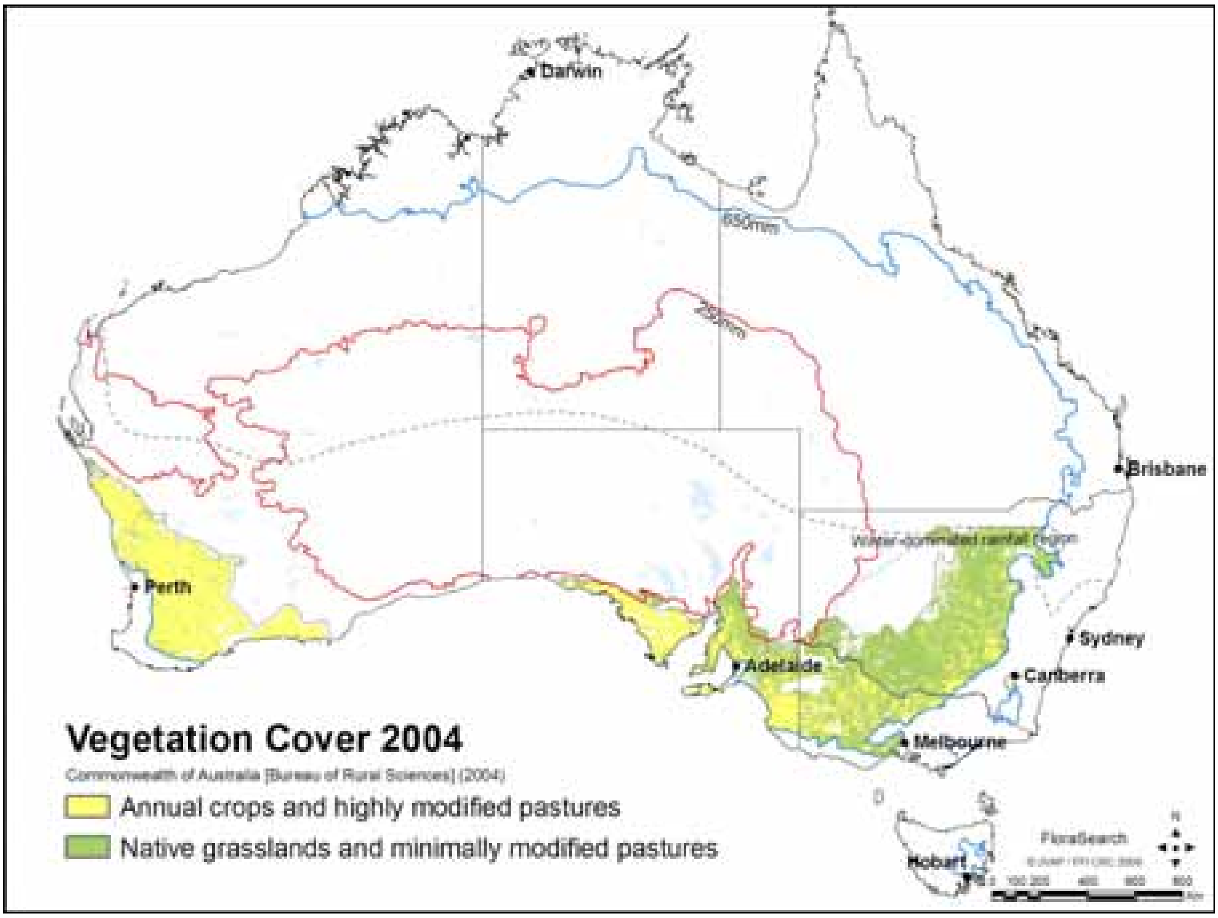
In Australia, large tracts of land (>250 million ha) are currently used for dryland annual cropping and livestock grazing (BRS 2004). Within the southern mainland states there is around 57 million hectares of dryland cropping and grazing (SW Australia = 18 million ha + SE Australia = 39 million ha) that could be diversified by greater use of sustainable and resilient woody biomass crops (see Fig. 14 and Table 10). Bartle *et al.* (2007) discuss many of the issues and potential scale of biomass production from new woody crops in dryland agriculture in Australia and suggest strong potential for development in these lower rainfall regions.

Table 10. Potential area available to new woody crop production in the lower rainfall regions of southern Australia.

	Millions of Hectares		
State	**Annual Crops / Highly Modified Pastures**	**Grassland Grazing / Minimally Modified Pastures**	**Total**
Western Australia	16.9	0.8	17.7
South Australia	7.2	3.8	11.0
Victoria	5.3	4.0	9.3
New South Wales	5.6	13.5	19.0
Total	**34.9**	**22.1**	**57.0**

Based on vegetation mapping conducted by the Bureau of Rural Sciences (BRS 2004).

Fig. 14. Potential low rainfall woody crop areas of Australia.



Industry Engagement

While governments can do much to guide new industry development in directions that foster recognition of regional priorities and infrastructure endowment, it is the free market decisions of private investment that will undertake the actual development.

Woody biomass crops have no precedent in wheatbelt agriculture. Given the large body of Research and Development (R&D) underway, R&D groups like the FFI CRC have a wide range of knowledge about the technologies that determine costs and benefits of biomass supply. There is an opportunity for R&D groups to engage with processing and marketing side entrepreneurs and provide the best available supply side analysis. This will also provide feedback to R&D to reveal factors that are of particular importance to processors and which should be included in supply side R&D.

This form of industry engagement was pioneered in the late 1990s when Enecon (an engineering development group from Vic) and Department of Conservation and Land Management (CALM, now Department of Environment and Conservation, DEC) in WA approached the Western Power Corporation (now Verve Energy) with a view to Western Power using mallee biomass to generate renewable energy credits (RECs) under the then soon to be proclaimed Renewable Energy Act. Western Power was keen to collaborate and it was decided to approach JVAP for funds to assist in undertaking a feasibility analysis. The feasibility analysis showed that it appeared commercially feasible to develop a form of integrated processing of mallee where four products would concurrently be produced, i.e. eucalyptus oil, activated carbon (from the wood fraction using technology licensed to Enecon by CSIRO), electricity and Renewable Energy Certificates (RECs, Enecon 2001). This study resulted in the construction of demonstration scale integrated wood processing plant for operational scale testing of the process. This testing work is now complete and further redesign and planning is underway.

This experience gave researchers at WA DEC and subsequently within the Salinity CRC (now FFI CRC), confidence that a useful contribution to new industry development could be made in this way. A CRC project called the '*New Industry and Marketing Project*' (NIM Project) was devised to create and apply a framework to routinely engage new industry entrepreneurs and deliver supply side technical and economic analysis to their feasibility assessment. It was anticipated that the NIM project would have made a significant contribution to the FloraSearch Project, but this did not emerge. In doing so it revealed one of the major difficulties in dealing with entrepreneurial developers – they only initiate activity when they see the opportunity to be ripe. They set the time schedule and as providers of a technical service NIM and any other project like it will have to wait until the particular prospect is ready.

The NIM project has recently completed delivery of a bulk sample of debarked, chipped mallee wood to a panel-board manufacturer. It is expected that this emerging prospect will lead to further engagement to assess supply side options.

The '*New Industry and Marketing Project*' project will also prepare a generic scale framework to guide the routine application of a supply side feasibility process and this will be further developed in the proposed FFI CRC project to be called '*Biomass Supply Analysis*'. The NIM project has assembled a list of several emerging new industry developments around Australia that may provide opportunity for industry engagement. In selecting possible collaborators the objective has been to ensure that a good range of geographic and product type options are included and that the prospects chosen are credible.

Farm Economics and Regional Industry Potential Analysis

The regional industry analysis of farm economics combines data on plant productivity, species' attributes, establishment and maintenance costs, delivered prices for industry feedstocks, and harvest and transport costs, to estimate the economic viability of biomass industries for primary producers by analysing expected cash flows resulting from the agroforestry project. These projects typically have high setup and establishment costs in the initial years, followed by several years of modest maintenance costs, before the crop matures, is harvested and income from the sale of plantation products are finally realised. The financial viability of the agroforestry enterprise depends on its ability to create a positive cash flow over the life of the project. To determine whether a new investment in farm forestry is more profitable than an existing enterprise it is necessary to compare the expected economic performance of each enterprise.

Investment analysis (Discounted Cash Flows and Annual Equivalent Returns)

Discounted Cash Flow (DCF) analysis is a commonly used evaluation technique for economic comparisons of different commercial enterprises (Abadi *et al.* 2006). It is an approach that converts projected costs and returns of each enterprise into present day values and factors in different time preferences and financing charges. In our analyses the financing charges of the new enterprise is expressed as the "Discount Rate", that is the cost of raising and servicing the capital required for the investment. Choosing an appropriate discount rate is crucial to the calculation of the Net Present Value (NPV) of the enterprise. In our analyses we have used a discount rate of 7% which approximates the current commercial rate for borrowing, less the inflation rate, for farm forestry enterprises (Abadi *et al.* 2006, Peirson *et al.* 2002). The expected cash flows of each agroforestry enterprise has been discounted back to its present value and summed to determine its Net Present Value (NPV) using the formula:

$$\mathrm{NPV} = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - C_0$$

Where

t - the time of the cash flow
n - the total time of the project
r - the discount rate
C_t - the net cash flow (the amount of cash) at time t.
C_0 - the capital outlay at the beginning of the investment time ($t = 0$)

To allow economic comparisons across the range of potential agroforestry options, and with current annual-based cereal and livestock industries in the region, we have explored the expected Annual Equivalent Returns (AER) for the first 20 years of each enterprise. Annual Equivalent Returns can be thought of as an annuity where the NPV is spread evenly across the life of the enterprise. This approach addresses the issue that first and subsequent harvest cycles of each agroforestry enterprise varies according to the industry selected, specifications of the raw materials harvested, and plantation growth rates of different species used in each region. AER analyses allow meaningful comparisons of investments having longer or variable period returns (e.g. agroforestry crops) with those having annual returns (e.g. annual crops).

The economic analyses used in our regional industry analysis approach are all based on contractor rates for site planning and preparation, planting, maintenance, harvesting and transport. They specifically exclude direct landholder investments in capital items such as new land by tenure / lease, and machinery used to undertake site preparations, maintenance, harvesting or transport. The analysis also excludes any values derived from government financial incentives or taxation subsidies, environmental credits and services or other on-farm economic benefits of perennial revegetation. At this stage, the analyses do not factor in the opportunity costs of land being assigned to new woody crops.

Spatial economic analyses

FloraSearch *Regional Industry Potential Analysis* (RIPA) case studies have been conducted in the '*Upper South East Region*' (in 2006) and for '*Bioenergy in southern Australia*' (in 2008) and are presented in later sections of this report. The RIPA approach and methodologies are detailed in the previous FloraSearch 1a (Bennell *et al.* 2008) and FloraSearch 2 (Hobbs *et al.* 2008c) report. Each case study incorporates all plantation establishment and maintenance costs for each biomass industry group of species. Planting densities are set at 1000 plants per hectare for all biomass industry species groups except for the Saltbush Fodder Species group which uses 2000 shrubs per hectare. Establishment and maintenance costs are based on those reported by Bennell *et al.* (2008) and Hobbs *et al.* (2006 and 2008c) for broadacre biomass industries and Bulman *et al.* (2002) and Mt Lofty Ranges Private Forestry (2006) for farm forestry woodlots in the Adelaide Hills. Harvest cost varies depending on each industry type and the degree of biomass sorting and product quality controls (see Table 11). For wood fibre, bioenergy and oil mallee costs are based on continuous flow in-field biomass chipping technologies described by Enecon Pty Ltd (2001) or in-field log chippers used in existing Tasmanian Bluegum (*Eucalyptus globulus*) industries (Timbercorp 2006). Off-farm fodder harvest costs are based on forage harvesters.

In our analyses coppicing species have a 30% increase in the biomass productivity rate compared to the initial seedling growth rate following the first (and subsequent) harvests. This increase is due to coppicing plants having effectively more stems per hectare and established energy investments stored in root biomass. For unharvested carbon sequestration biomass crops of woodlots we have incorporated an estimate of below ground biomass +15% as a proportion of above ground biomass.

Freight costs are a significant contributor to the economics of biomass commodity industries, especially for producers of high volume / relatively low value products that need to be transported to distant mills and processing plants (Bennell *et al.* 2008, Hobbs *et al.* 2006 and 2008c). Transport costs are dependant on vehicle travel speeds and are variable in their proportion of running costs and driver salaries. To increase the accuracy of spatial economic models we detailed different road types and surfaces and applied a +20% cost to unsealed roads and a +40% cost for farm track and paddocks. Transport paths and associated freight costs have been mapped and evaluated between each square kilometre of land potentially available for new woody biomass industries and each existing processing facility.

The Regional Industry Potential Analysis economics module then combines information on plantation productivities, changes in plantation product component yields (i.e. biomass fractions) with plant age, establishment costs, maintenance costs, harvest costs and delivered feedstock values. It uses sensitivity analyses to determine economically optimal harvest cycles for each industry type. Spatial economics models are constructed for each industry type and applied to spatial surfaces of plantation productivities for each industry species group and road transport costs (where applicable) for every hectare of land potentially available to revegetation industries in the region. Cash flows over the first 20 years of each production system (under a financial discount rate of 7%) are converted to Annual Equivalent Returns (AER $/ha/year) which may then be compared with annual returns from existing agricultural industries. These analyses illustrate the spatial distribution of likely landholder returns for a number of existing and potential industries in southern Australia.

Table 11. Primary production, freight costs and discount rate used in regional industry potential analysis.

	Plant density and type / ha	**Site planning, setup and land preparation [$/ha]**	**Seedlings, planting, fertiliser and watering [$/ha]**	**Weed/Pest management and control [$/ha]**	**Harvest costs [$/green t]**
Primary Production Costs	1,000 trees 2,000 shrubs	305 300	350 500	85 50	10 (5-25.5)[#1]
Freight costs - includes truck return trip ($/t/km)	0.115 for sealed roads / 0.138 for unsealed roads / 0.161 for farm tracks and paddocks				
Discount rate	7%				

[#1] Harvest cost (using "chip-in-field" or fodder harvest technologies) variations per green tonne of total biomass: $10 bioenergy; $15 pulpwood, fibre/particleboards; $25.5 oil (including oil extraction, based on Abadi *et al.* 2006); $5 off-farm fodder; $0 in situ fodder; +$10/g tonne for biomass requiring sorting. Other costs: $10/ha annual maintenance costs; $90/ha post-harvest cleanup and fertilizer application cost for phase crops

Woody Crop Commodity Prices

Later in this report we provide 2 case studies on woody biomass crops. The '*Upper South East Region*' case study was conducted in 2006 and '*Bioenergy in southern Australia*' in 2008. As these spatial and economic studies were conducted at two different times we provide a description of the estimated woody crop commodity values used in those studies and explain differences in these values based on changing commodity trade values and markets during those 2 years. These values have been adjusted for each product group following market price trends for each commodity type and allowances for differences between international trade values in US dollars and Euros where applicable.

Export woodchips

Export hardwood (broad-leaved) pulpwood chip prices are measured in term of Australian dollars per bone dry tonne ($/bdt). In 2006, these prices increased by 11-57% from $93-146/bdt in 2001-02 to $162/bdt in 2005-06 (ABARE 2004, Neilson and Flynn 2006, Gunns 2006) with current exports having greater proportions of plantation woodchips. In February 2008, Great Southern Ltd (2008) announced a new price agreement for the sale of hardwood woodchips to Japanese pulp and paper customers for the 2008 calendar year. The new price of $207.40 per bone dry tonne (bdt) was agreed for plantation hardwood supplied from the Albany region in Western Australia. This price represents an increase of $18.00 per bdt more than 2007 prices. Standards are high within this sector and purchasers demand woodchips virtually free of bark and other contaminants. With a moisture content of approximately 45% by weight the 2006 freshwood chip value equates to approximate $90/green tonne (in 2006) for dryland plantation Eucalypts and Acacias and a current value of $115/green tonne (in 2008).

Australian pulpwood

Australia pulpwood chips are typically valued per freshwood weight of approximately $80/green tonne for hardwood species and $50/green tonne for softwood species (George Freischmidt, pers. comm. 2006). Feedstocks need to meet high quality standards, with low bark contaminants, to attract the best prices. A feedstock that has already been chipped in-field with significant contaminants removed prior to delivery is likely to have an average value at closer to $85/green tonne (in 2006) at the mill gate. Assuming a similar trend in prices to those of export woodchips current prices of Australian fresh hardwood pulp chips would equate to ~$108/green tonne (in 2008).

Medium density fibreboard (MDF)

In 2006 the current gate price of logs used for medium density fibreboard production in southeastern Australia is approximately $60/green tonne (range $50-70, George Freischmidt, pers. comm. 2006). These MDF log prices are dependent on logs with low contaminants, especially bark detritus. A feedstock that has already been chipped and cleaned in-field is likely to have an average value at closer to $65/green tonne (in 2006) at the mill gate. Given increased demands for wood fibres in the last 2 years the current price would be ~$80/green tonne (in 2008).

Particleboard

Logs and other raw wood sources for particleboard production in southeastern Australia were valued in 2006 at approximately $40/green tonne at the mill gate (range $30-50, George Freischmidt, pers. comm. 2006). Particleboard production can utilise poorer quality source material than paper and other fibreboard industries and are able to utilise sawdust, filler-like materials (eg. regrind) and other coarser source materials. Particleboard mills often utilise wastewood streams from nearby or adjoining sawmills (such as Benalla Particleboard Mill) which may result in poorer prices paid for alternate feedstock sources. A prechipped feedstock may attract a slightly higher premium of around $43/green tonne (in 2006) and with particleboard product price increases of about %3.5 per annum this equates to a current biomass price of ~$49/green tonne (in 2008).

Bioenergy

Based on values of export thermal coal prices, relative calorific value of Eucalyptus and Acacia species compared with Australian exported thermal coal a likely delivered price of whole plant woody biomass for electricity generation would be $28/fresh weight tonne (in 2006). However, thermal coal prices have risen dramatically in the last two years and based on a recent string of export trades of Australian thermal coal of over $A134/tonne, this equates to a rise in the current value of whole plant woody biomass to over $44/fresh weight tonne (in 2008).

In 2006 crude oil was values at around US$70/barrel (A$120/barrel). Strong crude oil prices of ~US$125/ barrel in 2008 (A$132/barrel) have also driven up the price of ethanol and biodiesel. Based on biomass energy values and moisture content the price of whole plant green biomass for liquid biofuel generation is estimated at $50/fresh weight tonne (in 2008).

More detailed discussions of bioenergy prices and markets are given in Section 4 '*Case Study 1: Woody Bioenergy Crops Woody Bioenergy Crops for Lower Rainfall Regions of Southern Australia*' of this report.

Firewood

Wholesale delivered prices of cut and split Eucalypt firewood in the metropolitan market is reported at $125 per air dried tonne (Poynter and Borschmann 2002) with allowances for inflation the price in 2006 was in the vicinity of $135 per air dried tonne. This estimate is at the conservative end of 2006 reports of $140 - 150 per air dried tonne with a maximum moisture content of 20% (Peter Bulman, pers. comm. 2007). Assuming no cost for air-drying, a conservative price estimate equates to around $100 per fresh weight tonne (in 2006). Current firewood market prices are highly variable around the country but they suggest an average delivered wood price of around $120 - 150/ air dried tonne (in 2008, VicForests 2008).

Eucalypt leaf for oils

The price of Eucalyptus oil produced from Western Australia mallee species in 2006 ranged between $7/kg to $12/kg for specialty and pharmaceutical use (OMC 2006). Limited trades on international markets in February 2006 priced *Eucalyptus polybractea* (blue mallee) oil at $17.22/kg ($US12.75/kg, George Uhe 2008) which was more than twice the value of *Eucalyptus globulus* oil in that month. Industrial grade and volumes of oil are expected to only attract a price of about $3/kg. Current best selections of mallee Eucalypt species have cineole contents of over 8% per dry tonne of leaves, which equates to about 4% of leaf fresh weight.

Using in-field processing with mobile distillers and a bulk oil price of $3/kg values the leaf fraction at $80/freshweight tonne, and at an oil price of price of $7.52/kg the gum leaves are worth $210/freshweight tonne (in 2006). In the last 2 years the Australian value of Eucalyptus oil has been relatively stable, although there have been notable increases in international trade values (in US dollars) these have been counter-balanced by a stronger Australian dollar. In 2008, the Australian value of Eucalyptus oil remains about the same as those reported for 2006.

Integrated wood processing plant (oil / charcoal / bioenergy)

Initial projections valued the delivered feedstock at $30 per green tonne (Enecon 2001). However, given inflation costs since 2001, the increased markets and value of energy resources, wood charcoal and Eucalypt oils a higher delivered feedstock value around $36 per green tonne (in 2006) or more could be expected. Since 2006, these energy and wood charcoal values have increased further and Eucalypts oil has been stable (Table 6, Fig. 9, Table 7) this balance results in current value of woody biomass for integrated wood processing of ~$45 per green tonne (in 2008).

Fodder shrubs

Lucerne hay has an average crude protein (CP) of 20 % of dry matter and metabolisable energy (ME) of 9 MJ/kg dry matter and clover hay has CP 12% and ME 9 MJ/ kg. Other highly valued fodder resources include cereal barley (CP 10%, ME 12) and peas (CP 24 %, ME 13) (FeedTest - Agriculture Victoria 2006). As Oldman Saltbush's dry weight nutritional value (CP 20-25%, ME 11-12, digestibility 76-80%) often exceeds that of the highly valued lucerne the fodder value of saltbush is on par to that of lucerne. Average 2006 prices of hay for sale from the Australian Fodder Industry Association (March 2006, for SA, Vic. and NSW, moisture content ~10%) shows lucerne hay was valued at $211/t (range $154-242/t), pure clover hay $177/t ($170-180/t), clover/rye pasture hay $153/t ($120-160/t) and oat hay $146/t ($135-150/t) in 2006.

Allowing for moisture contents of the different products, and the slight diminishing nutritional value due to salt content in some Oldman Saltbush (*Atriplex nummularia*) stands (say -10%) and seasonal variations in demand, saltbush leaves and fine twigs are worth between around $45/green tonne (winter-spring in 2006) when other fodder is readily available and $65/green tonne (summer-autumn in 2006) when competing directly with other equally high quality hay products. Due to its lower nutritional value the fodder value of Orange Wattle's (*Acacia saligna*) leaves is approximately 50% of Oldman Saltbush.

The value of fodder and hay is seasonally sensitive and increase by 50% in price over the course of year (even higher during drought events). In 2007 and 2008 lucerne hay in NSW reached values of over $500/t (AFIA 2007). In modest drought conditions saltbush fodder value could reach over $170/green tonne. May 2008 prices for lucerne hay in NSW, Vic. and SA averaged $359/t (range $275-550/t). This values Oldman Saltbush (*Atriplex nummularia*) at around $60/green tonne (winter-spring in 2008) and $110/green tonne (summer-autumn in 2008) when competing directly with other equally high quality hay products.

Carbon sequestration

International trade in 2006 valued a tonne of carbon dioxide at €12.85/tonne (ECX 2008, average trade-weighted price 29/09/2006) and with an exchange rate of A$1= €0.5891 (on 29/09/2006, RBA 2008) carbon dioxide had a tradeable value at around A$21.81/t (in 2006). From our destructive samples the average ratio between fresh weight whole plant biomass and carbon dioxide equivalent is 1:0.891 (Hobbs *et al.* 2009a). Using this ratio and European September 2006 trade prices equates to a value of A$19.43 per fresh weight tonne (in 2006) of above ground biomass.

Current December 2008 ECX Futures (ECX 2008, 21/05/2008) are priced at €25.73/t CO_2-e (Fig. 3, A$15.87/t CO_2-e, RBA 2008, 21/05/2008 exchange rate). However, spot price trades (non-futures) values have been highly variable in recent years and was below €5.00/t CO_2-e for all of 2007 with a strong rebound in April 2008 (ICE 2008). Australian biomass traded on the European exchange would be valued at A$14.14 per fresh weight tonne (in 2008).

Summary of FloraSearch commodity values 2006 and 2008

Two different case studies were conducted in 2006 and 2008, and as a subsequence the following Table 12 provides a summary of estimated woody crop commodity values for both years. They include influences of market price trends for each commodity variable, and different conversion rates between Australian dollars and US dollars/Euros where applicable. Likely price ranges of each

FloraSearch industry commodity type at corresponding mill gate, port, delivery centre or in situ locations is also included in the table.

Table 12. Summary of estimated 2006 and 2008 delivered feedstock values by industry type.

Industry and Commodity Type	Delivery Location	Likely delivered value [$/freshweight tonne]			Market Price Trend
		Likely range 2006 and 2008 combined	2006	2008	
Export pulp - woodchip	Port	80 - 115	90	115	increasing to stable
Australian pulp - woodchip	Mill	75 - 110	85	108	increasing to stable
Australian MDF - woodchip	Mill	50 - 83	65	80	increasing
Australian particleboard - woodchip	Mill	30 - 55	43	49	stable
Electricity generation - whole plant biomass	Powerplant	25 - 56	28	44	strongly increasing
Liquid fuels - whole plant biomass	Processing Plant/Refinery	25 - 80	30	50	increasing to stable
Firewood (bulk supply)	Distribution Centre	90 - 155	100	120	stable to increasing
Eucalyptus bulk oil - leaf	Mobile Processing Plant	60 - 140	80	80	stable
Eucalyptus essential oil - leaf	Mobile Processing Plant	190 - 400	210	210	stable
Integrated wood processing - whole plant biomass	Processing Plant	32 - 55	36	45	increasing
Carbon sequestration - whole plant biomass	In situ	5 - 46	20	15	volatile price /increasing volume
Fodder - Saltbush leaf (Autumn)	In situ/Paddock/Mill	55 - 170	65	110	increasing
Fodder - Saltbush leaf (Spring)	In situ/Paddock/Mill	40 - 80	45	60	increasing

3. Factors Affecting the Economic Performance of Mallee Production Systems

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Introduction

There are strong societal drivers for increasing the proportion of perennial plants in dryland farming systems in the south west of Australia. A substantially increased perennial component in the landscape could retard the process of secondary salinisation; thereby helping to protect the agricultural land resource, remnant biodiversity and town and transport infrastructure. Diversification into new perennial crops could also make farming businesses more robust in the face of climate change and the long term trend of declining terms of trade for conventional food production. However, the inclusion of perennial species into farming systems remains a challenge. To make a meaningful impact on landscape sustainability, a sizable component of existing annual crop and pasture systems will need to be displaced by perennials. Existing perennial crop options are constrained by low profitability and complexities associated with their integration into existing land use (Lefroy *et al.* 2005, Pannell *et al.* 2006). Therefore, existing options need to be improved or new perennial crop options need to be developed.

Mallee eucalypts have been proposed as an alternative crop plant for the production of bulk industrial products such as reconstituted wood products and bioenergy (Bartle and Shea, 2002). Eucalyptus oil is an additional product, which is currently used for low volume specialty uses but with potential for large scale industrial use (Coppen, 2002). Several mallee species endemic to the south western agricultural region have been identified as having good potential for domestication. A key advantage of mallee is its strong coppicing ability, allowing harvesting on a 3-5 year cycle indefinitely. Mallee is also quite resistant to grazing by sheep, enabling it to be dispersed amongst annual crops and pastures with relatively minor modifications to farm management. The major disadvantage of integrated belts of trees is the potential to create a substantial zone of suppressed crop and pasture yields adjacent to the trees, due to lateral tree roots competing for soil moisture (Sudmeyer *et al.* 2002).

Western Australian farmers have recognized the potential for mallees to improve landscape sustainability and provide enterprise diversification. Although markets for mallee biomass are largely undeveloped, some 20 per cent of wheatbelt farmers (~1000 farmers) have planted in aggregate more than 12,000 ha of mallee; most of which is configured in narrow belts within cropping and grazing paddocks. The uptake of mallee to date has been motivated largely by the provision of environmental services, such as erosion control and recharge reduction. However, the promise of an emergent industry has also been important.

Industry development will require the synchronisation of products derived from mallee and their receiving markets, to accommodate potentially large volumes of biomass. Given this rationale, bulk commodity markets must be targeted which have a low risk of being oversupplied (Cooper *et al.* 2005). To be economically competitive, it is likely that mallee will need to generate multiple products from different plant components (Bartle *et al.* 2002). Additional "product value" could be afforded by the valuation of environmental services, such as carbon sequestration and the protection of biodiversity. Maximizing the return from each biomass component will be made more efficient through integrated processing technologies, sometimes referred to as the biorefinery concept (Bartle *et al.* 2007, Ragauskas 2006).

The scope for mallee to be substantially increased in farming systems, to the point where landscape scale recharge reduction is achieved, will be dictated by its ability to contribute to farm profits. In this paper, a discounted cash flow analysis model is used to explore the factors affecting the economic performance of a mallee biomass production system. New data on above ground biomass production and biomass partitioning by mallee are incorporated into the analysis. Important parameters effecting profitability are identified and sensitivities explored. A number of different production system options are then examined to assess how the mallee production system can be improved. The analysis provides a useful framework for prioritizing future research and development effort.

Mallee Biomass Production System

For the purposes of this study, the mallee production system involves growing narrow belts of mallees in farm paddocks in what is often termed an alley farming configuration. This is the most commonly practiced system of integrating mallees into Western Australian farming landscapes. The belts consist of 2 rows of mallees separated by a width of 2m. The belts are separated by wide alleys (40-100m) in which conventional annual crops or pastures are grown. The mallee belts are generally planted in straight lines or aligned along the contour.

It is envisaged that the mallees will be harvested repeatedly on a short cycle, typically 3-6 years. The conceptual biomass harvest and supply chain was based on principles developed by Giles and Harris (2003). The harvest machine is self propelled, straddles a single row when operating and moves continuously along the row. All above ground biomass is collected and chipped by the harvester and delivered continuously into tractor drawn haulout bins, which transport the chipped biomass out of the paddock to a roadside landing. The biomass is transferred from the haulout to road trailers in a single action. The road trailers transport the biomass to a processing facility. At the processing facility, the biomass can be separated into different components and converted into a variety of products.

Economic Analysis Methodology

The analytical tool used in this study was an adapted form of the ‘Imagine’ model, a paddock scale model specifically designed to test the economics of integrated farming systems (Abadi et al, 2006). The model uses the discounted cash flow analysis method to compare the equivalent annual return (EAR) of land occupied by a mallee belt with conventional agricultural returns. The influence of the mallees on adjacent land used, assumed to be annual cropping and pasture, is taken into account. By manipulating model parameters, sets of parameter values which allow a mallee production system to be more or less competitive with other land uses can be explored. Therefore, the model provides guidance on the impact of building mallee into broad acre farming systems. It can also aid in the prioritization of research and development directions for improving the contribution of mallee to farming businesses.

The model does not attempt to provide information relevant to a biomass processing facility, except for indicating the factory gate price required by growers to enable mallee biomass production to be competitive with other land use options. The model operates at the paddock scale only and does not take into account whole farm budget considerations. Therefore, the impact of replacing a portion of existing land uses with mallee on the spread of fixed costs and overheads across the farm business is not taken into account. For these reasons, the results of this study are only indicative of the effect of adoption of mallee belts on farm business profitability.

The analysis included parameters related to the following aspects of the mallee supply chain:

- Tree establishment and management costs
- Biomass growth and yield at harvest
- Interactions with adjacent agriculture
- Harvest and transport costs
- Factory gate returns

Mallee establishment costs include all costs associated with planning, ground preparation, weed control, seedlings and planting labour. The values used in the analysis were based on current farm revegetation costs in Western Australia. Management costs include insurance, annual weed control adjacent to the mallee belts and periodic weed and pest control following mallee harvesting.

The harvest cost incorporates the cost of harvesting, chipping, hauling out and loading chipped biomass into a road trailer. Transport costs includes a fixed loading/unloading cost and travel costs at a per tonne per kilometre rate. A step function for harvest cost was derived from the assumption that a mallee harvester has a design chipping capacity of 75 green tonnes per productive machine hour, a maximum ground speed while harvesting of 5km per hour and an annual throughput of 120,000 green tonnes per year; based on harvester specifications developed by Giles and Harris (2003). If standing biomass exceeds 60 green tonnes per hectare, equal to 15 green tonnes per row kilometre, the harvester throughput is constrained by chipper capacity. If the standing biomass is less than 60 green tonnes per hectare, the harvester throughput is constrained by ground speed and progressively diminishes as standing biomass reduces. This has the effect of increasing costs from a baseline of $15.00 per green tonne when the chipper throughput is at design capacity.

The harvested component of mallee includes all above ground biomass. Different components of this biomass have differing utility as product feed stocks. For the purposes of valuing the biomass, it was useful to partition the biomass into “large” dimension wood, twig and bark, and leaf fractions. The definition of “large dimension” wood was made on the basis that this biomass fraction can be converted into wood chips. In this study, this fraction was assumed to include all debarked woody matter with a diameter greater than 17mm.

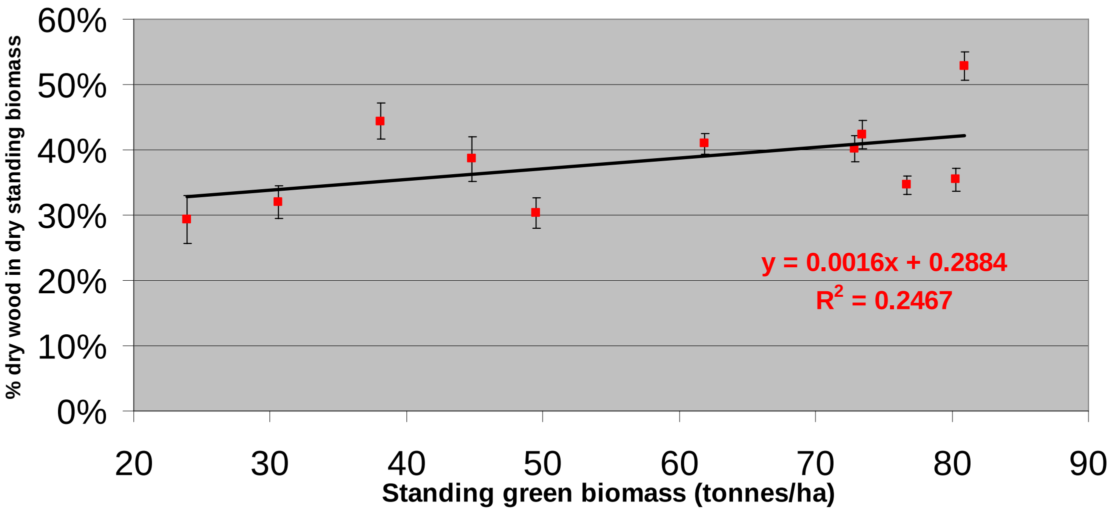
Work in progress by the authors has generated detailed information on biomass production by *Eucalyptus loxophleba* subspecies *lissophloia*, the major species planted in the 300-400mm annual rainfall zone of south western Australia. Allometric equations were developed at twelve sites to estimate standing biomass along 720m of belt at each site. This work included destructive sampling of 575 trees across the twelve sites. The sites represent ‘first harvest’ mallee production and ranged in age from 5 to 9 years. The mean annual increment (MAI) of above ground biomass production ranged from 5.7 to 7.3 dry tonnes per hectare per year for the six most productive sites; assuming that the mallee belt width was 5 meters. At eleven sites, dry mass of biomass components (wood, leaf, twig and bark) was measured from 82 trees of varying size classes. The mean moisture contents for each fraction were measured to be 38.6% for wood, 44% for twig and bark and 47% for leaf components respectively. Component moisture content did not vary greatly between sites (Table 13).

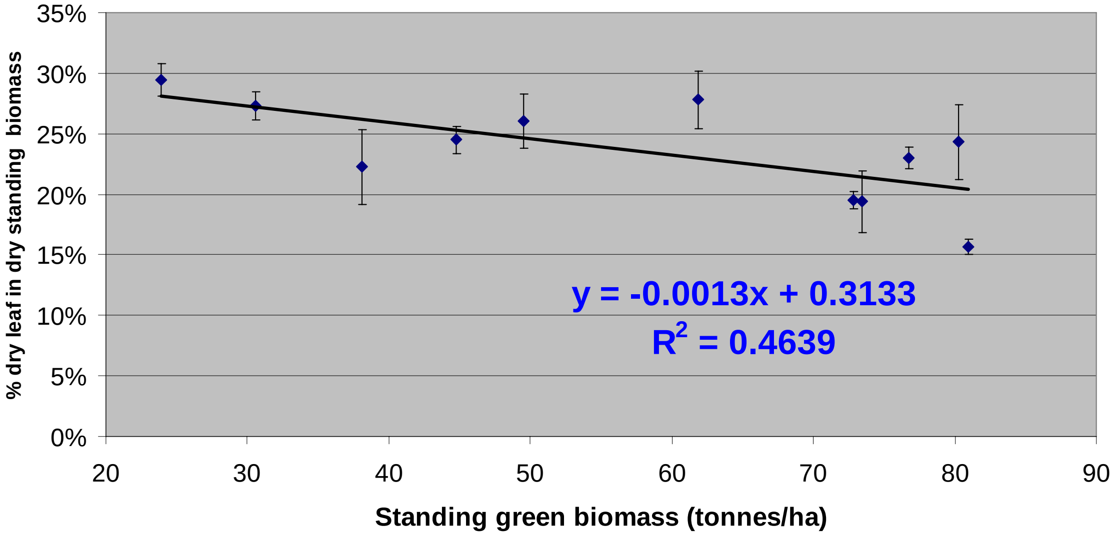
Results from destructive sampling produced weak linear correlations between dry wood and dry leaf biomass as a function of standing biomass, across a standing biomass range of 20-90 green tonnes/ha (Fig. 15). These correlations reflect the gradual increase in the large wood proportion and decrease in the leaf proportion that would be expected as the trees grow.

Table 13. Moisture content of above ground biomass (whole tree and components) of *E. loxophleba* subspecies *lissophloia* in Western Australian farm plantings.

Site number	Overall	Std Err	Wood	Std Err	Bark	Std Err	Twig	Std Err	Leaf	Std Err
1	**44.1%**	0.43%	**38.7%**	0.66%	**42.6%**	-	**45.4%**	0.74%	**50.8%**	2.09%
2	**43.3%**	0.42%	**39.5%**	0.73%	**42.0%**	0.56%	**43.6%**	0.83%	**47.0%**	0.82%
3	**42.5%**	0.42%	**40.3%**	0.81%	**44.1%**	0.78%	**43.4%**	0.57%	**47.1%**	0.67%
4	**42.1%**	0.88%	**37.4%**	0.85%	**43.9%**	0.45%	**45.1%**	1.48%	**45.4%**	1.33%
5	**41.6%**	0.24%	**36.9%**	0.53%	**42.0%**	0.51%	**42.8%**	0.74%	**48.1%**	0.92%
6	**43.7%**	0.74%	**39.4%**	0.95%	**42.6%**	0.63%	**47.0%**	0.89%	**47.3%**	0.98%
7	**42.8%**	1.76%	**39.2%**	0.51%	**46.4%**	1.65%	**43.9%**	2.61%	**45.1%**	2.79%
8	**41.7%**	0.73%	**37.5%**	0.53%	**38.8%**	1.40%	**42.9%**	0.91%	**45.3%**	0.96%
9	**42.7%**	0.39%	**37.4%**	0.54%	**44.0%**	0.48%	**44.3%**	0.87%	**47.1%**	1.25%
10	**43.6%**	0.85%	**40.2%**	1.06%	**47.7%**	0.82%	**44.2%**	1.32%	**46.0%**	1.22%
11	**45.6%**	0.38%	**40.4%**	0.24%	**46.7%**	0.59%	**44.6%**	0.51%	**50.8%**	0.80%

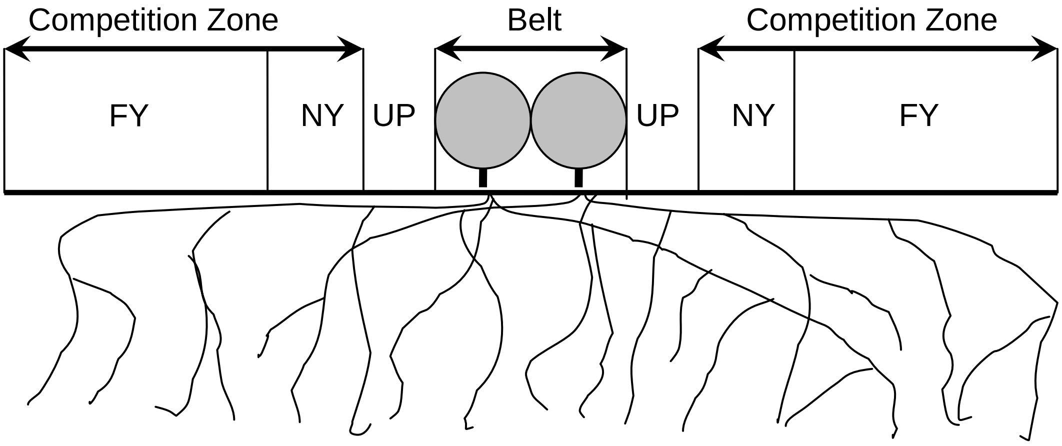
Fig. 15. Dry wood and leaf proportions of standing dry biomass against standing green biomass, for "first harvest" mallees across 11 sites in Western Australia. Standard errors of estimates are also shown.





To account for the effect of mallee belts on adjacent agriculture (annual crops and pastures) the conceptual model developed by Cooper *et al.* 2005 was used. This model identifies three land zones influenced by a mallee belt: the land occupied by the mallee belt (belt B), land immediately adjacent to the mallee belt which is not used for annual crop or pasture (unplanted UP) and land used for conventional agriculture in the zone of influence by mallee roots (Fig. 16). Crop and pasture yield suppression, due to competition for moisture by tree roots, has been reported in Western Australian dryland farming systems (Sudmeyer *et al.* 2002, Sudmeyer *et al.* 2004). For simplicity, the competition zone is further separated into an 'equivalent no yield zone' (NY) and an 'equivalent full yield zone' (FY). To provide an equivalent return to the displaced agricultural activity, the mallee belt must provide a return which compensates for the land occupied by the belt itself, the unplanted land adjacent to the belt and the 'equivalent no yield zone'.

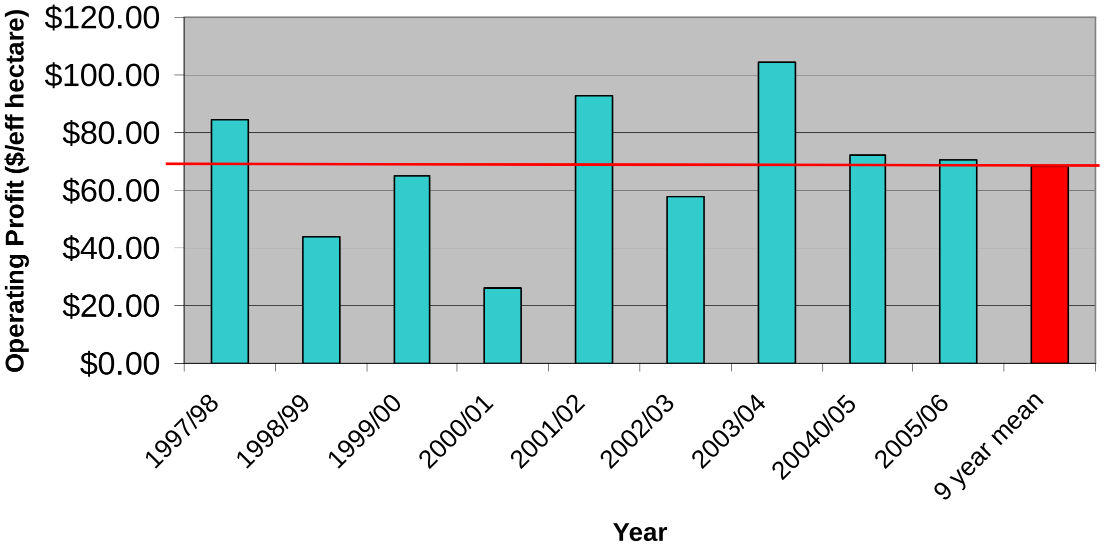
Fig. 16. The zones of influence of a mallee belt where it has displaced a portion of a conventional agricultural production system.



It could be expected that as the mallees grow and extend their root systems laterally, the width of the no yield zone will increase. A study to explore this relationship in regularly harvested mallee has recently been initiated by the authors; however there were no data available to calibrate the model in this study.

To enable a comparison of returns from mallee with returns from existing agricultural activities, published surveys of farm incomes per hectare were used to derive a long term baseline agricultural return for farming districts in the low rainfall (less than 400mm mean annual rainfall) zone of south western Australia (Bankwest 1997-2006, Fig. 17). Using data for the top 75% of farming businesses, the mean CPI adjusted operating profit over 9 years in the target farming zone was $66.80 per effective hectare. Operating profit was defined as farm income less operating costs less depreciation expense. An effective hectare was defined as land used directly for the purposes of producing crops or livestock. It excluded non arable land such as salt lakes, rocks and bush.

Fig. 17. Mean annual operating profit for the top 75% of farming businesses in the 300-400mm zone of south western Australia (source Bank West; CPI adjusted)



Base case scenario

Initially, a base case scenario was developed to provide a frame of reference for subsequent analysis. Many of the assumptions used in the base case scenario were adapted from Cooper *et al.* 2005, who used the Imagine model as part of a wider conceptual analysis of farm economics, water use and industry feasibility assessment for a mallee production system (Table 14). Under this scenario, it was assumed that the first harvest occurs 5 years after mallee establishment in the field using nursery grown seedlings, with subsequent harvest of coppice on a 3 year cycle. The total length of the analysis was 20 years using a discount rate of 7%. No salvage value was allocated to the mallee belts; however the mallees would be expected to maintain their coppicing ability beyond the 20 year analysis period. These analyses are based on a planting density of 2667 stems per belt hectare to maximise leaf component production and oil fractions of woody biomass. In the future, where woody component fractions are likely to be more valuable, lower planting densities will be more appropriate (~1000 stems per hectare or less).

Table 14. Base case scenario assumptions used in economic analysis model

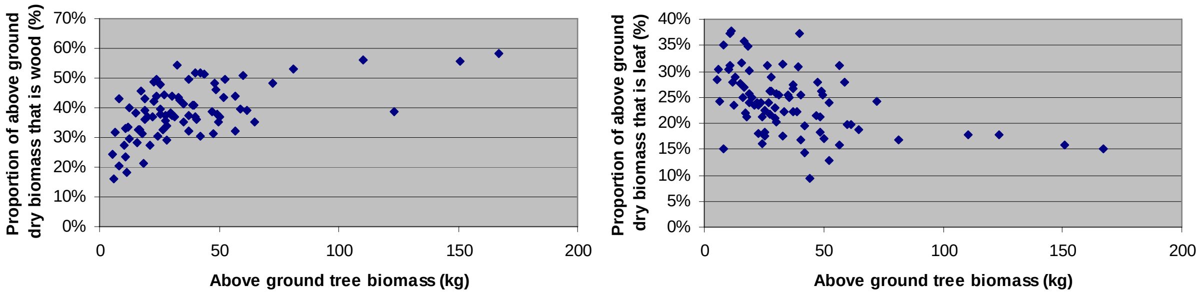
Parameter	Base Case Value
Project lifespan	20 years
Discount Rate	7% per annum
Mallee Establishment cost	$1334.00 per ha
Annual maintenance and insurance costs	$51.00 per ha per year
Post harvest weed and pest control	$54.50 per ha
Mallee age at first harvest	5 years
Mallee yield at first harvest	7 dry tonnes per hectare per year (equates to standing biomass of 61.0 green tonnes/ha; assuming standing biomass has a 42.6% moisture content) where the belt zone (5m width) is the occupied hectare.
Regular coppice harvest cycle	3 years
Harvest cost	Step function: if standing biomass >=60 green tonnes per ha, the harvest cost = $15.00/green tonne; if standing biomass < 60 green tonnes per ha, the harvest cost = 680.77*standing biomass$^{-0.9362}$
Transport horizon	75km (equates to mean haulage distance of 54.94 km)
Transport cost	Fixed cost of $2.50 per green tonne, plus $0.07 per green tonne per km
Delivered biomass price	Bone dry wood = $90/tonne Bone dry leaf = $112.60/tonne (8% oil at $1.20/kg; 92% residue at $18/kg) Bone dry residue (twig and bark) = $18/tonne
Land occupied	Mallee belt width = 5 meters Unplanted zone width = 2.5m No Yield Zone width: A function of years since establishment or harvest First harvest: No Yield Zone Width = 0.55*(sapling age-1) Coppice harvests: No Yield Zone Width = 1.1*(coppice age-1)
Variable cost of crop or pasture establishment	$140.00 per hectare per year

1. This is the mean transport distance for rectilinear transport within a 75km horizon, assuming the amount of mallee planted per unit land area is constant for all transport annuli.

2. The mallee belt zone is defined as being 5 meters wide, which approximates the projected canopy area of the mallees. The unplanted zone is 2.5m each side of the belt. The equivalent no yield zone is an additional 1.1m either side of the belt beyond the unplanted zone. The variable cost of planting and growing an annual crop or pasture is assumed to be $140/ha per annum. The unplanted zone incurs an annual weed control cost of $36/ha per annum.

The mallee biomass yield at first harvest was based on actual growth data collected across multiple sites by the authors. The proportion of each biomass component in the total above ground biomass was modelled as a function of standing above ground biomass. The linear functions in Fig. 15 relating dry wood and leaf biomass to standing green biomass were used in the adapted Imagine model to estimate the biomass composition of the standing biomass at first harvest. For standing green biomass increasing above 100 tonnes/ha, it was assumed that the dry large wood proportion and dry leaf proportion plateau respectively at 60% and 15% of total above ground dry biomass; based on individual tree composition data (Fig. 18). Subtraction of these values from the standing biomass, after adjusting for moisture content, enabled determination of the twig and bark proportion. In the absence of data for coppice, these functions were also used to estimate the value of the standing coppice biomass.

Fig. 18. The proportion of standing dry biomass which is wood and leaf against standing green biomass, for 82 individual trees.

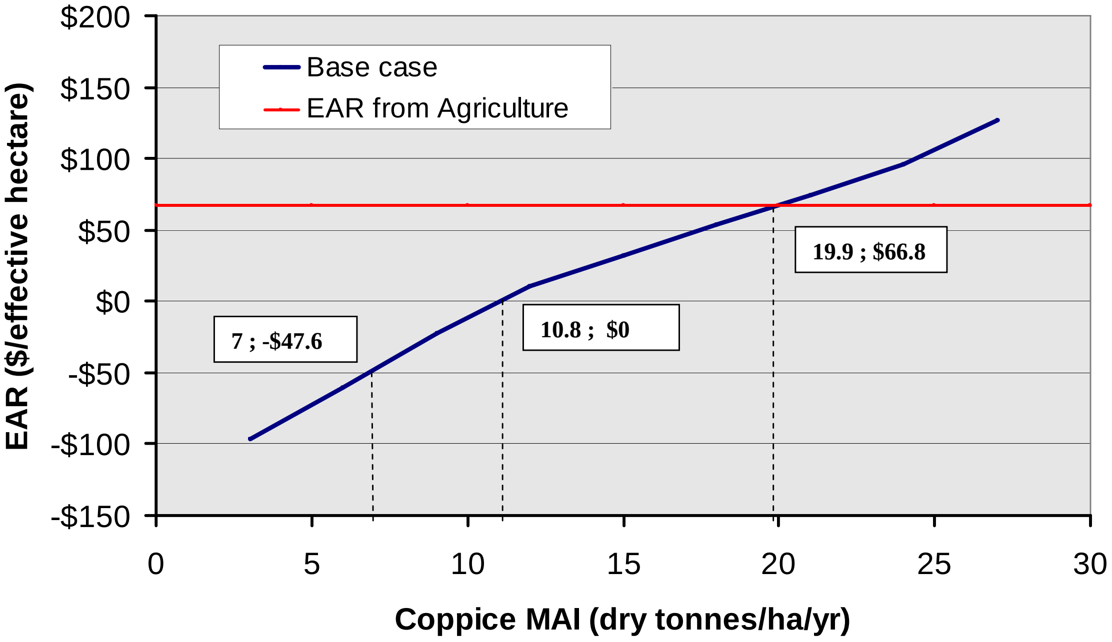


The baseline delivered price received for dry wood, twig and bark, and leaf fractions in this analysis were \$90.00/tonne, \$18.00/tonne and \$112.60/tonne respectively. These values are indicative of prices obtainable for products derivable from the different biomass components. Dry wood has potential to be used to make panel products, such as MDF or particleboard, or charcoal products. The dry leaf fraction contains ~8% cineole, which could provide a return to the grower in the order of \$1200/tonne as an industrial solvent. The leaf residue (post oil extraction), twig and bark fractions are anticipated to have relatively low value utility as a feed stock for conversion into electricity or biofuels. By aggregating the value of the wood, leaf and bark and twig components and adjusting for moisture content, a value for total green biomass was derived. This value was directly related to biomass yields and harvest costs in the adapted Imagine model. For the production system envisaged, comminuted green whole tree biomass is the form in which biomass would be delivered to a processing facility. For these reasons, green total biomass was used to represent the value of the biomass produced by farmers.

Competition penalties imposed by mallee belts on adjacent crops and pastures was captured by modelling the no yield zone width as a linear function of mallee age since establishment or harvest. The function was designed to equate with the mean annual no yield zone width of 1.1m used by Cooper *et al.* 2005 in their base case scenario. Based on observations of mallee growth, the function generates a width of competitive influence for a given tree age in the order of 1-2 tree heights from the tree stump line. Although derived using a highly simplified approach, this width of influence range is comparable to field measurements (Sudmeyer *et al.* 2002, Sudmeyer *et al.* 2004).

Under the base case, the mallee production system required a coppice MAI of 10.8 dry tonnes per hectare per year (total above ground biomass) to give a net present value of zero from the area of displaced agriculture. To provide an equivalent annual return of \$66.80 per hectare per year, an estimate of the opportunity cost of displacing annual crops and pastures, a coppice MAI of 19.9 dry tonnes per hectare per year was required (Fig. 19). Note that this MAI refers to biomass production from the belt zone (5m width) and not the total effective area occupied by the mallees in the farming system. For observed mallee biomass growth rates in the order of 7 dry tonnes per hectare per year for a harvest cycle, the effective area occupied by the mallee belt generates an annual loss of \$47.60 per hectare per year.

Fig. 19. The Base Case Scenario – EAR of a mallee production system against coppice growth rates (expressed as mean annual growth increment in dry tonnes of above ground biomass per year) for base case assumptions.



Sensitivities

The base case scenario provides the platform for exploring the sensitivity of mallee system profitability to variation in a range of parameters. The EAR of the modelled mallee production system was highly sensitive to delivered coppice growth rates and delivered biomass price (Fig. 20). Other important parameters included harvest costs, establishment costs and the level of competition between mallees and adjacent crops and pastures (Fig. 21 to Fig. 23). Note that the sensitivity to establishment cost was independent of growth rates; this was not the case for the other parameters reported here.

The relative importance of yield and revenue parameters was compared by determining the percentage change in each parameter (relative to the base case) required for the mallee production system to give an EAR of $66.80 per hectare per year (Table 15). The relative importance of cost parameters was compared by testing the effect of eliminating the cost on the EAR generated by the mallee production system (Table 16).

Fig. 20. Sensitivity to delivered biomass price.

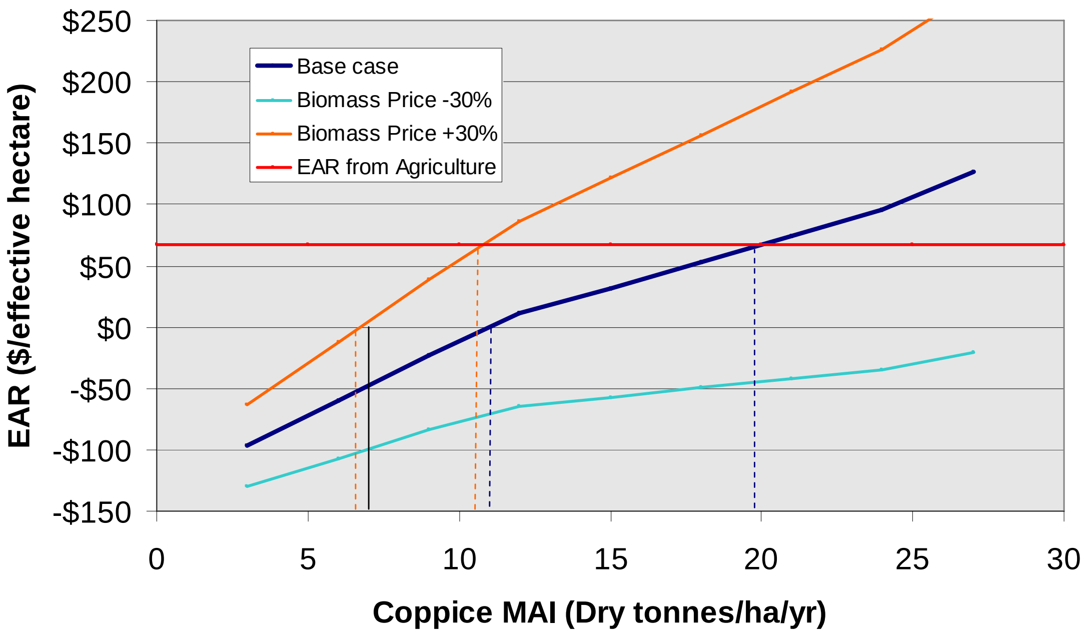


Fig. 21. Sensitivity to harvest cost.

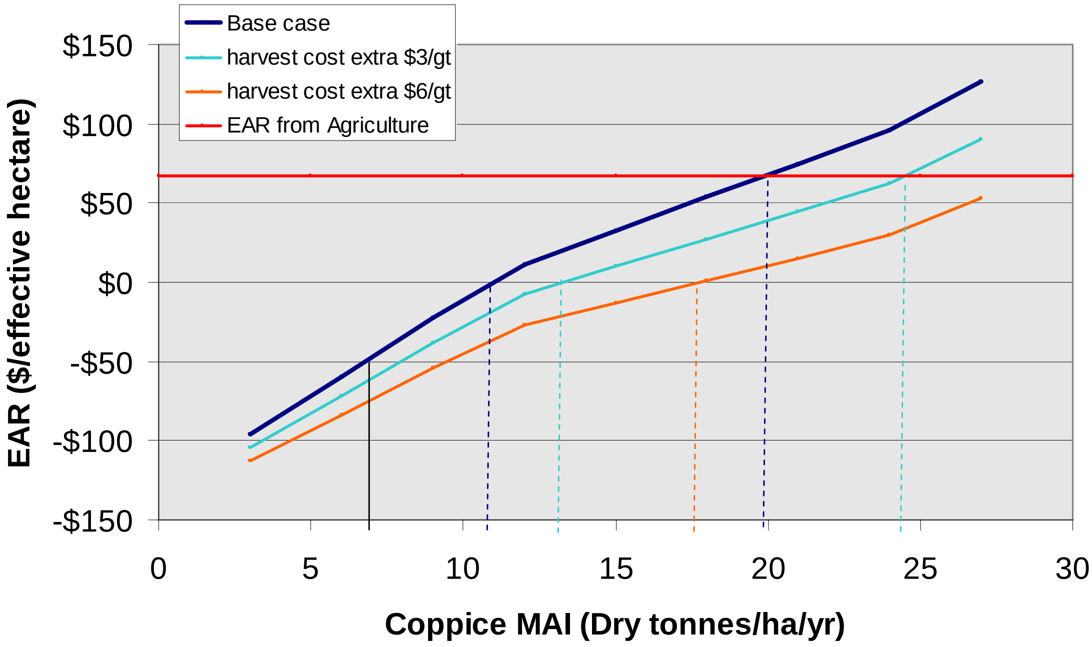


Fig. 22. Sensitivity to establishment cost.

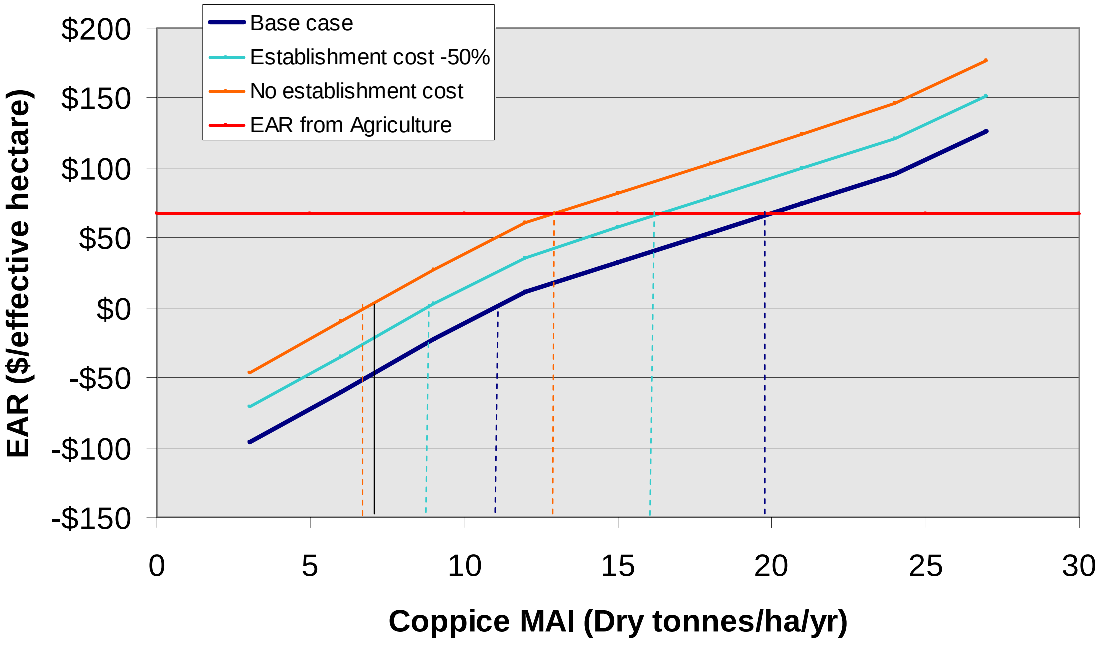


Fig. 23. Sensitivity to no yield zone width.

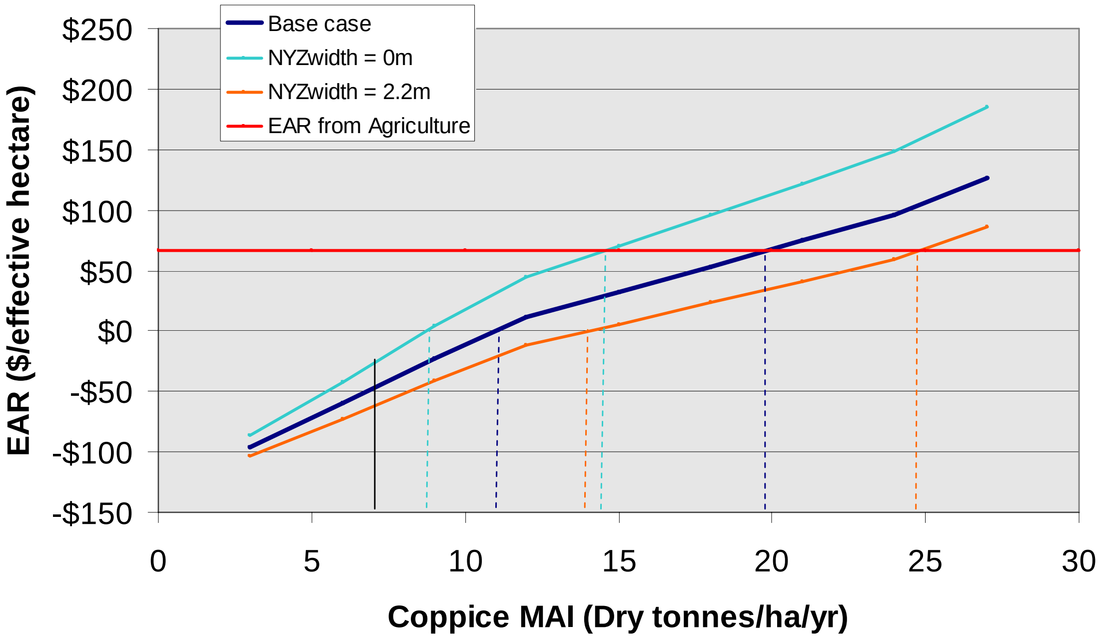


Table 15. Percentage change in production/revenue parameter values required for the mallee production system to provide an EAR of $66.80/hectare (from land where agricultural production is displaced).

Parameter	Base Case Value	Percentage Increase required
Coppice MAI	7 dt/ha/yr	181%
Overall delivered biomass price	$38.87/green tonne	66%
Dry Wood Price	$90/dry tonne	138%
Leaf Oil Price	$1.20/kg	184%
Residue Price	$18/dry tonne	404%

Table 16. The effect of reducing cost parameter values to zero on mallee production system EAR (from land where agricultural production is displaced).

Parameter	Base Case Value	EAR ($/ha) if cost parameter = 0 (Base Case = -$47.60/ha)
Harvest Cost	A function of standing biomass	$42.54
Establishment Cost	$1334/hectare	$2.55
Transport cost	$2.50/green tonne plus $0.07 per green tonne per km	-$19.31
Discount Rate	7%	-$23.52
NYZ width	1.1 meters	-$26.82

Scenarios

The sensitivity analysis showed that improvements to any single cost or revenue parameter alone are unlikely to allow mallee to be competitive with existing agriculture. Instead, improvements are required across all facets of the production system. A number of scenarios were developed to explore how mallee profitability could be improved on multiple fronts.

Scenario 1: Higher value product options from leaf and residue fractions

The residue fraction (twig, bark and post distillation leaf matter) is a sizable component of the total above ground biomass. Higher value may be obtainable from this fraction by developing new biomass processing technologies and product options. A number of emerging products have potential to be made from mallee biomass: including metallurgical charcoal (Langberg *et al.* 2006), densified fuel pellets and pyrolysis fuels (Polagye 2005). It is possible that some or all of these product options could support a delivered biomass price for biomass growers greater than that used in the base case scenario.

Due to it being a large component of the standing biomass, even a modest increase in the value of the residue fraction can increased the EAR from the mallee production system significantly. Doubling the value of the residue (to $36 per dry tonne) increased the mallee EAR from -$47.60/hectare to -$19/hectare under remaining base case assumptions. Setting the delivered value of the residue to a similar amount to the wood and leaf fractions (~$90/dry tonne) increased the mallee EAR to $66.00/hectare.

The current value of eucalyptus oil is in the order of AUS $10/kg delivered to the market; however the world market is limited in size. The base case return to the grower used in this analysis was $1.20/kg, which is an estimate for a long term competitive price assuming penetration into larger scale commodity markets such as industrial solvents. However, in the medium term higher prices are likely to be obtainable as production gradually expands. Doubling the delivered price to \$2.40/kg increased the mallee EAR from -\$47 to \$15 under remaining base case assumptions. If the delivered price was increased to \$3.60/kg then the mallee EAR increased to \$77 under base case assumptions.

Scenario 2: Manipulation of coppice cycle length

For a give suite of product opportunities, the profitability of the mallee production system could be improved by manipulating coppice cycle length. Within the 20 year analysis period, five different coppice cycle lengths were tested to examine the effect on mallee profitability. These were 2, 3, 4, 5 or 6 coppice harvests over the 20 year project life; equating to 2.5, 3, 3.75, 5 and 7.5 years between harvests respectively. Note that 5 coppice harvests on a 3 year cycle was the base case scenario. All other base case assumptions were maintained.

There was a complex interaction of factors affecting mallee profitability under different coppice length cycles. Shorter cycles were penalized by higher harvest costs, particularly in the low MAI range. Longer cycles had the advantage of a greater wood proportion in the standing biomass at harvest, which corresponded with higher overall biomass value. However, longer cycles were penalised by increased competition losses in adjacent crops and pastures and greater discounting of harvest returns. Where coppice was in the MAI range of 5-10 dry tonnes per hectare per year, a coppice cycle length of 3.75 years (corresponding to 4 coppice harvests during the 20 year project life) gave a slight improvement over the base case. At a coppice MAI of 7, the mallee EAR for 4 harvests was -\$41.14/ha compared with -\$47.60 for the base case scenario. For coppice MAI between 10 and 15 dry tonnes per hectare per year a coppice cycle length of 3 years (the base case) was optimal.

The sensitivity of mallee EAR to the value of the wood and leaf fractions was also tested for coppice cycle lengths of either 3 or 7.5 years. Mallee EAR was more sensitive to the price of the wood fraction compared with the leaf fraction and this effect was exacerbated as coppice MAI increased and coppice cycle length increased. This was due to contribution of wood to overall biomass value exceeding that of leaf, particularly for higher standing biomass values.

Scenario 3: Environmental services payments

The base case scenario did not include valuation of environmental services provided by mallee such as carbon sequestration, erosion control, biodiversity protection and/or salinity abatement. For a given parameter set, the difference between the Net Present Value (NPV) from the mallee land use and the NPV from annual crops and pastures allowed the determination of an annuity payment for environmental services required for a mallee production system to break even with existing agriculture.

Under the base case scenario, an environmental services annuity payment of \$114.60/ha/yr was required for the mallee system to provide an EAR equivalent to agricultural return of \$66.80 per hectare per year. Farmers are unlikely to value environmental services this highly under current farm business settings (Bathgate and Pannell, 2002, Pannell *et al.* 2006). Some level of external valuation, for example an environmental stewardship payment, which enables environmental services to provide a direct contribution to farm profits will be required for these services to contribute to the competitiveness of mallee production systems.

Carbon sequestration is a service provided by mallee with a high likelihood of becoming valued in Australian farm businesses in the near future. This is the result of policy evolution in response to the threat of climate change due to anthropogenic carbon emissions. Unlike annual crops and pastures, the mallee production system is capable of developing a permanent store of carbon in the below ground biomass. Assuming a below ground storage rate of 2-4 tonnes $CO_{2\ \mathrm{equiv}}$ per year; equating to approximately 30% of above ground biomass production; and a carbon price of \$10/tonne $CO_{2\ \mathrm{equiv}}$ the mallee system could generate an additional annual return of \$40/ha. In practice, it is difficult to predict the likely price of carbon if emissions reduction policies are implemented in Australia. However, under the base case assumptions used this study, the value of carbon required to make the mallee production system competitive with existing agriculture is substantially higher than reported carbon trading prices in the established European market (Flugge and Abadi, 2006).

The scope for market valuation of other environmental services payments, such as erosion control, salinity abatement and biodiversity protection, is less tangible. There appears to be growing interest in developing markets for environmental services around the world; however the design of effective schemes is complex and challenging (Salzman, 2005). Particular difficulties relate to achieving equity in the valuation of services provided by individual farms, without creating market distortions which either create unnecessary costs or reduce effective service provision. In an environmental stewardship scheme recognising service provide by perennial crop plants, it will be important for farmers to receive service payments in timeframes that are meaningful to their business and personal goals (Pannell *et al.* 2006). In Western Australia a number of State and Federal nature conservation initiatives already provide financial incentives payments for farm revegetation; particularly where revegetation is linked to the protection of high value nature conservation assets (Munro and Moore, 2005). These “up front” payments have the effect of partially or fully offsetting establishment costs for mallee belts.

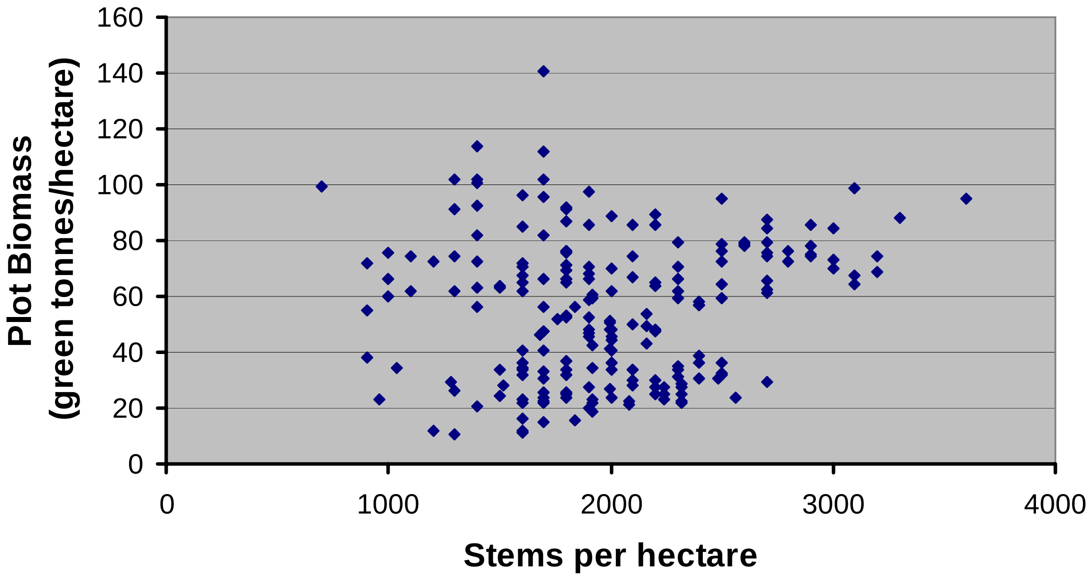
Scenario 4: Reduced establishment costs

It may be possible to reduce establishment costs through a combination of technological improvement and wider plant spacing. The cost of nursery grown seedlings is a substantial component of mallee establishment costs; with unit costs typically in the range of 25-35c per seedling. At the standard planting density of 2667 stems per belt hectare (2 rows occupying a 5m wide belt with seedlings spaced at 1.5m along the rows) and a seedling price of 27.5 cents, the base case scenario seedling cost equates to $733 per hectare.

Technologies to reduce establishment costs include direct sowing methods, which avoid the nursery component, or cheaper nursery production methods. The major challenge for direct sowing is to overcome risk factors for seed germination and early seedling growth which are controlled or negated in the nursery environment: these include erratic rainfall, inconsistent sowing depth, environmental extremes such as frost, weed competition and mortality due to pests and diseases. Important strategies for reducing nursery costs include achieving greater economies of scale and producing smaller seedlings over a shorter period before transplanting into the field. The Joint Venture Agroforestry program (JVAP), a consortium of national R&D Corporations, is actively exploring these lower cost establishment pathways (G Woodall, Centre for Excellence in Natural Resource Management, pers. comm. 2007).

Quantitative date on the growth response of mallee under different planting densities is not available. However, little relationship between planting density and standing plot biomass was observed in 210 plots across 12 sites measured by the authors (Fig. 24). Care must be taken is extrapolating from these observations; given that the plots span a range of age classes, soil types, establishment success rates and management histories. The response of different planting densities to coppicing treatments is also unknown. However, it appears to be plausible that mallee planting density could be reduced from 2667 stems per hectare without compromising biomass production

Fig. 24. Plot biomass[1] against standing stem density for 5-9 year old plots of *E. loxophleba* ssp. *lissophloia* in Western Australia (n=210).



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[1] Plot biomass assuming mallee belt occupies a 5m wide zone.

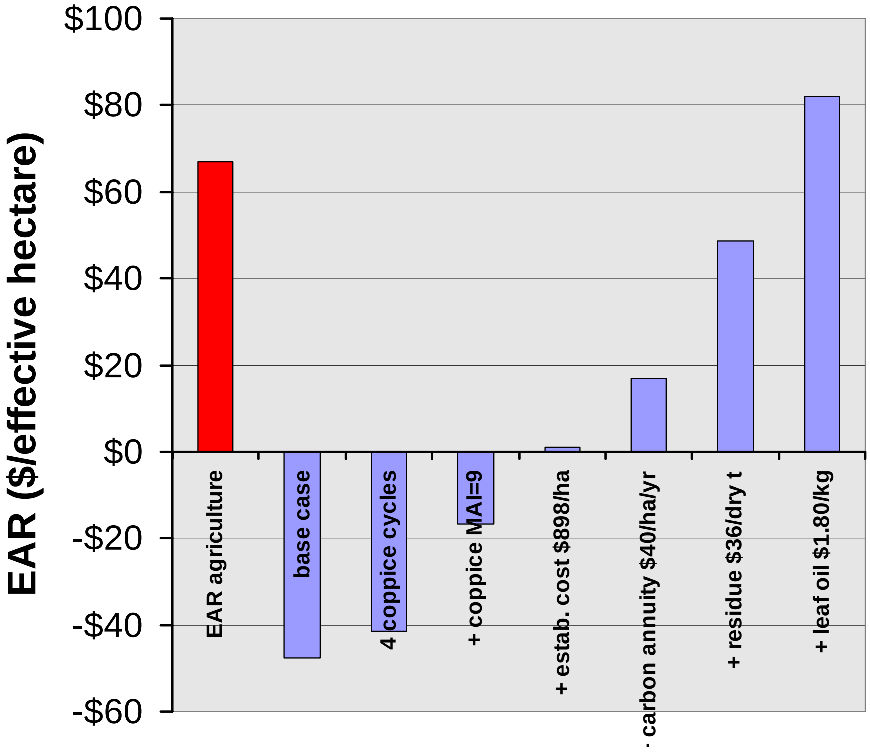
Scenario 5: System improvement on multiple fronts

Scenarios 1-4 show that marginal gains in any one of the development areas described will not be sufficient to make mallee highly competitive with current agriculture. However, combining these strategies into a "packaged" solution may provide enough overall improvement for mallee to be a viable perennial crop. This is demonstrated conceptually in Fig. 25, where relative to the base case scenario:

1. The interval between coppice harvests is increased from 3 to 3.75 years.
2. Coppice yield is increased from 7 to 9 MAI.
3. Establishment costs are reduced by 25%.
4. A carbon sequestration annuity of $40 per hectare per year is achieved.
5. The value of the residual biomass (twig, bark and spent leaf) is doubled.
6. The value of the leaf biomass is increased by 50%.

For many of the mallee production system parameters, such as growth rates and establishment costs, there are environmental and/or technical constraints to increasing revenues or reducing costs. As such, this analysis highlights the importance of achieving the highest possible price for mallee biomass in order to improve overall system performance.

Fig. 25. Cumulative improvement in mallee production system profitability, where gains are made across a suite of production parameters.



Discussion

In order for perennial revegetation to make a meaningful contribution to landscape sustainability, substantial displacement of existing annual crops and pastures will be required. The profitability of perennial options will be a crucial determinant of the level of adoption by farmers (Pannell *et al.* 2006). This study has attempted to provide insights into the profitability of mallee belts integrated into low rainfall, broad acre farming systems. The results indicate that for observed levels of mallee biomass productivity and projected returns for mallee biomass, adoption of mallee at a significant scale is unlikely without improvements in mallee production system performance on multiple fronts.

Based on sensitivity and scenario analysis, a number of strategies exist to improve the economic competitiveness of the mallee crops. It is suggested that future research and development of the mallee production systems is structured around these strategies, which include:

- **Maximise the price paid for delivered mallee biomass.** Optimal bio-processing models which utilize and add value to all biomass components require development. Many biomass processing technologies exist, however the next phase of development requires their commercialization and combination into an integrated "biorefinery package". The demonstration scale Integrated Wood Processing plant at Narrogin Western Australia, developed by the State Government owned energy generation company Verve Energy, represents the most developed example of such a system for mallee so far (Verve Energy, 2007). This demonstration plant successfully produced electricity, eucalyptus oil and activated carbon from mallee biomass; however system integration issues remain a challenge. Future system design will need to ensure that biomass production is well interfaced with systems of processing and product manufacture. Parameters of particular importance include the size of the overall biomass resource and the composition of delivered biomass. Similarly, the supply chain needs to be designed to be highly complementary with processor feed-stock requirements. Innovation in developing new and existing markets for mallee derived products is another key requirement.

- **Improve biomass yields.** Yield improvement can be achieved by several means. Firstly, site types with the least constraints to mallee productivity can be targeted. Favourable site attributes include deep profiles amenable to root exploration and relatively high soil water holding capacity (ref). A criterion for site selection would also include sites with relatively low returns from conventional agriculture. Deep sandy soils, at risk of wind erosion, could be an example of a site type with high suitability for mallee belts. Secondly, selection and breeding improvement programs can improve the genetic potential for rapid growth and improved biomass quality for product derivation. Significant biomass productivity gains have been achieved from breeding programs for other forestry species (ref). Thirdly, active interventions to capture the agricultural water surplus can be implemented. The direction and capture of surface water flows onto mallee belts, using systems of shallow contour banks, is an example of a relatively simple water harvesting system.

- **Reduce establishment costs.** Some level of cost reduction should be achievable through a combination of technological and agronomic improvements. Government policies which offset establishment costs are currently important and warrant further scrutiny to determine their cost effectiveness in contributing to environmental benefits.

- **Reduce harvest costs.** The harvest system is critical for the economic competitiveness of mallee production systems. It is clear that the development of the low cost, conceptual continuous flow harvesting system used in this study is a vital development requirement. Existing harvesting technologies, using conventional forestry equipment, are substantially more costly and therefore not viable.

- **Develop environmental service payments.** It will be important for the mallee industry to be well positioned to benefit from environmental services payments, which may become available in the future. Research to quantify these benefits is therefore a priority. Determination of carbon sequestration capacity of mallee belts, particularly in the below ground biomass, is likely to contribute to an additional revenue stream in the near future. Studies to enable monetary valuation of wind erosion reduction, dryland salinity abatement and biodiversity protection services provided by mallees may also be valuable. However, expenditure on research into these areas must be balanced against the likelihood that they will be able to contribute to grower profits under future settings.

The economic model used in this study has some important limitations which should be addressed by future refinements. These include:

- **Biomass growth and utility:**
  Variation in biomass partitioning as the mallees grow under a repeated harvesting regime has implications for the ease and cost harvesting, biomass utility and biomass value. Growth curves for mallee coppice are currently not well understood. The assumption of linear MAI curves in this analysis is an oversimplification and may bias the findings by making shorter harvest cycles appear more favourable. Key areas of current research include:

  1. Understanding patterns of growth through time and under different management regimes, in particular the season and frequency of harvesting. This includes the dynamics of biomass partitioning as plants age and the effect of nutrient cycling and depletion on coppice growth.

  2. Understanding the effect of biomass production and supply chain systems on the utility of the biomass, including system losses. What proportion of the above ground biomass can be comminuted into wood chips, which are a relatively high value product and have a strong effect on breakeven yields and delivered prices? Can the assumption of a minimum dimension of >17mm diameter inside bark be validated? With respect to leaf oil products, how will movement through the supply chain affect oil volatilization and loss from the system?

- **Competition with adjacent crops and pastures:**
  Competition effects have been poorly quantified in the field but have been shown to be highly important in the economic model. More research is needed to better understand this area for regularly harvested mallee, particularly in relation to seasonal effects. Competition could be expected to be less for mallee harvested on a shorter harvest frequency. The advantage of shorter cycles over longer cycles will be exacerbated substantially if this is the case. High levels of variation between sites and across seasons, as has been observed in other studies, are likely to make the incorporation of these effects into economic models complex (Oliver *et al.* 2005).

- **Whole of farm economic analysis:**
  The gross margin analysis method used in this study is indicative of the profitability of converting a broad acre cropping paddock into an alley farming system. However, whole farm budgeting analysis is required to quantify the effect of this type of land use change on the overall farming business. Whole farm modelling would also better enable management and risk management implications of adopting mallee belts to be explored. For example, the protection of young coppice from grazing damage is likely to necessitate modifications to grazing management across the farm.

Although the development of mallee into a commercially competitive crop remains highly challenging, the prospect is real. The findings of this study are intended to help guide the targeting and prioritisation of resources for developing mallee as a crop for the western Australian wheatbelt. The premise of this work is that profitability will be the critical determinant of widespread adoption by farmers. Engagement with potential biomass processors to ensure biomass production, supply chain and processing activities are well coordinated is an important task for industry developers; given the sensitivity of on farm profitability to delivered biomass price.

4. Case Study 1: Woody Bioenergy Crops for Lower Rainfall Regions of Southern Australia

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Introduction

FloraSearch and the WA Search reports (Hobbs *et al.* 2008c, Bennell *et al.* 2008, Olsen *et al.* 2004) identified the most prospective industry types for the wheat-sheep zone of southern Australia. They identify the high priority or "best bet" industries and detail some emerging industries that may be serviced by woody crop production in the mid-low rainfall areas of Australia. Bioenergy markets for electricity generation, liquid fuels, fuel pellets and integrated tree processing for multiple products are emerging from a world environment of higher fossil fuel costs, climate change, environmental awareness and advances in technology.

Governments around the world are encouraging the production and consumption of renewable energies to reduce greenhouse gas emissions in response to the threat of climate change; to strengthen national energy security; and to promote better community health.

Mitigation of climate change has stimulated huge investment into the use of renewable fuels as one method of reducing carbon emissions. There is a range of research projects underway around the world to develop new bioenergy technologies and improve existing technologies. Burning biomass as an energy source returns to the atmosphere the CO_2 that was absorbed by the plants and there is not net release of CO_2 if the cycle is sustained. Fossil energy is consumed in producing bioenergy but the energy used is usually a small fraction of the energy produced. When producing liquid bioenergy more input energy is required but roughly 4-5 times the output energy is produced per unit input. The replacement of fossil fuel used represents a significant reduction in CO_2 additions to the atmosphere.

New industrial process development is a lengthy and expensive step-by-step process usually following the steps below:

- Bench scale plant in the laboratory and used for small trial runs
- Larger plant in laboratory working continuously
- Pilot plant adjacent to the laboratory
- Demonstration scale plant
- First commercial plant
- Second commercial plant, which incorporates lessons learned from the first commercial scale plant.

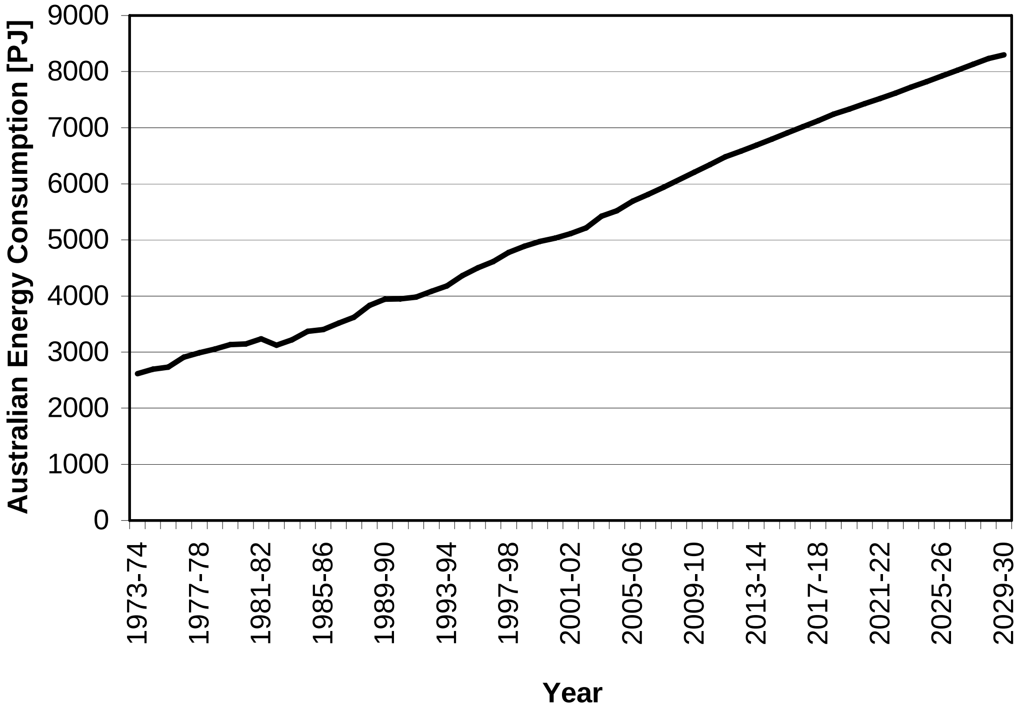
It is quite common for this sequence to take ten years or longer.

The viability of these new industries is also dependant on the provision of consistent and continuous supplies of woody biomass feedstocks. In the initial stages of developing these new industries some difficulties and risks may stem from infant primary productions systems, harvest technologies and supply chains. Initially benefits may be gained from utilising biomass derived from annual biomass crops and conventional annual crop or forestry waste streams prior to the establishment of consistent woody biomass crop supplies for these new energy industries.

Energy Demands in Australia

Australia consumes around 5500 Petajoules (1 PJ = 10^{15} joules) of energy ever year across our industrial, mining, agricultural, commercial and residential sectors (see Fig. 26). Approximately 900PJ of energy is used to generate electricity (see Table 18). In Australia electricity generation is predominantly based on black and brown coal deposits with current ABARE (2005b) forecasts expecting this heavy reliance on coal resources to continue. Our major coal resources, used to generate electricity, are widely variable in their inherent energy values largely due to their variable moisture and carbon contents (see Table 19, Table 20). The value of thermal coals for both domestic and export markets have increased by at least 12% in recent years (see Table 21, ABARE 2005b).

Fig. 26. Primary energy consumption across all energy sectors in Australia since 1973-74.



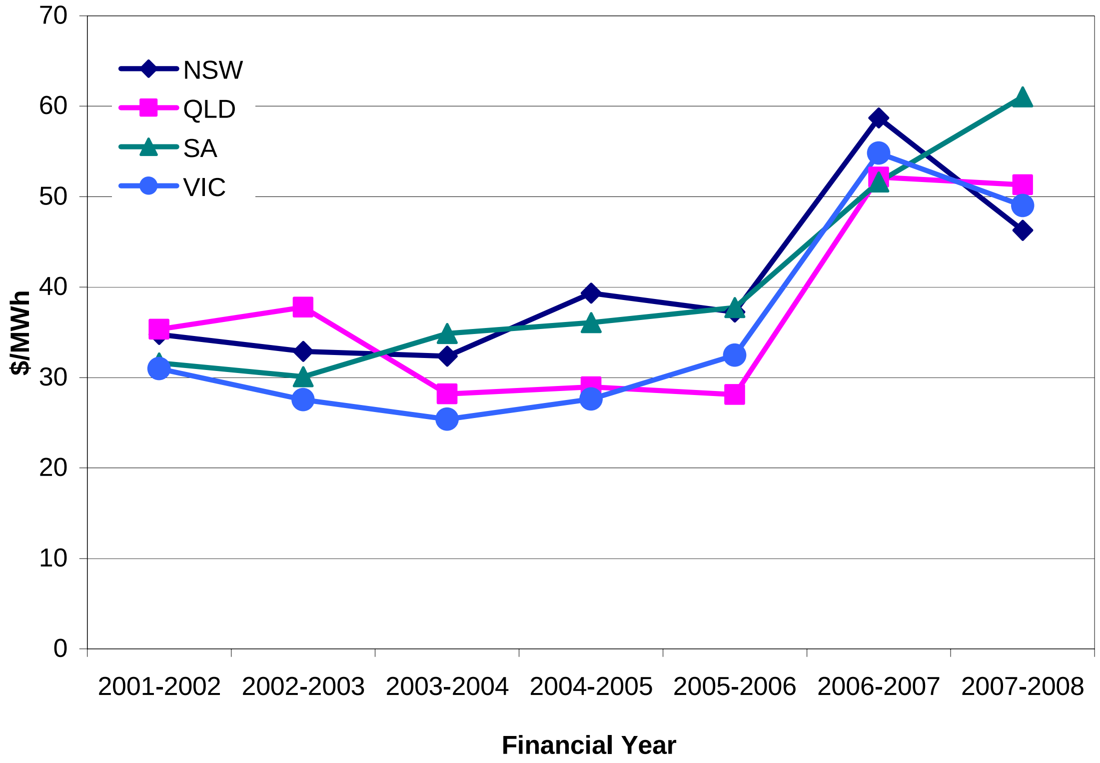
Source: ABARE 2008

21.3 million people currently live in Australia (May 2008) and we consume and export vast amounts of energy through the combustion of coal, oil and natural gas for heat and electrical energy, and export large quantities of coal every year (see Table 17). In Australia we are large consumers of electrical energy, not just for our households and offices but also from a variety of mining and manufacturing industries. Our national maximum instantaneous electricity generation capacity is 47 Gigawatts (Department of Resources, Energy and Tourism, 2008) and this equates to 220 kilowatts per person. The cost of generating this power is increasing and dramatically since 2005-06 (Fig. 27).

As part of Australia's response to global warming, the federal Government initiated the Mandatory Renewable Energy Target (MRET) in April 2001 (DCC 2008c). This target required the generation of 9,500 gigawatt (GW) hours of extra renewable electricity per year by 2010. This equates to residential energy requirements of 4 million Australians. Recently, the Federal Government has committed to increase the Mandatory Renewable Energy Target five-fold from 9500GWh to 45000 GWh by 2020. Renewable Energy Certificate (REC) prices have increased strongly since the beginning of the year reaching more than $53, well above expected values (see Fig. 28). Other policy commitments are on their way at both state and federal level that will have an impact on future supply / demand for RECs.

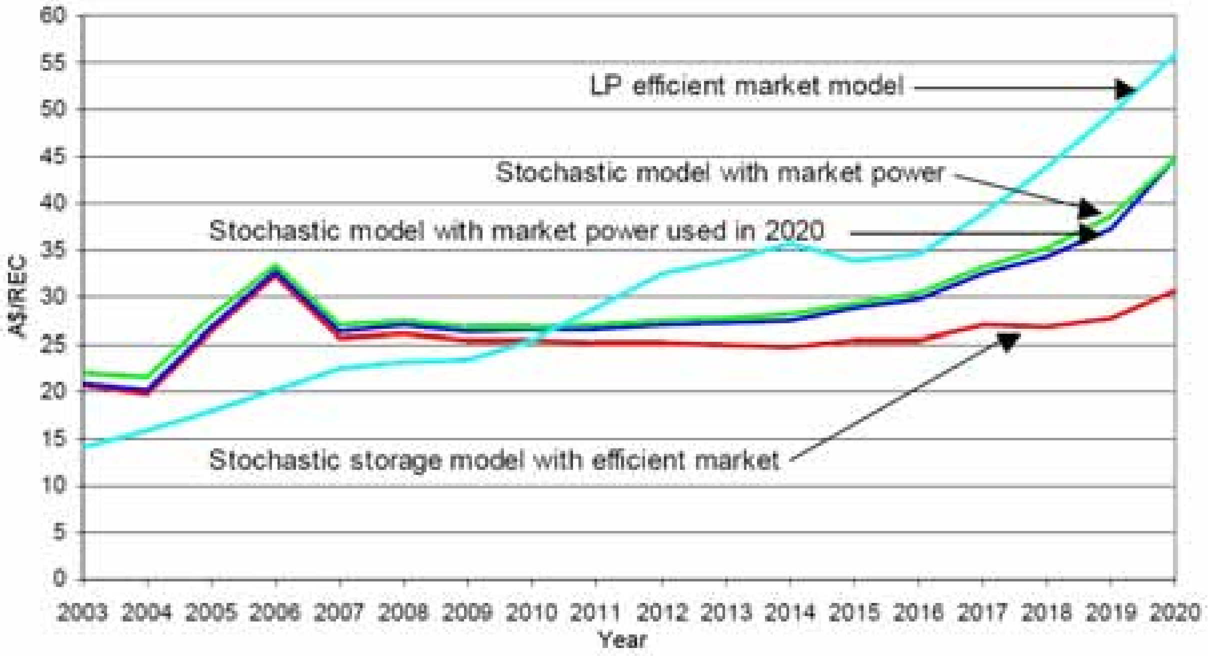
Bioenergy production could reduce or stabilise the contribution of energy markets to global warming through the use of renewable crops that potentially could result in a carbon neutral energy system. Power plants fuelled by biomass could conceivably contribute 1,000 megawatts (MW) of Australia's electricity generating capacity to replace an equivalent electricity production capacity from coal-fired power plants. This level of displacement, if achieved, would lead to a fall of about 7.4 million tonnes a year in net carbon dioxide emissions. Biofuels such as ethanol can also be used to replace petrol or diesel powered vehicles, similarly reducing net carbon dioxide emissions.

Fig. 27. Cost of electrical energy in Australia in recent years.



Source: NEMMCO (2008)

Fig. 28. Modelled expected prices for Renewable Energy Certificates in Australia.



Source: Intelligent Energy Systems (2002)

Thermal coal

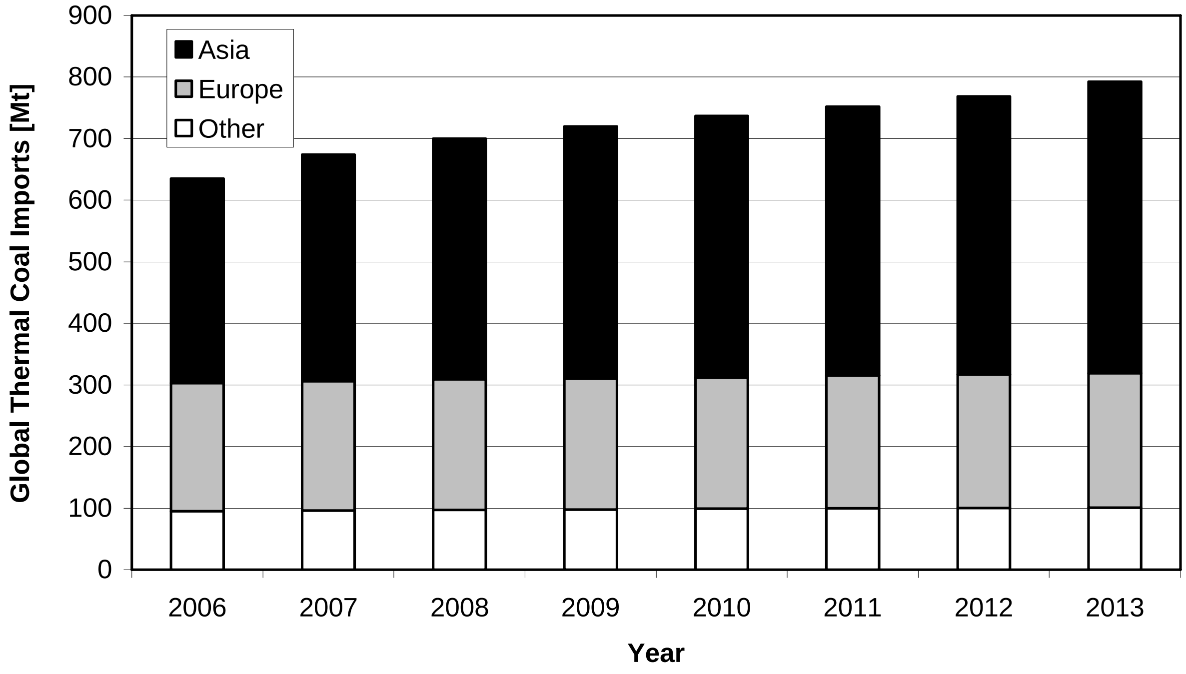
The spot price for Newcastle thermal coal averaged US$66/t in 2007 and has recently reached as high as US$140/t in February 2008 (ABARE 2008, Steelguru 2008). Contract prices for thermal coal exported to Japan for 2007-08 were settled at US$55.50/t. However, ABARE (2008) indicate that current demand and supply issues will substantially raise contract prices in 2008-09. In the medium-term (2008-2013) global thermal coal imports are expected to increase by 2.7% per annum to about 790 million tonnes with Australia providing approximately 21% of this commodity. These expected increased are dominated by continued growth in Asian electricity generation and consumption.

Table 17. Recent and projected production and export of thermal coal in Australia.

Australia	Unit	2006	2007	2008^f	2009^f	2010^f	2011^f	2012^f	2013^f
production	Mt	174.2	181.1	179.6	191.4	199.3	211	230.7	237.1
exports									
volume	Mt	110.8	111.6	107.7	119	129.5	146.6	160	168
value*	A$m	7623	6947	8142	14235	15112	16361	15999	15046

^{f} ABARE forecast; *In 2007-08 dollars, Source: ABARE (2008)

Fig. 29. World recent and projected global import volumes of thermal coal.



(Source: ABARE 2008)

Table 18. Recent and projected electricity generation by fuel type in Australia.

Electricity generation, by fuel	2004-05 [PJ]	2009-10 [PJ]	2014-15 [PJ]	2019-20 [PJ]	2029-30 [PJ]
Thermal					
Black coal	469	513	578	640	757
Brown coal	187	199	211	226	256
Oil	11	11	12	13	15
Gas	128	157	184	221	321
Total thermal	796	880	985	1101	1349
Renewables					
Hydro	58	61	61	62	65
Wind	5.5	13.5	20.9	21.7	28.4
Biomass	3.3	5.4	7.4	11.2	23.1
Biogas	2.1	4.7	5.2	5.8	7.7
Total renewables	69	85	94	101	124

Source: ABARE 2005b

Table 19. Energy content of major solid fuels in Australia.

Type by Location	GJ/t		GJ/t
Black coal		*Black Coal (cont)*	
New South Wales		Western Australia	
Exports		Steaming coal	19.7
- coking coal	29.0	Tasmania	
- steaming coal	27.0	Steaming coal	22.8
Electricity generation	23.4		
Steelworks	30.0	**Brown Coal / Lignite**	
Washed steaming coal	27.0	Victorian brown coal	9.8
Unwashed steaming coal	23.9	South Australia	15.2
Queensland		Brown coal briquettes	22.1
Exports			
Coking coal	30.0	**Other**	
Steaming coal	27.0	Coke	27.0
Electricity generation	23.4	Wood (dry)	16.2
Other	23.0	Bagasse	9.6

Source: ABARE 2005b

Table 20. The calorific value and carbon content of major southern Australian coal resources.

Coal Type and Location	**Gross Calorific Value [#1] [GJ/dry t]**	**Carbon Content [#1] [%dry weight]**	**Moisture Content [#2] [%fresh weight]**	**Gross Calorific Value [GJ/fresh weight t]**
Black Coal (Collie WA)	25.1	69.5	26.0	20.0
Black Coal (Hunter Valley NSW)	25.6	63.2	3.3	24.7
Black Coal (Liddle NSW)	20.7	50.6	3.3	20.0
Black Coal (Mt Piper NSW)	27.5	67.3	3.2	26.6
Brown Coal (Gippsland Vic)	26.4	67.5	60.6	10.4
Brown Coal (Leigh Creek SA)	21.2	54.3	31.0	15.1

Sources: CSIRO Biofuels Database 2006, DEH 2005.

Table 21. Recent historical, and predicted, volumes and values of Australia thermal coal exports.

Recent Years	**Unit**	**2003-04**	**2004-05**	**2005-06**	**2006-07**	**2007-08**	**2008-09**	**2009-10**
Volume	Mt	106.7	106.4	109.0	124.7	128.5	130.5	131.7
Value	A$m	4481	6337	6860	6954	6472	6038	5609
Unit value	A$/t	42.00	59.55	62.90	56.40	50.40	46.30	42.60

Source: ABARE 2005b

Results from detailed destructive sampling of Eucalyptus (mainly mallees) and Acacia species in the wheat-sheep zone of South Australia provides us with information on biomass fractions and fresh weight water content of hardwood species (Hobbs and Bennell 2005). The average moisture content of whole 10 year old plants is 39% (range 34-44%), with no significant difference between Eucalypt and Acacia species. The average dry biomass ratio by weight of Stemwood: Twigs: Leaf and Fine Twigs was found to be 38:31:31.

The average gross calorific value of fresh weight biomass from Australian hardwood species is greater than some coal deposits used to generate electricity in Australia (see Table 22, Table 20). Many current coal powered generation plants can readily accept 5% plant biomass blended with coal with no requirement for engineering modifications. Higher proportions of plant biomass are likely to require only minimal engineering changes in generation facilities.

Table 22. The calorific value and carbon content of selected Australian hardwood species.

Species	**Gross Calorific Value [#1] [GJ/dry t]**	**Carbon Content [#1] [%dry weight]**	**Moisture Content [#2] [%fresh weight]**	**Gross Calorific Value [GJ/fresh weight t]**
Acacia saligna	19.1	49.4	*39.0*	11.5
Atriplex nummularia	16.8	42.3	*39.0*	9.2
Corymbia maculate	19.1	48.7	*39.0*	11.4
Eucalyptus camaldulensis	19.4	49.5	*39.0*	11.8
Eucalyptus cladocalyx	19.0	49.0	*39.0*	11.4
Eucalyptus cneorifolia	19.9	49.9	*39.0*	12.3
Eucalyptus globulus	19.2	49.1	*39.0*	11.6
Eucalyptus grandis	18.8	48.8	*39.0*	11.2
Eucalyptus horistes	20.0	49.0	*39.0*	12.4
Eucalyptus occidentalis	19.0	49.3	*39.0*	11.4
Eucalyptus sideroxylon	19.9	50.9	*39.0*	12.3
Eucalyptus polybractea	19.7	48.7	*39.0*	12.1
Melaleuca uncifolia	20.9	52.0	*39.0*	13.3
Average Eucalypt/Acacia	19.4	49.3	39.0	11.8
Black Coal (avg. of Table 20)	24.7	62.7	9.0	22.8
Brown Coal (avg. of Table 20)	23.8	60.9	45.8	12.8

Sources: [#1]CSIRO Biofuels Database 2006; **[#2]**Average moisture content of whole native plants (*estimated for species*) Hobbs and Bennell 2005.

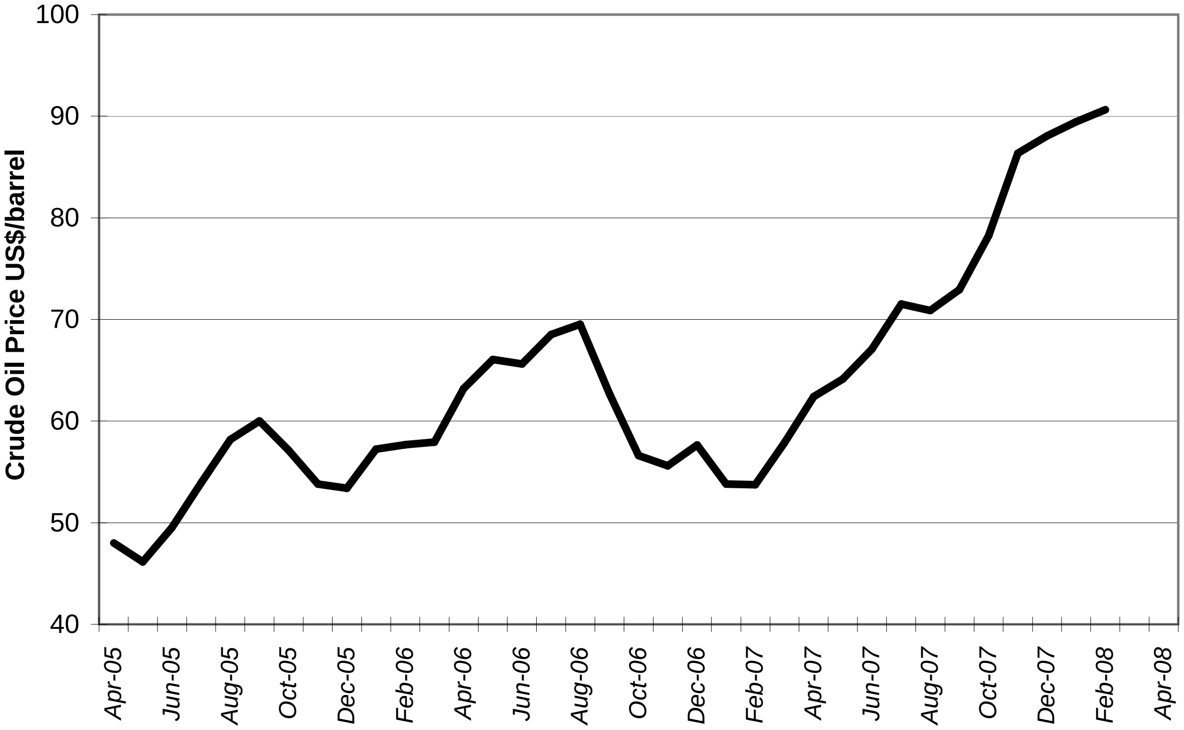
Transport Fuels

The world price of oil has escalated from around US$25 in 2001 to over US$60/barrel in 2006 and is currently in excess of $100 /barrel (EIA 2008). West Texas Intermediate (WTI) crude oil spot prices increased from $101 to $120 per barrel over the first 3 weeks of April 2008 as supply disruptions in Nigeria and the North Sea and continuing strong demand growth in the emerging market countries pressured oil markets. WTI crude oil prices, which averaged $72 per barrel in 2007, are projected to average $110 per barrel in 2008 and $103 per barrel in 2009 (Energy Information Administration USA).

Earlier reports of the viability of biomass the liquid fuel technology could now be viewed as out of date as a consequence of these dramatic changes. For example, Enecon (2002), using information provided by the Centre for International Economics, concluded that 'the prospect for the next 15 years at least is for declining rather than increasing crude oil prices.' They used a crude oil price of $22/barrel in their assessment of the comparative costs of ethanol, methanol (manufactured from woody feedstocks) and petrol, projected for the year 2015.

The Biofuels Taskforce (2005) has reported to the Prime Minister on status, potential and issues of biofuels development and adoption in Australia. This report draws upon ABARE analyses of the viability of ethanol and biodiesel in the current policy and market environment. ABARE's models are based on assumed oil price of US$32/barrel and an US$/A$ exchange rate of 0.65. They also state, *"Should the long-term oil price be higher, all other things being equal, the commercial viability prospects of biofuels would improve."* They conclude, based on an US$/A$ exchange rate of 0.65, that ethanol producers would remain viable beyond 2015 with a oil price of US$42-47/barrel with out government assistance, and biodiesel producers would require an oil price of US$52-62/barrel to remain viable without assistance.

Fig. 30. Indicative world oil prices (West Texas Intermediate) in recent years.



Source: EIA (2008)

Liquid Biofuels

In our earlier FloraSearch reports ethanol and biodiesel production from woody biomass was identified as two potential industries for Australia (FloraSearch 1 and 2, Bennell *et al.* 2008, Hobbs *et al.* 2008c). At the time two factors downgraded the priority of these industry types: 1/ the relatively low price of mineral oil based fuels; and 2/ the infant stage of the technology required to convert woody biomass to ethanol or biodiesel. In recent years we have seen changes in both of these areas.

The technologies of converting woody biomass to produce ethanol have also progressed in the last two years. Globally, there has been significant investment and progress in lignocellulosic ethanol technologies for bio-fuels. In the USA a large increase in ethanol as a motor fuel is expected because of 2 policy initiatives: a $USA 0.51 tax credit per gallon of ethanol used as motor fuel and a new mandate for up to 7.5 billion gallon of 'renewable fuel' to be used as a petrol supplement by 2012.

(Farrell *et al.* 2006) this project demand is increasing the likelihood that lignocellulosic biomass (wood and agricultural residue) will become an important feedstock for the production of bio-fuel. These materials typically comprise of cellulose (40 - 60 %), hemicellulose (20 - 40 %) and lignin (10 - 25%) that will be a residue and can be used as a fuel for energy production (Hamelinck *et al.* 2003).

Lignocellulosic biomass can be converted to ethanol by hydrolysis where the cellulosic part is converted to sugars and subsequent fermentation converts these sugars to ethanol. To increase to yield of hydrolysis a pre-treatment step softens the biomass and breaks down cell structure to a large extent. There are several options for pre-treatment and hydrolysis but current technological development is focused on enzymic hydrolysis which requires very mild process conditions, while giving good yield, lower capital investment and less environmental risk. This technology is relatively immature requiring an expected 10 years before being industrially adopted but is provides the possibility for significant improvements in production costs.

Biodiesel production is mostly derived from oilseed plants such as canola, tallow (animal fat) and used cooking oil. New technologies to create biodiesel from woody feedstock using pyrolysis is not yet commercially viable in Australia, however, significant research is currently underway to develop a practical ‘Second Generation’ technologies for this purpose.

Bioethanol production in Australia

Biofuel ethanol in Australia is currently produced by fermenting plant products such as sugar, molasses and cereals. Two ethanol plants with combined production capacity of 152 megalitres (ML) are currently operating in Australia. By the end of this year it is expected that 4 ethanol plants will be operating in Australia, with a combined production capacity of just under 270 ML. Currently planned projects could also produce an additional 500 ML by the end of 2010. The use of ethanol for transport fuel is growing rapidly in Australia where it is typically blended at 10% (E10) with petrol and is now available at more than 600 service stations across the country. If 25% of Australia vehicles used E10 the total Australian market for fuel ethanol would be ~6,500 ML and save more than A$5 billion worth of petrol imports.

Globally, ethanol makes up no more than 2% of all transport fuel, but total consumption in 2007 was 45–50,000 million litres (ML), with Brazil and the United States consuming 80% of the world total and growing at ~15% per year (BAA 2008). Global fuel ethanol sales are growing much faster than petrol sales. Blends vary from as little as 5% (E5) to pure (100%) ethanol, but the most common blends are E10, E22, and E85. The European Commission targets to replace 10% of its transport fuels with renewable ethanol and biodiesel by 2020 (European Commission 1997).

Current fermentation or ‘First Generation’ ethanol production competes with food resources such as cereals and sugars used for human consumption. Future demands for ethanol are likely to be met by new ‘Second Generation’ technologies (eg. ‘lignocellulosic’ conversion to ethanol).

Willmott Forests Limited recently announced they intend to invest in 3 year, $20 million project designed to commercialise a new patented fuel ethanol production process through their subsidiary Ethanol Technologies Limited (Ethtec, 2008). They intend to develop technologies to convert fibrous biomass to ethanol and generate surplus electricity from combustion of the lignin co-product. The intended process consists of 4 parts: 1/Hydrolysis of woody biomass using concentrated sulphuric acid, extruder and tube reactor treatments to produce sugars; 2/ Lignin separation from sugars and acid recovery, lignin for combustion/energy; 3/ Fermentation of the pentose and hexose sugars to ethanol; and 4 /Ethanol recovery using potassium carbonate, and water recycling. Their feasibility studies have concluded that fuel ethanol produced by the Ethtec process will have a crude oil equivalent cost in the range of US$36-50 per barrel and is highly competitive with the current crude oil prices. The pilot plant is situated at the NSW Sugar Milling Co-Operative Harwood Mill and Refinery in Northern NSW and will use pine forest wastes and bagasse.

Biodiesel production in Australia

In January 2008, there were 10 biodiesel plants with combined production capacity of just under 560 megalitres (ML). Only 4 of these plants are currently operating to produce approximately 85 ML of biodiesel from tallow and used cooking oil (BAA 2008). With increasing feedstock prices the industry is investigating alternative oil sources. Transesterification of vegetable oils and animal fats can produce a biodiesel with similar properties to petrodiesel and suitable for use in most diesel engines. Although the biodiesel derived from vegetable oils, animal fats, used cooking oil, oilseeds (e.g. canola, sunflower) and palm oil can be used in most diesel engine it often retails as a blend with petrodiesel. Australia's capacity to replace petrodiesel with locally-produced biodiesel could increase to 10–40% with the development of 'Second Generation' technologies and the adoption of alternate biomass feedstocks.

In 2007, Australia consumed around 60 million litres (ML) of biodiesel but this only represents~0.4% of diesel fuel used for road transport (BAA 2008). Australian mining companies and transport fleets are trialling B20 blends and biodiesel is increasing becoming available at many service stations across the country. Europe accounts for more than 80% of global biodiesel consumption where sales have grown to around 5 billion litres and the European Commission targets to replace 10% of its transport fuels with renewable fuels by 2020 (European Commission 1997). China also targets 15% replacement of petrodiesel by 2020. The use of biodiesel in the United States for transportation and heating oil has also grown rapidly in recent years following petrochemical security and pricing issues in the world. Greenhouse gas emissions in response to the threat of climate change, energy security and crude oil price are all drivers of this change towards renewable liquid fuels.

Woody Biomass to Refined Energy Technologies

A number of technologies are emerging and being developed for converting woody biomass to liquid fuels. Recently Enecon Pty Ltd completed a study of bioenergy technologies and opportunities for the Avon Catchment region in WA. Enecon (2007) provides a more detailed description of major technology pathways being developed to produce liquid fuels. The following section provides a summary of these technologies based on those reported by Enecon (2007).

Pyrolysis

Pyrolysis involves the heating of biomass in the absence oxygen to prevent burning. Heat is not produced so external heating of the biomass is required to break down the biomass into solid, liquid and gaseous fractions. The temperature, time for heating and other variables determine whether the pyrolysis action produces predominately charcoal solids (typically via slow processes) or bio oil liquids (typically via fast pyrolysis).

For successful fast pyrolysis the biomass feed requires some preparation:

- Grounding into small particles that allows the particles to heat rapidly when they are introduced onto the pyrolysis reactor and facilitates the conversion to large percentages of oil.
- Drying to contain around 10% moisture or less. Moisture in the biomass feed carries through the process and dilutes the oil that is produced.

Fast pyrolysis largely converts woody material into liquid bio oil with charcoal as a secondary product. The fast pyrolysis process as commercialised by Canadian company Dynamotive (2008) heats wood feed to almost 500ºC in approximately one second, and typically converts two thirds of the biomass feed into liquid bio oil. The construction of such a plant is expected to cost between $40 and $50 million dollars depending on the extent of facilities, location and site works required. As more full-scale pyrolysis plants are built and operated over coming years, these costs are expected to reduce.

Slow pyrolysis operates with different temperatures and achieves a different product mix to fast pyrolysis. Notable in Australia is the pyrolysis technology being developed by BEST Energies in New South Wales. A demonstration scale plant is operational in NSW and the focus of this plant is to process biomass for charcoal and syngas rather than the maximisation of liquid products as targeted in fast pyrolysis processes.

Bio oil is quite different to biodiesel produced from tallow, palm oil or other oilseed crops. The two liquids have different feedstocks, production processes and chemical compositions. Bio oil cannot currently be used in vehicle engines, although research is underway at Monash University and in Europe and the USA to resolve this. Bio oil can be used as a fuel for heating or steam generation or as a fuel for power generation in gas turbines.

Bio oil cannot be produced at a cost that will make it competitive with Australian coal or natural gas, which are among the cheapest fossil fuels in the world. However it does have a number of immediate applications that may be commercially competitive on a case-by-case basis:

- For supply of electricity at remote locations as a replacement for diesel generators
- For supply of heat in locations that do not have access to natural gas
- As a replacement for heating oil

There is considerable interest in pyrolysis charcoal for a variety of product markets:

- **Stationary energy -** It has been considered as a renewable feed component for coal-fired power stations.
- **Metallurgical charcoal -** The CSIRO has examined the use of wood charcoals as a reductant in various metallurgical industries.
- **Industrial fuel -** It is technically feasible to use charcoal as a renewable fuel. For mallee feed at a cost of $30 per tonne, such a pyrolysis plant could produce liquid fuel at a cost roughly comparable with current prices for LPG, heating oils and diesel. A sustained price increase for crude oil will improve the competitive position for bio oil.
- **Soil improvement -** Adding carbon to soils via charcoal (“agrichar”) appears to have multiple benefits. The carbon is sequestered (with the possibility that carbon sequestration payments may be included in future trading regimes). Also the carbon is reported to enhance the yields of plants grown in the improved soils.
- **Activated carbon -** As with many other charcoal materials, it should be possible to make activated carbon from pyrolysis charcoal. This could be achieved via steam activation or acid activation.

Other products from pyrolysis include:

- Food flavourings - Fast pyrolysis is already used in North America for the production of chemicals e.g. production of smoke flavourings for food.

- Resin chemicals - A number of research groups around the world have demonstrated that bio oil can be used in the manufacture of resins. The phenolic materials present in the lignin can replace other materials currently used in phenol formaldehyde and similar resins. These resins are widely used for engineering wood products (including plywood and oriented strand board) and have other industrial applications.

Biomass to transport fuel

Biomasses to Liquid (BtL) fuels are at an early commercialisation stage of development. BtL involves the gasification of biomass into mainly hydrogen and carbon monoxide (called “syngas”), followed by a synthesis step to produce a range of alternative fuels, most notably methanol, dimethyl ether, and synthetic diesel. Gasification is a high temperature process, which operates in an oxygen-starved environment. Choren in Germany is undertaking the most commercially advanced work. A large scale BtL synthetic diesel plant is currently under construction, and this is expected to be followed by construction of the first commercial scale plant (sized to use one million tonnes dry biomass per year as feed supply) in Germany towards the end of this decade. Choren is sizing its commercial plants to achieve the economies of scale possible with large industrial facilities. Product cost would currently be more expensive than conventional liquid transport fuels, but with further technology development and suitable feedstock price BtL is a good prospect for the future, probably within a decade.

A variety of liquid transportation fuels can by synthesised using thermo-chemical conversion of woody biomass. Examples of such fuels are:

- Methanol

- Dimethyl ether (DME)

- Synthetic diesel fuel created via the Fischer-Tropsch process.

Methanol is an established chemical commodity that is currently produced around the world from natural gas and coal. It has well-established international markets and provides the feedstock for the manufacture of several bulk chemicals such as formaldehyde. Methanol is not currently a major transportation fuel, but has been identified as a suitable fuel for use in future fuel cell vehicles.

DME is an extremely clean burning fuel, with physical properties very similar to LPG. It is used in a number of chemical processes but at this stage it is still regarded as an experimental fuel, with motor vehicle companies such as Volvo trialing its use.

Fischer Tropsch synthesis of fuels and chemicals is well established from fossil fuels most notably coal. Fischer Tropsch diesel may be used as a direct substitute for diesel, as this fuel meets the specifications for petroleum diesel.

BtL fuel is produced in a two-step process. The first step involves preparation of synthesis gas (a mixture of carbon monoxide and hydrogen) from a biomass feedstock and conversion of the synthesis gas into liquid fuel via chemical processing involving catalyst beds. Biomass gasification is a relatively well-developed technology, with some large-scale gasifiers having operated for close to two decades. Such an example is the Lahti gasifier in Finland, which has gasified biomass for co-combustion with coal. The synthesis process involves passing the gas over catalytic beds tailored for the end product fuel. The gasification process can use a variety of biomass types within compositional constraints, as the objective is to transform the biomass into carbon monoxide and hydrogen. BtL plants are invariably required for technical and economical reasons to be large industrial facilities.

Biomass would be treated to remove dirt, dry it to the required moisture level, and obtain the required biomass particle size specifications. Oil mallee biomass would in principle be a suitable fuel.

Hamelinck *et al.* (2003) modelled Biomass Integrated Gasification Fischer Tropsch plants and determined the investment cost of a 367 MW input BIG-FT system to cost in the range $280-450 million US dollars (2004), depending on configuration. Hamelinck calculated that in the short term, the production cost of F-T diesel would be US$15/GJ, and in the longer term with technology refinement, could reduce to US$10/GJ. Assuming a lower heating value of 43.5 GJ/tonne and a density of 780 kg per cubic metre (actual values from the Güssing plant), the near term production cost would be US 50.9 cents per litre. This cost estimate assumes a biomass cost of US$2/GJ from dry biomass, which equates to approximately US$40 per dry tonne or approximately or A$30 per green tonne (in 2008).

BtL is one of the more prospective bioenergy technologies on the horizon able to produce liquid fuels that will fit into the existing liquid fuel markets. The synthesis pathway to make gasified wood into liquid fuels can also be used with gasified coal, or a syngas from natural gas itself. There is already a significant industry worldwide that uses natural gas to make chemicals/fuels such as methanol this way.

Biomass to ethanol

Wood contains significant quantities of sugar that may be converted to ethanol, provided these sugars are first “released” from the wood and made available for fermentation. It is also possible to break the wood into small molecules (“syngas”) via gasification, and then rebuild those molecules into ethanol via chemical synthesis. These different technologies have been broadly understood for many years but have never moved past the pilot or demonstration stage. This may change over the next few years, as earlier in 2007 the US government announced significant funding support for six commercial scale biomass to ethanol plants to be built in the USA. This work is largely a result of the “US Biofuels Initiative” which aims to make cellulosic ethanol cost competitive with gasoline by 2012 and to replace 30 percent of current levels of gasoline consumption with biofuels by 2030.

The total investment on these projects over the next five years could exceed A$1 billion. In less than ten years it should be possible to engage with companies offering proven biomass to ethanol technology for the construction and operation of biomass to ethanol plants. A full-scale biomass to ethanol plant is expected to use more than half a million tonnes of green biomass each year.

A number of alternative process pathways are available to turn woody biomass into ethanol (Abengoa Bioenergy 2008). They all have three main stages:

- Pre-treatment of the biomass to make it amenable for further processing
- Break the wood down into components, via hydrolysis or via gasification
- Reform those components into ethanol, via fermentation or catalytic synthesis.

Hydrolysis breaks wood into its basic sugars. The cellulose and hemicellulose components of wood are essentially long, molecular chains of sugar. They are protected by the lignin in the wood that binds the biomass together. So-called C6 or hexose sugars are associated with the cellulose. C5 or pentose sugars are associated with the hemicellulose. Conventional yeast is adapted to C6 sugars, but the fermentation of pentose sugars to ethanol requires yeasts that are genetically adapted or different micro-organisms altogether. These technologies include 2 form of hydrolysis:

Acid Hydrolysis - Acids can be used to break cellulose and hemicellulose into their component sugars.

Enzyme Hydrolysis - Hydrolysis can also be achieved using enzymes (Iogen Bioenergy 2008). The enzymes need to be specifically matched to the biomass feedstocks and the biomass needs to be more homogeneous than for acid hydrolysis. In recent years there has been a dramatic fall in the cost of enzymes, with the US National Renewable Energy Laboratory reporting a thirty fold reduction in enzyme costs.

Apart from the well-developed fermentation processes new technologies are being developed for ethanol production. These include:

- Gasification and Reforming where synthesis gas from the thermal gasification of biomass can be chemically processed using catalysts to produce ethanol. The reforming process eliminates the need for micro-organisms to produce the ethanol, which is instead produced via chemical processing.

- Gasification and Fermentation - a novel fermentation process that can convert carbon monoxide and hydrogen (biomass gasification) into ethanol. The organism consumes carbon monoxide, carbon dioxide, and hydrogen to produce ethanol and acetic acid. Preliminary calculations would indicate that ethanol yields of 375-400 litres per tonne of wood could result.

With the financial support being provided by the US government ethanol from biomass appears to be better placed now than ever before for a move from technical feasibility to commercial operation. If work in the USA goes according to plan there will be commercial scale examples of biomass to ethanol in operation in a few years, although it will take several more years before the lessons learnt from the operation of these initial plants are used to design and build additional plants. A reliable, commercial scale biomass to ethanol technology may be achieved within ten years.

Pilot projects are being developed in Australia. Ethanol Technologies Limited (Ethtec), a Willmott Forests Limited company, has announced that work has begun on a three-year AU$20 million project designed to commercialise a new patented fuel ethanol production process (Ethtec 2008). The technology converts fibrous biomass to ethanol and generates surplus electricity from combustion of the lignin co-product.

The individual processes to be brought online at the new plant include:

- Hydrolysis: concentrated sulphuric acid treatment of woody biomass feedstock.

- Lignin separation and acid recovery: separation of the lignin and the acid from the sugars, recycling of the acid for continuous production and recovery of the lignin for combustion to provide process energy.

- Fermentation: simultaneous fermentation of the pentose and hexose sugars to ethanol using newly developed micro-organisms.

- Ethanol recovery: from the fermentation broth by induced phase separation using potassium carbonate, simultaneously treating and recycling the water to production.

Feasibility studies have concluded that fuel ethanol produced by the Ethtec process will have a crude oil equivalent cost in the range of US$36-50 per barrel when the ethanol is used in blends with petroleum fuels. This cost of ethanol, without government subsidies, is highly competitive with the current cost of crude oil that is in the range of US$90-100 per barrel.

Biorefining

Processing crude oil in an oil refinery is an accepted practice worldwide. Importantly it allows the maximum value to be extracted from the crude oil, by making products for energy, and also products for plastics and other applications. Many groups are examining biomass in a similar light, with a view to creating commercial "biorefineries". Such processing facilities would utilise biomass for energy but they would also create additional value by taking some of the processed biomass to make chemicals or other high value products. A number of overseas organisations are developing new processes to turn biomass into plastics and other chemicals. The US Government is allocating significant funds to speed up the development of a commercial biorefining industry. In 2007 the US Department of Energy made a provisional allocation of up to US$200 million to support a five year program for development of new biomass processing technologies that combine the production of renewable transport fuels with bio-based chemicals that substitute for petroleum based feedstocks. There are already commercial scale plants in the USA that produce renewable plastics.

Fuel pellets

Wood pellet consumption in Europe is already significant for both domestic and industrial applications and is forecast to grow rapidly in coming years, particularly as a result of renewable energy legislation within the European Community. Japanese consumers use pellets for heating, and at least one Japanese Power Company is trialling large-scale pellet use for renewable energy. The use of pellets is limited in Australia. Over the past decade wood energy pellets have filled a minor niche in North American and European energy markets, mainly in the domestic heating sector. However in recent times wood pellets have become an increasingly important energy source for both the domestic and industrial energy sectors, mainly as a result of increased emphasis on renewable energy sources. This is expected to increase further as a result of policy initiatives by various governments, particularly in Europe. At present energy from biomass contributes approximately 4 percent of the total EU energy supply, predominantly in heat and, to a lesser extent, in combined heat and power (CHP) applications. By 2010, biomass is expected to account for as much as 8 percent of the total EU energy supply. This target underpins the European Energy White Paper (COM-1997-599) to double the EU's renewable energy sources from 6 to 12 percent of gross energy consumption, and is also an element of the plan for the EU countries to meet their overall European Kyoto Protocol target (European Commission 1997). Use of biomass has been encouraged in several European countries through the introduction of domestic carbon taxes and grants for low carbon fuels.

Pellets are manufactured by grounding wood into small particles and then dried and processed with readily available equipment. Compared with the original wood these pellets have relatively high energy content, and are easy to transport, store and utilise for heat and power. Wood pellets are short cylindrical pieces of biomass with a diameter 6-8 mm and are produced from sawdust, cutter shavings, chips or bark by grinding the raw material to a fine powder that is pressed through a perforated matrix or die. The friction of the process provides enough heat to soften the lignin in the wood. During the subsequent cooling, the lignin stiffens and binds the material together. The manufacturing process increases the bulk density of the feedstock from typically 100 to 650 kg/m3. The energy content of pellets is approximately 17.5 GJ/tonne with moisture content of 8-10 percent. Pellet plants can be built at a wide range of sizes and larger plants will generally offer economy of scale, but may also face greater costs for feed brought in from a larger growing area.

Preliminary modelling has been carried out by Enecon (2007) to estimate the costs for production, transport and storage of pellets made in the Avon catchment and shipped to Europe. A pellet business appears to be quite profitable for a range of publicly quoted European pellet prices, however, pellet pricing in Europe varies significantly by country, and pricing within countries may vary significantly from year to year. Particular emphasis was given to a pellet business opportunity in this study because of its potential for short-term commercial exploitation.

Integrated tree processing plant (oil / charcoal / bioenergy)

The development of an integrated tree processing (ITP) demonstration plant at Narrogin in WA has been reported in depth by Western Power (2006) and Enecon (2001). Most of the engineering of the ITP plant was completed in 2005 and the plant tested during 2006. The concept is based on utilising in-field chipping harvest technologies to deliver 20,000 tonnes of chipped mallee (Eucalyptus spp.) wood, twigs and leaves to the plant per annum for processing to produce 7.5 GWh/year of electricity, 690 tonnes/year of activated carbon, and 210 tonnes/year of Eucalyptus oil. The ITP plant will incorporate a fluidised bed carbonising plant, steam distillation plant, thermal gasifier spent leaf combustor plant and a 1 MW steam turbine power generation plant. Additional benefits will be derived from greenhouse gas abatement scheme from renewable energy generation, rootmass fixation and standing woody crop biomass.

Regional Woody Crop Production

The development of regional productivity models has been focussed on Bioenergy Species and Oil Mallee Species (as defined in the FloraSearch 3a report, Hobbs *et al.* 2009a). The models have been based on relationships between our observations of plantation productivity in the region and soil-climate models. Raupach *et al.* (2001) developed the "*BiosEquil Model*" and created a national productivity surface coverage suitable for computer-based Geographic Information Systems (GIS). The *BiosEquil Model* coverage provides coarse resolution (~1km²) data for Australia. This productivity modelling methodology has been described previously in the FloraSearch Stage 2 report (Hobbs *et al.* 2008c). Regional spatial and economic models for proposed Bioenergy industries are based our latest models (Hobbs *et al.* 2006, 2008a,c) for green biomass accumulation rates shown in Fig. 31 and Fig. 32.

Alternative spatial production predictions have also recently been built using 3PG process models for the collaborative JVAP *Regional opportunities for agroforestry* project (Polglase *et al.* 2008) using low resolution soil information and CSIRO *Lower Murray Landscape Futures* project (Bryan *et al.* 2007b) where high quality soils data is available. These 3PG models are currently restricted to limited range of species and the model outputs were not available at the time of the analyses presented in this report. Bryan *et al.* (2007b) demonstrates that the Biosequil and 3PG models are strongly correlated and raises the issue that the highest quality and resolution biophysical data, and refined model calibration datasets, be used for future models of woody crop production. Equally, new model predictions must also take into account climate changes that will influence crop growth in the future.

In this study we have selected two suites of species for bioenergy crop production. The first, '*Bioenergy Species*' are discussed and detailed in the FloraSearch 2 and 3a reports (Hobbs *et al.* 2008c, Hobbs *et al.* 2009a) and include fast growing Eucalypt woodland and forest species (eg. *Eucalyptus cladocalyx, E. occidentalis, E. camaldulensis/rudis*). The second, '*Oil Mallee Species*' include oil bearing, but less productive Eucalypt mallees (eg. *E. polybractea, E. loxophleba* ssp. *lissophloia, E. porosa*). The species chosen for each group are not limited to those listed above but can be substituted by similarly productive species suited to each location, soil and climate type. Coppicing species have a 30% increase in total biomass productivity in subsequent harvest resulting from having effectively more stems per hectare and established investments in root biomass.

Fig. 31. Green biomass productivity of bioenergy species in southern Australia (at 1000 plants per ha).

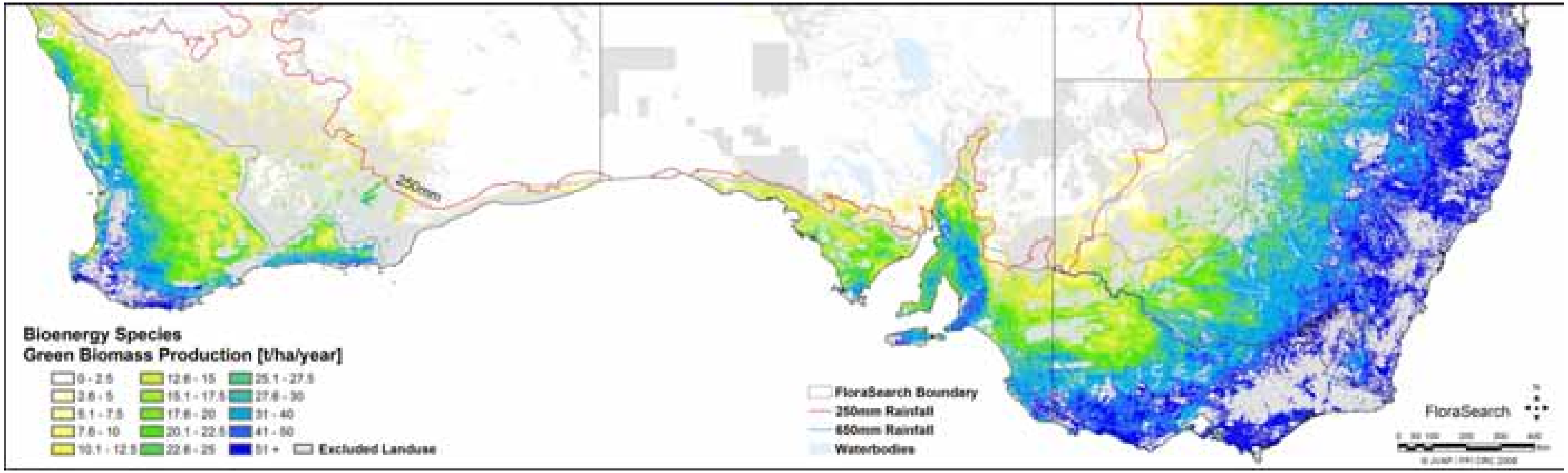
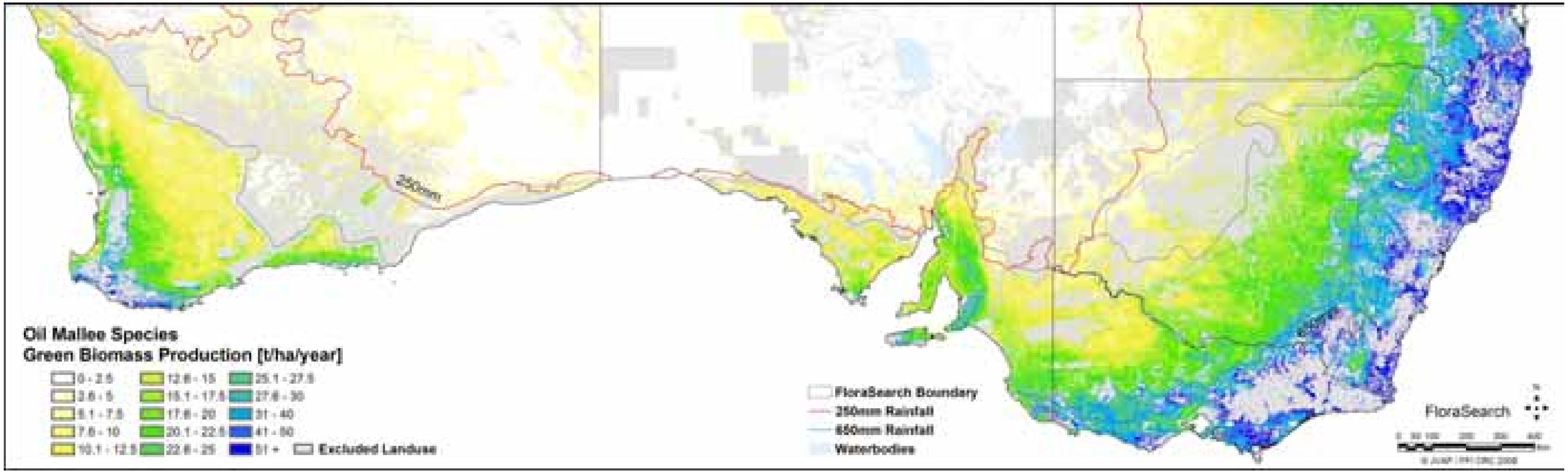


Fig. 32. Green biomass productivity of oil mallee species in southern Australia (at 1000 plants per ha).



Regional Industry Potential Analysis for Bioenergy 2008

New industry modelling approach

The *Regional Industry Potential Analysis* (*RIPA*) is a methodology for evaluating the potential plantation productivity and industry product yields, economically optimum harvest intervals of woody crops, landholder annual equivalent returns (AER) from each industry type and location, and sensitivity analyses. The methodology of the *Regional Industry Potential Analysis* is detailed in the FloraSearch 1a and 2 reports (Bennell *et al.* 2008, Hobbs *et al.* 2008c) and should be read prior to reviewing the current outputs. The following section is based on that methodology and has been conducted for generic bioenergy markets. *RIPA* allows spatial and economic evaluations across existing available land with potential for woody crops, and new industries based on energy demands and supporting existing infrastructure. This study provides a hypothetical exploration of new investments in infrastructure or prospective industry types for woody bioenergy crops.

In brief, the *RIPA* model consists of a series of models predicting potential spatial distributions of individual species based on bioclimatic relationships, spatial plantation productivities and yields of biomass components, point-based economic models of optimised annual equivalent returns from short cycle woody perennial woody crops, and transportation network models for each industry type. Finally, the *RIPA* integrates point-based economic models with spatial information to predict agroforestry equivalents to gross margin analyses (used to evaluate the short-term economic performance of crops and livestock). The integrated *RIPA* model is not scale dependant - for this study we have undertaken analyses at a one kilometre resolution but the following study (see Section 5, '*Case Study 2: Woody Crop Potential in the Upper South East Region of SA*') is conducted at one hectare resolution due to the availability of more detailed mapping of region landuse, vegetation and soil mapping, and computational limitations. ArcGIS 9.1 (ESRI 2005) geographic information system software is used for these spatial models and analyses.

The analyses presented in this section are focussed on electricity infrastructure and demands. The population and industry driven demands for other renewable fuel types (eg. liquid fuels from wood biomass, heating energy) are paralleled by electricity consumption and associated infrastructure. In this study we use electricity demands as a surrogate for demands in other energy types. Fig. 34 to Fig. 36 illustrates the scale and distribution of energy-hungry populations, electricity generation and transmission infrastructure, and current solid fuel (coal and renewable woody/ bagasse biomass) energy generation facilities in mainland southern Australia.

We have mapped existing infrastructure which may be utilised for bioenergy industries (eg. roads, processing plants, electricity substations etc.; see Fig. 35, Fig. 36, Hobbs *et al.* 2008c). Our analysis of population densities, existing powerplants using renewable solid biomass, supply distances from major generators (i.e. >20MW), existing substation locations and peak loads, transmission lines and regional wood crops productivity (see Fig. 34 to Fig. 38) has identified priority locations for new bioenergy processing facilities and provide indications of their feasibility. We have geographically located hypothetical new facilities to support prospective new bioenergy industries (Fig. 38). Fig. 39 shows the current and proposed locations of liquid biofuel processing facilities in southern mainland Australia. The biodiesel plants are based on tallow, used cooking oil or vegetable oils (or in combination). The ethanol plants are largely based on cereals (eg. wheat, sorghum). However, the proposed Willmott Harwood ethanol/electricity plant near NSW's north coast (Ethtec 2008) is planning to produce ethanol from lignocellulosic material such as wood, bagasse (waste from sugar production), crop stubble and municipal green waste.

Freight costs are a significant contributor to the economics of bioenergy commodities, especially for producers of high volume / relatively low value product that need to be transported to distant mills and processing plants (Bennell *et al.* 2008, Hobbs *et al.* 2008c). Transport costs are dependant on vehicle travel speeds and are variable in their proportion of running costs and driver salaries. Transport paths and associated freight costs have been mapped and evaluated between each hectare of land potentially available for new woody biomass industries and each existing or hypothetical facility. To increase the accuracy of spatial economic models we detailed different road types and surfaces to estimate maximum travels speeds on all major roads servicing southern Australia. The following equation was used in our models to account for transport costs by road networks:

$$\textbf{Transport cost multiplier} = \mathbf{0.0002466 * Road\ Speed^2 - 0.04553 * Road\ Speed + 3.092}$$

Using the base cost of \$0.14/t/km return trip included, and road speed information Fig. 34 demonstrates the range of freight costs from highway to farm tracks.

The economic module of the *RIPA* model incorporates all plantation establishment and maintenance costs for each biomass industry group of species. Planting densities are set at 1000 plants per hectare for all bioenergy and oil mallee species groups. Establishment costs are based on those reported by Hobbs *et al.* (2008c), Bulman (2002) and Mt Lofty Ranges Private Forestry (2006) for farm forestry woodlots and adjusted these values to 2008 prices given inflationary increases over time. For this study we have used a very generous establishment cost of \$1300/ha for trees and mallees (similar to Polglase *et al.* 2008). However, broadacre agroforestry establishment costs in flat, simple and sandy landscapes could be around 25% less than this figure, or even less if cheaper establishment techniques are developed (eg. direct seeding). Average annual maintenance costs have been set at \$15/ha/year to include occasional and sporadic activities such as firebreak control, supplementary fertilisers, follow-up weed and pest control. Harvest costs are set at \$12/ green tonne using continuous flow in-field biomass chipping technologies described by Enecon Pty Ltd (2001). A summary of establishment, harvest and transport costs are presented in Table 23.

The economics module then combines information on plantation productivities, changes in plantation product component yields (ie. biomass fractions) with plant age, establishment costs, maintenance costs, harvest costs and delivered feedstock values (see Table 12), a financial discount rate of 7%, and conducts sensitivity analyses to determine economically optimal harvest cycles (ie. on average, first = 8 years and subsequent = 5 years, slightly longer for slower growing species). Given the infant state of woody biomass crops for bioenergy in Australia and the world, and the wide range of estimates given for commodity values, we have explored several commodity values in our study and present a group of mid-range estimates (eg. \$20, \$30 and \$40/green tonne). Spatial economics models have been constructed and applied to spatial surfaces of plantation productivities and road transport costs (where applicable) for all land potentially available to this new industry type in the region. Cash flows over the first 20 years of each production system (under a financial discount rate of 7%) are converted to *Annual Equivalent Returns* (AER) which allows direct comparisons with annual gross margin analyses for existing annual agricultural.

New industry economic and spatial evaluations

Regional Industry Potential Analysis (*RIPA*) models have been applied for bioenergy and oil mallee integrated tree processing in the southern half of mainland Australia. Model outputs include parts of neighbouring higher rainfall and arid regions. However, our productivity models have not been calibrated for higher rainfall regions (eg. >700mm) and greater caution is required in interpreting economic results for areas outside of the FloraSearch zone. The *RIPA* model outputs of *Annual Equivalent Returns* for each bioenergy scenario are present in Fig. 41 to Fig. 44.

Prospective bioenergy and oil mallee systems (Integrated Tree Processing, see Fig. 44) could provide substantial returns in the region but these require a reasonable investment in new infrastructure to be viable. Carbon sequestration in unharvested woody crops could provide additional benefits and are analysed in the following regional case study (see Section 5, '*Case Study 2: Woody Crop Potential in the Upper South East Region of SA*') for a range of species groups including local native revegetation species. Carbon sequestration using unharvested *Bioenergy* species and current world carbon prices could provide reasonable returns to land holders when carbon trading is available (see Section 5).

Equally, if the average standing biomass and root biomass of harvested woody crops was included in carbon sequestration trading it could provide additional income streams to extractive agroforestry enterprises in the region.

Fig. 33. Influence of road speed on 2008 freight costs used in spatial economic models.

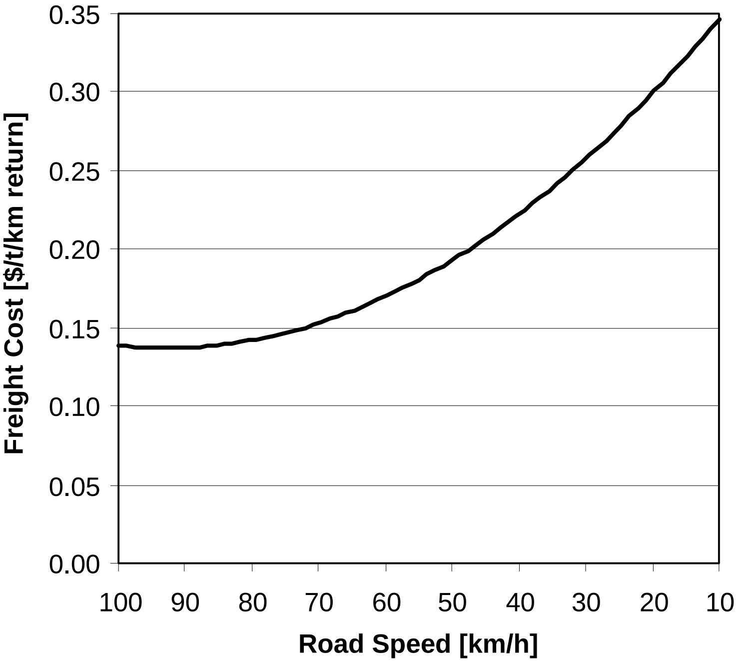


Table 23. Primary production, freight costs and discount rate used in regional industry potential analysis for woody bioenergy crops in 2008.

Establishment Costs ($/ha)	**Site planning, setup and land preparation**	**Seedlings, planting, fertiliser and watering**	**Weed/Pest management and control**	**Total Establishment costs [$/ha]**
Planting density = 1,000 trees/ha	425	800	75	1300

Production, Harvest and Investment Costs	**Average Maintenance Costs ($/ha/year)**	**Harvest Costs ($/freshweight tonne of total biomass)**	**Freight costs – includes truck return trip ($/t/km)**	**Discount rate**
Harvest cycle = First at 8 years, then every 5 years	15	12	0.14#	7%

base of 0.14 $/t/km (depending on road/track surface, see Fig. 54)

Fig. 34. Southern Australian mainland population centres and sizes.

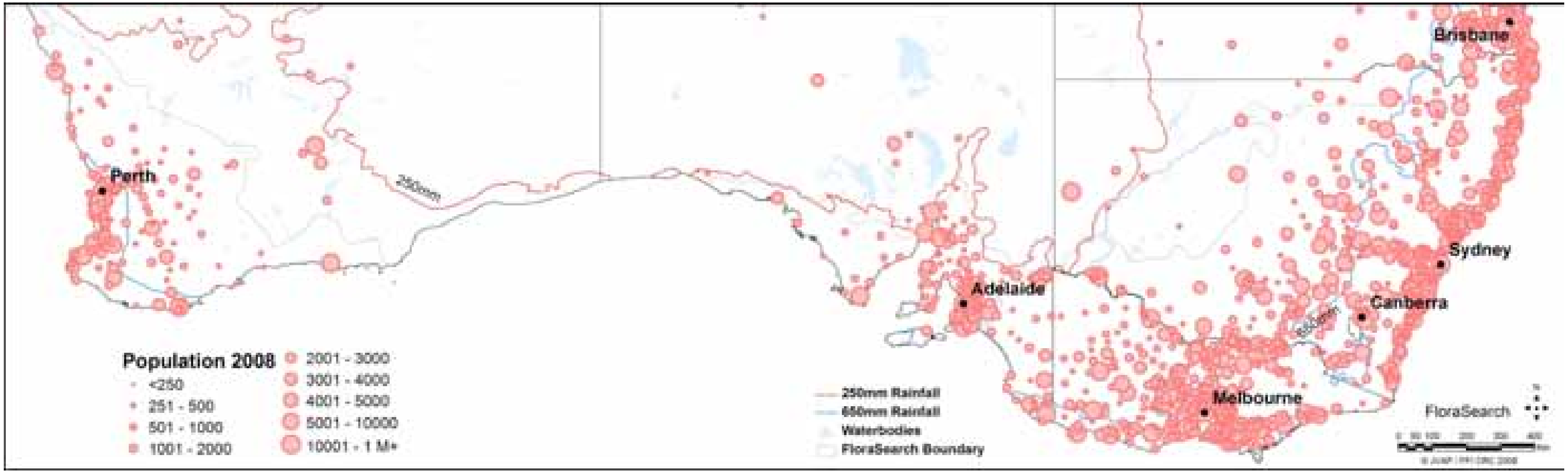


Fig. 35. Existing electricity infrastructure in southern Australia.

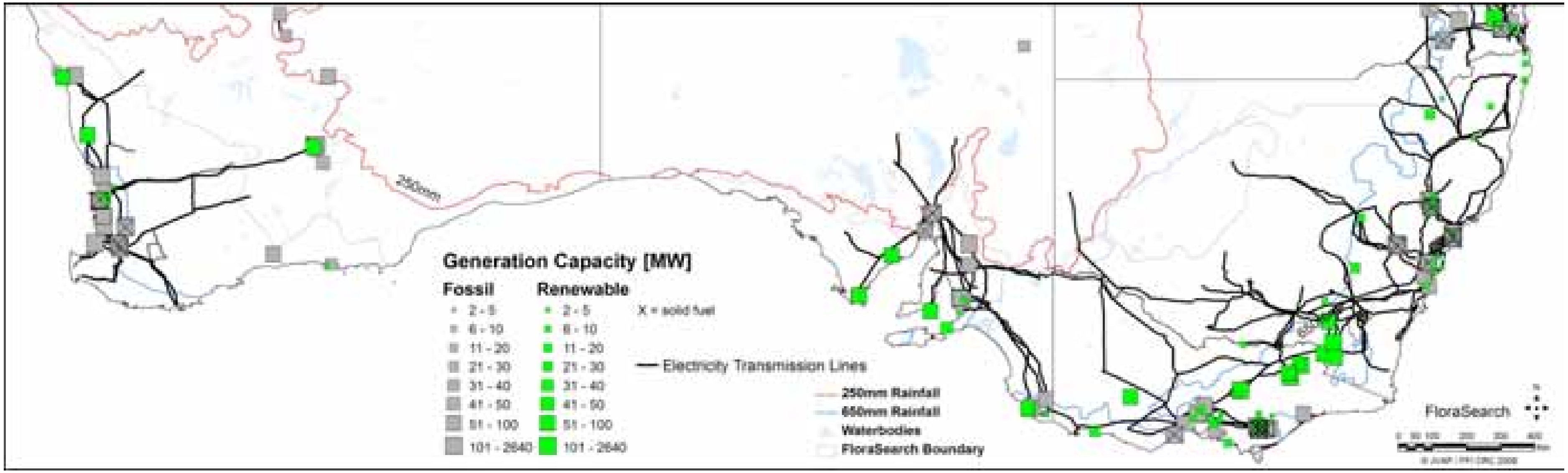


Fig. 36. Southern Australia electrical energy - present consumption centres and demand.

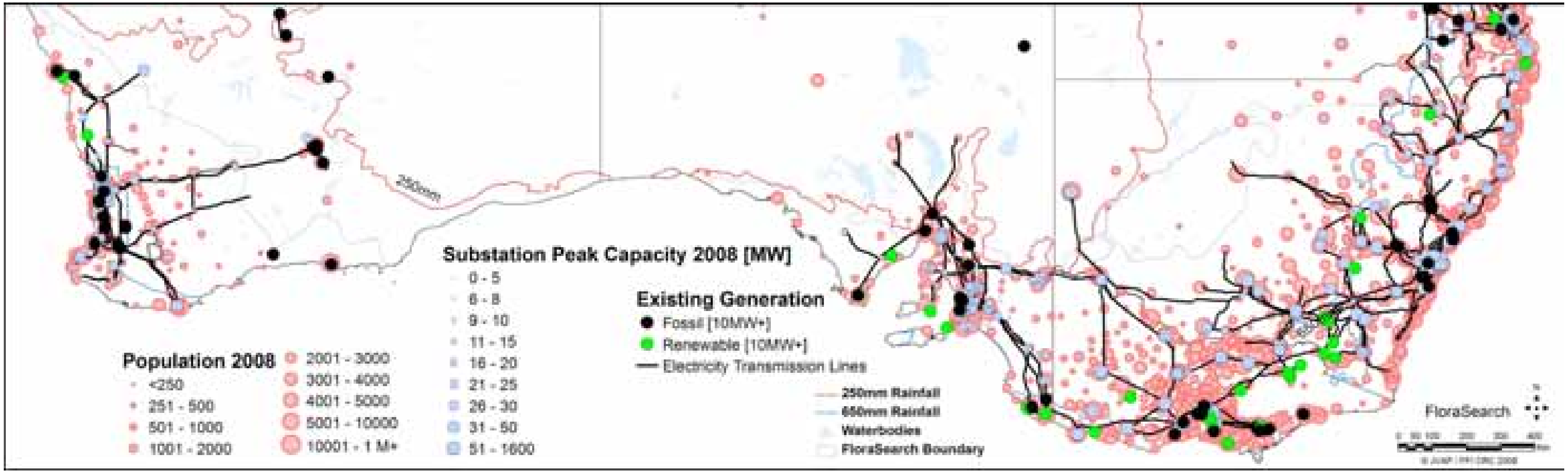


Fig. 37. Electricity demand versus supply distance in southern Australia based on population driven demand.

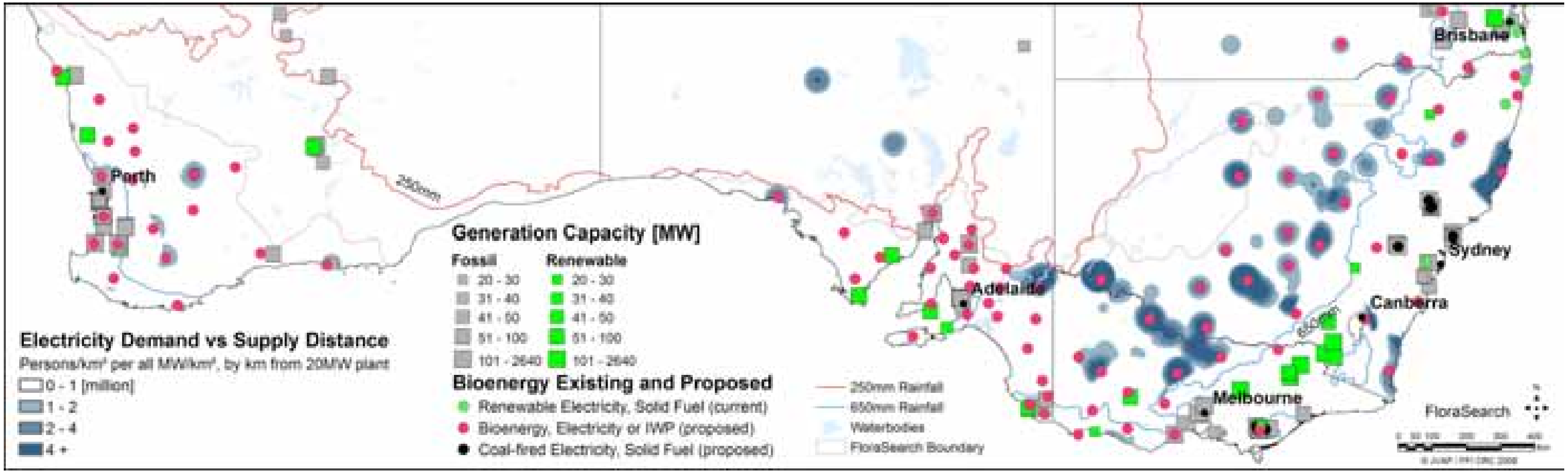


Fig. 38. Maximum green biomass productivity of bioenergy and oil mallee species in southern Australia (at 1000 plants per ha).

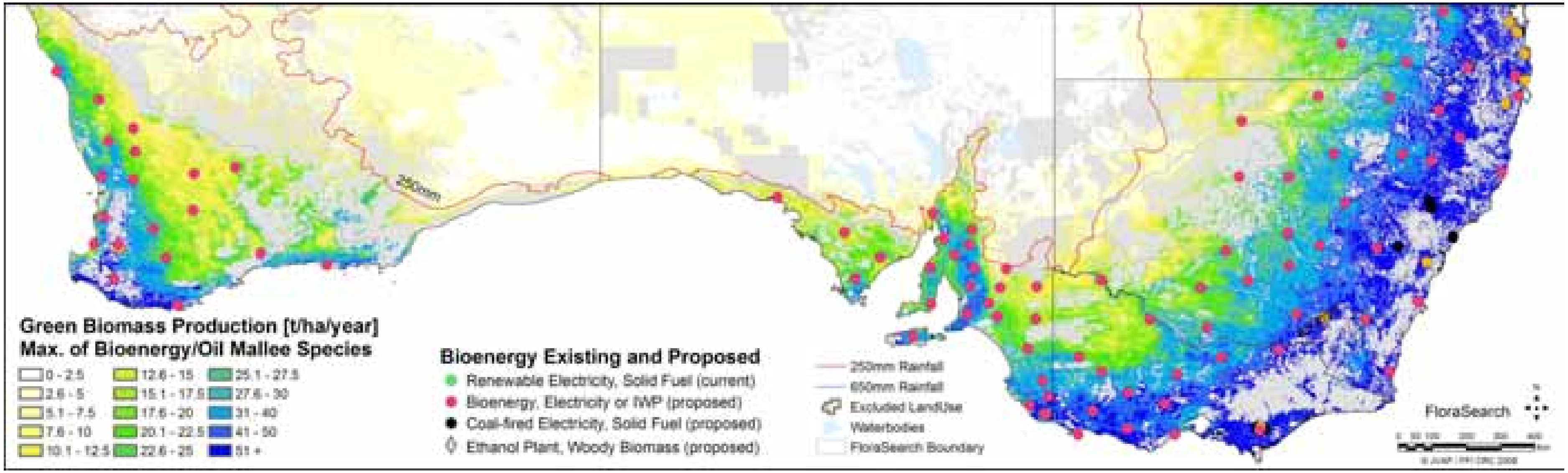


Fig. 39. Existing and potential bioenergy generation facilities with capacity or potential to use woody biomass feedstocks in southern Australia.

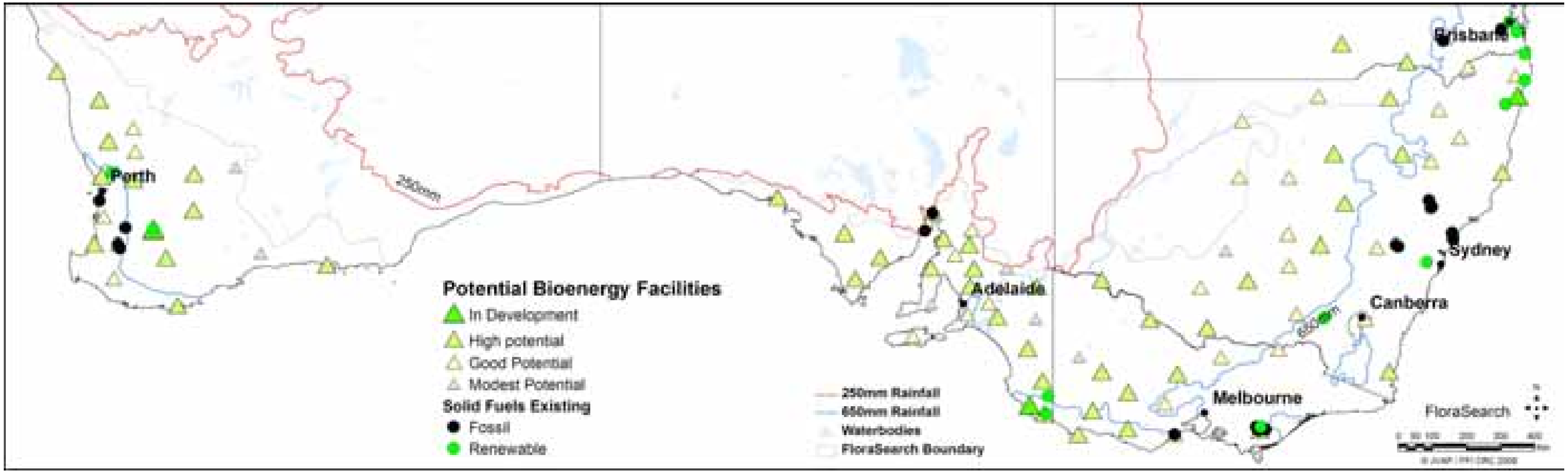


Fig. 40. Existing, currently offline and proposed liquid fuel refineries in southern Australia.

Fig. 41. Bioenergy annual equivalent returns based on $20/green tonne delivered price at existing and proposed facilities in southern Australia.

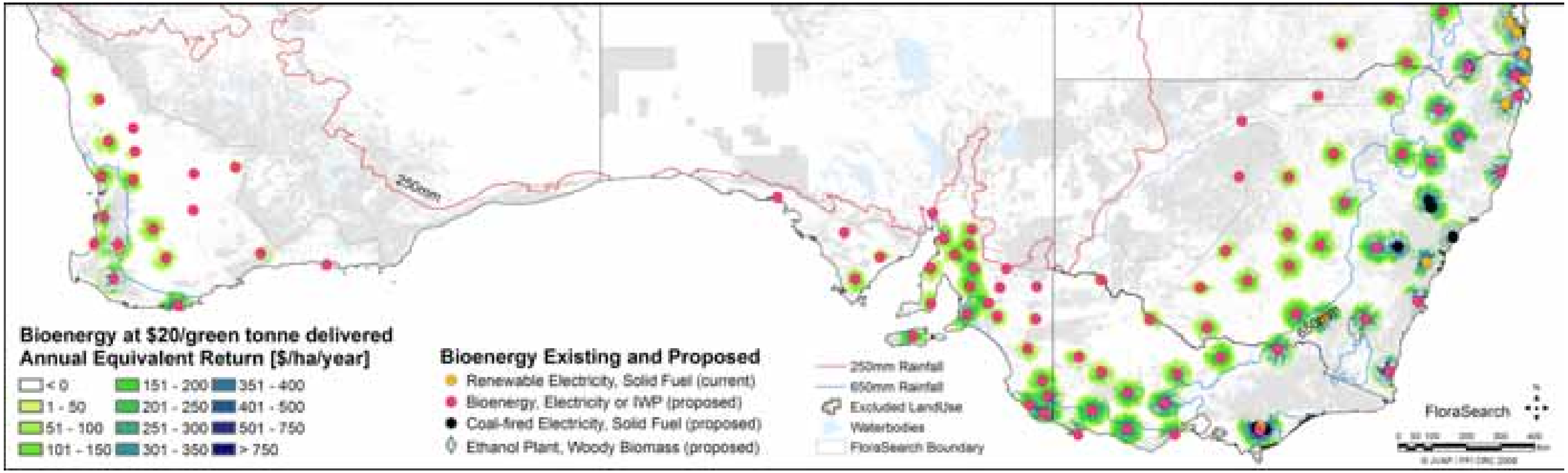


Fig. 42. Bioenergy annual equivalent returns based on $30/green tonne delivered price at existing and proposed facilities in southern Australia.

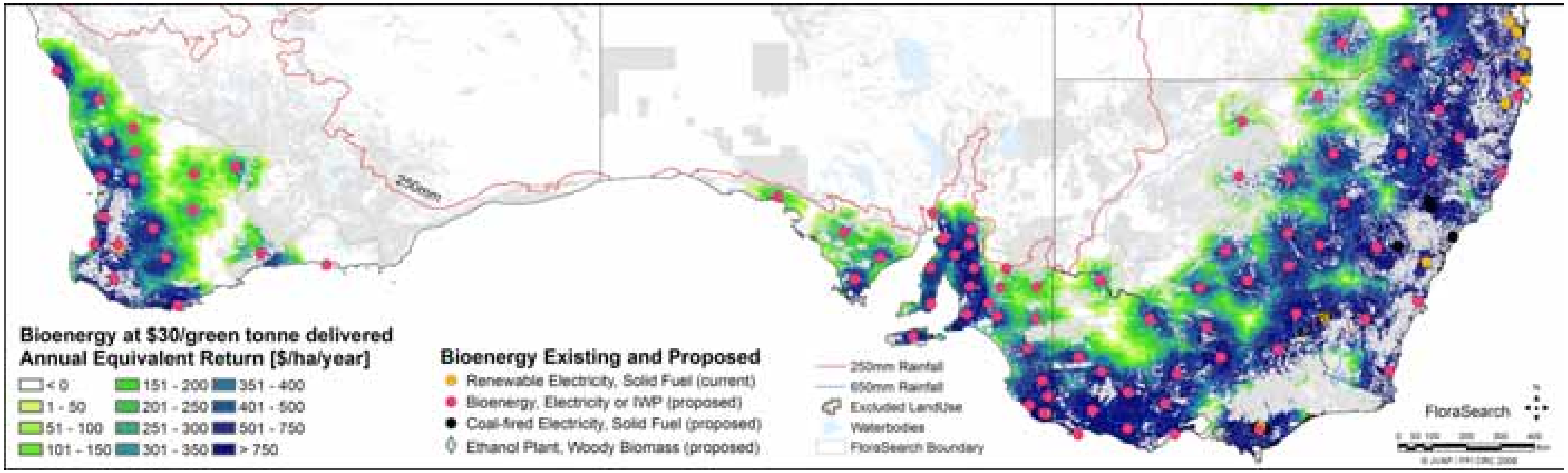


Fig. 43. Bioenergy annual equivalent returns based on $40/green tonne delivered price at existing and proposed facilities in southern Australia.

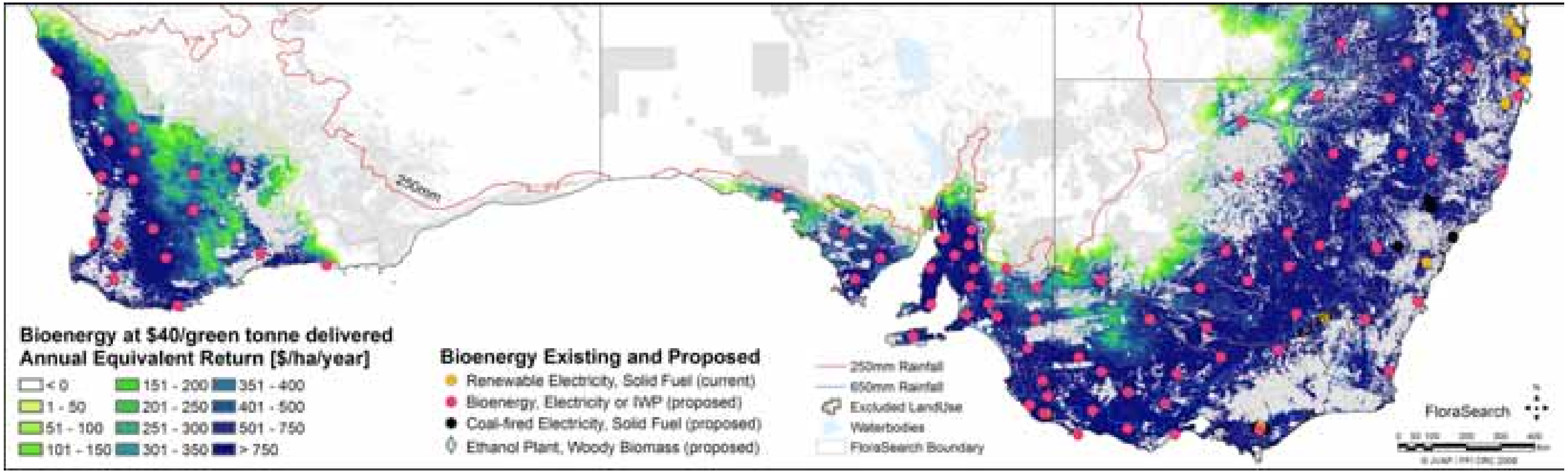
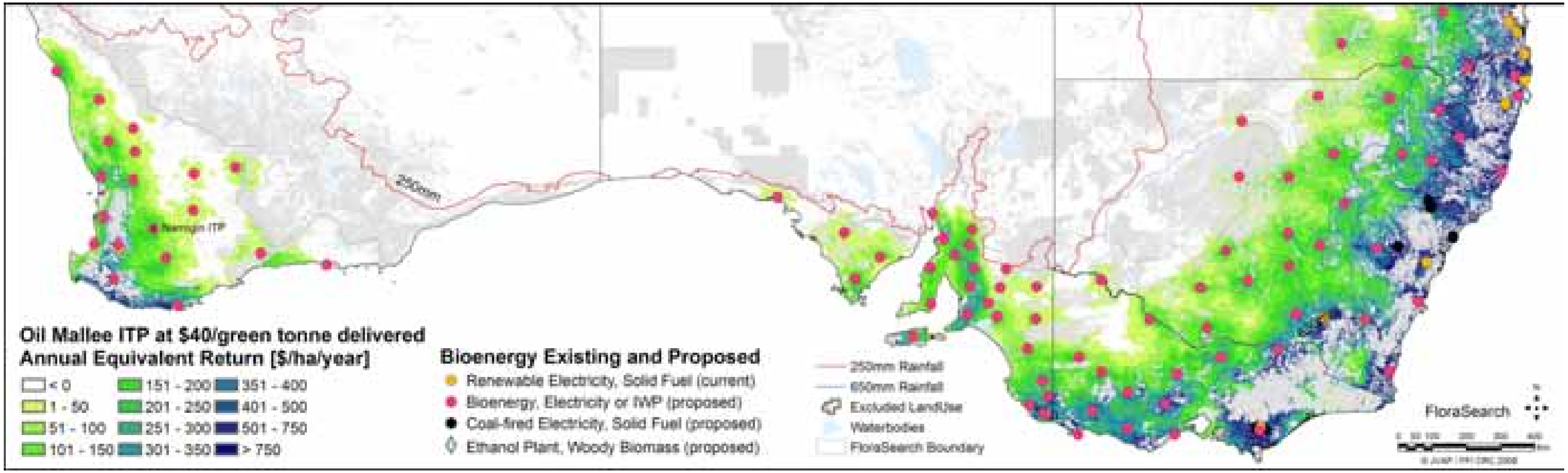


Fig. 44. Oil Mallee ITP annual equivalent returns based on $40/green tonne delivered price at existing and proposed facilities in southern Australia.



5. Case Study 2: Woody Crop Potential in the Upper South East Region of South Australia

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Introduction

The natural resources of South Australia's South East provide the backbone of a diverse range of ecosystems, agricultural pursuits, industries and vibrant communities. However, the landscapes and landuses in the region are affected by a number of both inherent and human induced natural resource management (NRM) issues. The Upper South East region (see Fig. 45, Fig. 47) is typified by low topography, poor water drainage, high water tables, inherently high soil and groundwater salt loads, and a history of substantial clearing of native vegetation for agriculture (Fig. 46). It faces significant NRM issues of water table induced salinity, dryland salinity, habitat and biodiversity loss, and wind erosion. The loss of perennial vegetation cover has contributed substantially to these NRM issues and it is well recognised that there is a role for agroforestry, perennial farming systems and habitat re-creation to alleviate some of the problems faced in the region.

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

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

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

Fig. 45. The focus area of the Upper South East biomass study.

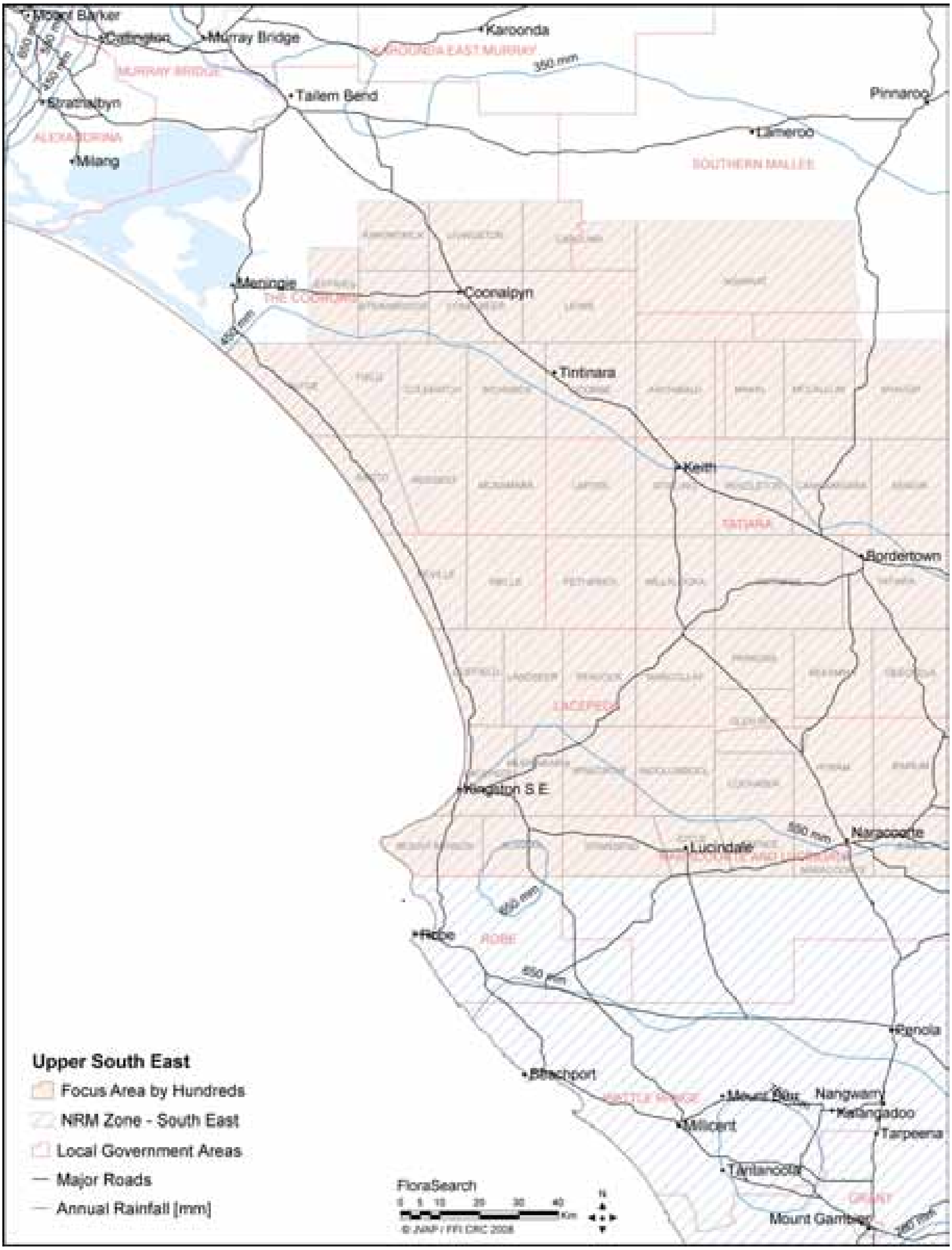
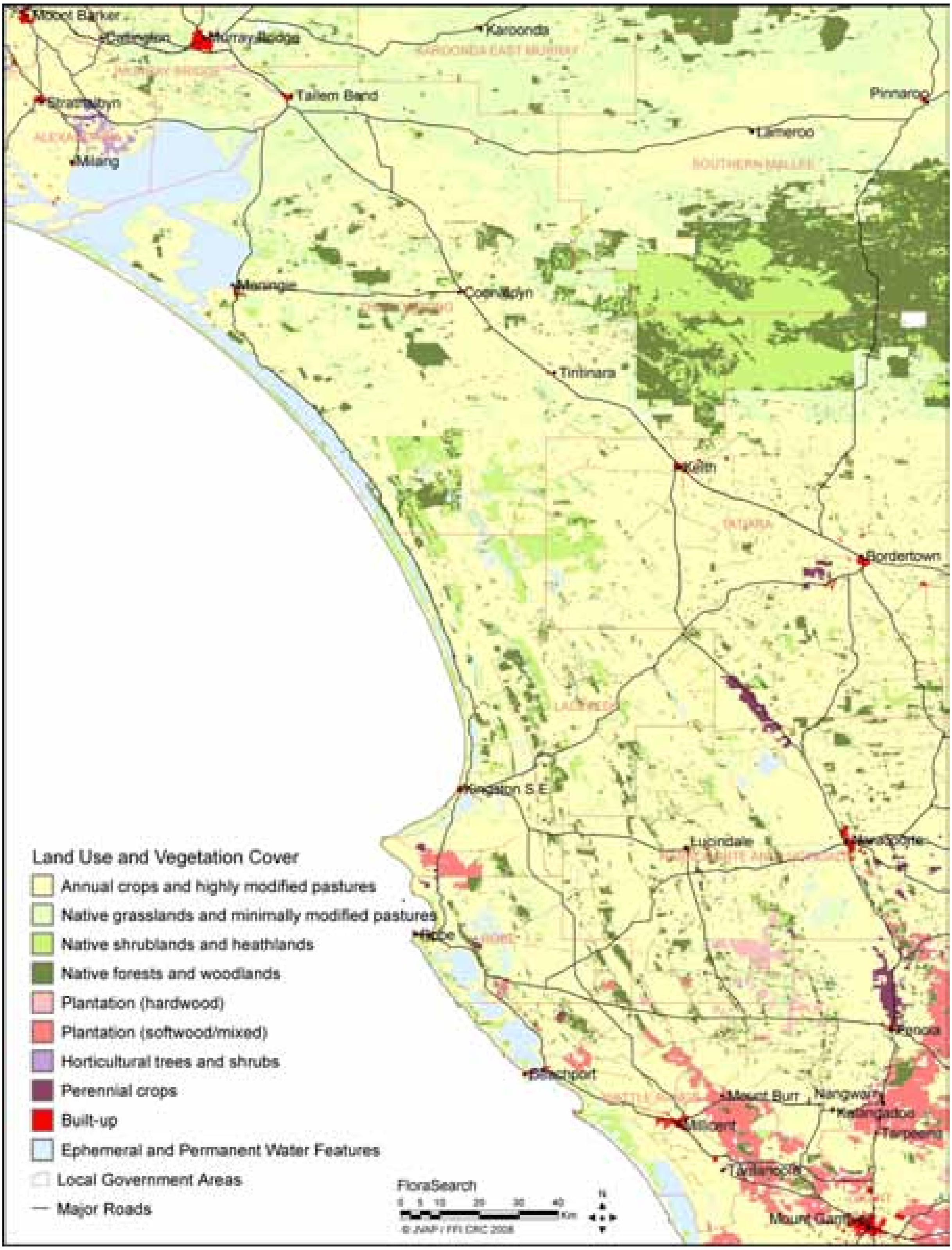


Fig. 46. Landuse and vegetation cover types in the Upper South East region.



Source: BRS (2004)

Supporting the development of the “best science” for NRM is the SA Centre for Natural Resource Management (SACNRM 2006) which develops and maintains partnerships with NRM Regional Groups, scientists and researchers, business and industry, governments and agencies, so that integrated natural resource management across South Australia is based on world-class research and development. The CNRM aims to create more sustainable environments through the development of new technologies and industries which benefit the environment and are economically sustainable. The CNRM undertakes a number of key research-related roles, including oversight of the South Australian R&D component of the National Action Plan (NAP) for Salinity and Water Quality. The CNRM identifies and negotiates supplementary funding and co-investment sources for NRM research, from both the public and private sectors. It has strong partnerships and linkages with business and industry stakeholders provide enhanced co-investment opportunities. The CNRM identified the need to better understand the ecosystem services and economic potential of farm forestry (agroforestry), woody perennial farming systems and revegetation in the Upper South East and subsequently contracted the FloraSearch group to conduct the research contained within this report.

The priority setting for FloraSearch’s research into biomass industries in the Upper South East Region is based on the key natural resource management issues that can be alleviated or addressed by revegetation activities such as agroforestry, woody perennial farming systems (including fodder shrubs) and habitat creation. The current *South East NRM Plan* (SENRCC 2003) identifies a wide range of NRM issues for the region, its goals and proposed activities. The following is a subset of those issues, goals and activities which relate to the Upper South East sub-region and issues which may be addressed by revegetation of agricultural lands:

Dryland Salinity
Goal - To manage and reduce the spread and severity of dryland salinity and optimise the productivity of saline lands.

- Groundwater recharge reduced by increasing the water holding capacity of soil, increasing groundcover, establishing deep rooted species, establishing healthy plant growth and reducing pondage of surface waters.

- Ecosystems enhanced and conserved.

Waterlogging
Goal - To reduce the impact of waterlogging on agricultural land whilst recognising the value of protecting and/or reinstating historic wetlands for biodiversity.

- Alternative production systems, which are tolerant of waterlogged areas further researched.

Soil Acidity
Goal - To reduce the rate of soil acidification in sandy soils and implement amelioration techniques to reduce the impact of soil acidification in affected areas.

- Slowing the rate of acidification by reducing nitrate leaching through planting perennial grasses and avoiding excess use of nitrogen fertilisers, recycling non-acid nutrients, rotating stock, and reducing the use of fertilisers containing large amounts of elemental sulphur.

Soil Erosion
Goal - To prevent and/or reduce soil erosion through the adoption of appropriate land management practices and techniques.

- Landholders are informed and implement management strategies, which reduce erosion potential. These may include maintenance of surface cover, the utilisation of management options such as forestry, windbreaks and retention and protection of existing vegetation to reduce wind velocity, maintenance of soil fertility to enhance vegetative cover, timing of cultivation, control of vermin, grazing management, and the utilisation of cover crops.

Ecosystem Fragmentation and Degradation
Goal - To reduce the disturbance and destruction of habitats and improve the health and viability of terrestrial native vegetation, wildlife species and ecological communities.

- Protection and enhancement of existing areas of habitat on private and public land.
- Improved diversity and quality of habitat.
- Improved viability of existing animal and plant populations.

Capacity Building
Goal - To ensure that the South East community is motivated, capable and has the capacity to achieve integrated NRM outcomes that benefit the economic, environmental and social wellbeing of the region.

- NRM information being accessed and research needs addressed.

The *South East NRM Plan* community consultative process identified the most highly ranked NRM priority issues for the region as Salinity (Land Resources), and Ecosystem Fragmentation and Degradation (Biodiversity). The focus on salinity is supported by evidence of the region's high risk status identified by the 2001 National Land and Water Resources Audit (NLWRA 2001). Barnett (2001) quantifies that 272,000ha of the South East Region is currently affected by secondary salinity (water table induced). The National Land and Water Resources Audit (NLWRA 2001) found that 5.7 million hectares were at risk or affected by dryland salinity in Australia, and that in 50 years time this area could rise to 17 million hectares. Without substantial and immediate changes to agricultural systems to reduce groundwater recharge and impact of dryland salinity Australia's productive capability and wealth from farm exports will diminish (Stirzaker *et al.* 2000, 2002). In the South East Region 87% of the original native vegetation has been cleared, 11 plant and 22 animal species have become regionally extinct, 333 plant species are considered threatened at the State level (63 endangered, 88 vulnerable, 180 rare and 2 not yet listed), and 27 of the 49 pre-European plant communities (55%) are considered rare or threatened (SENRCC 2003).

Many environmental and economic benefits can be achieved from increasing the use of perennial plant species in Australian landscapes (Australian Greenhouse Office and Murray Darling Basin Commission 2001). New plantations of woody perennial species can reduce groundwater recharge, dryland salinity, saline river discharges, wind erosion and drought risk, and increase landscape sustainability, biodiversity, livestock production, economic diversification and stability of financial returns. The losses from salinity affected agricultural land both in terms of productive capability and spatial extent are increasing every year in Australia.

For this study the Upper South East Region is classified as the area (see Fig. 45) bounded by the northern edge of the Natural Heritage Trust's South East Region (~35.49°S), the SA/Victorian border (140.96°E), a line between the southern edges of the Hundreds of Mount Benson and Jessie (37.03°S) and the SA coastline (~139.29°E) and covers approximately 1,922,456 hectares. It overlays the Local Government Areas of Naracoorte and Lucindale (northern half), Lacepede, Tatiara, The Coorong (southern two-thirds), and the Southern Mallee (southern quarter). The region supports a number of landuses predominated by cropping/grazing (~74%) and native woodlands, shrublands and wetlands (~24%) and minimal areas of forestry (<1%), urban and human services (<1%) and irrigated perennial crops and horticulture (<1%). The potential area for conversion to agroforestry, fodder shrubs and biomass industries is 1,421,317 hectares or approximately 74% of the region. This statistic is not intended to suggest that we have to displace all of the existing cropping and grazing areas in the region but indicates the scale of opportunity for the region to incorporate alternate or supportive woody biomass industries into these landscapes. More detailed analysis of the current area of each vegetation/landuse class and sub-division (Hundred) is presented in Hobbs *et al.* 2006.

The neighbouring lower South East Region is already serviced by a substantial forestry industry. Early forestry industry development was mainly based on lumber (starting c.1881 at Mount Gambier) from predominantly softwood *Pinus* species (with other mills at Nangwarry, Mount Burr and Tarpeena) with lumber products still featuring highly in the region. In 1960 the Millicent Pulp Mill was established (KCA 2006) and a second mill developed at Tantanoola in 1992 to produce primarily paper tissue and hygiene products from softwood plantation pines (*Pinus radiata*), although in the late 1990s the Millicent mill also utilised Eucalypt hardwoods. Carter Holt Harvey Panels operates a particleboard mill at Mount Gambier which utilises plantation pine to produce around 277,000m^3 of particleboard per year (CHH 2006). In recent times there has been significant investment and area planted with the hardwood Tasmanian Bluegum (*Eucalyptus globulus*) mainly for export pulpwood industries serviced by the deepwater port at Portland. Recently, the development of a new mechanical pulp mill near Penola has been approved (Penola Pulp 2006). The planned pulp mill will produce approximately 350,000 air dry tonnes of pulp per year to supply both the export and domestic paper markets from approximately 700,000 tonnes of plantation eucalypt woodchip.

Table 24. Proportion of vegetation and land use classes in the Upper South East region.

Vegetation/Landuse Class	**Description**	**Proportion of Area**
Annual crops and highly modified pastures	Annual crops (eg. cereals), grazing/pastures explicitly labelled as improved or modified	66.0%
Native grasslands and minimally modified pastures	Native grasslands or vegetation used for grazing/pastures not explicitly labelled as improved or modified	7.6%
Plantation (hardwood)	Hardwood plantation forests	>0.1%
Plantation (softwood/mixed)	Softwood plantation forests or plantations of mixed/unknown composition	0.3%
Perennial crops	Perennial cropping (eg. grapes etc.)	0.4%
Horticultural trees and shrubs	Horticultural trees and shrubs (eg orchards)	>0.1%
Built-up	Urban areas, transport, services etc.	0.6%
Native shrublands and heathlands	Native shrublands, heathlands and open woodlands (non-forest woody vegetation)	11.9%
Native forests and woodlands	Native forests and woodlands	10.8%
Bare	Non-vegetated not elsewhere classified	0.4%
Ephemeral and Permanent Water Features	Lakes, wetlands, water courses and reservoirs	2.0%

Based on national vegetation and landuse mapping by the Bureau of Rural Sciences (2004).

Livestock production is a major existing industry in the South East Region. As of June 30, 2005 there were 4,013,400 sheep and lambs and 665,000 meat cattle in the South East statistical district (ABS 2006). Several feedlots also exist in the region, including substantial feedlots at Meningie and Naracoorte, with smaller lots at Tintinara, Lameroo, Parrakie and Frances. Additionally, a livestock feed manufacturing plant exists in Murray Bridge. The fodder shrubs Tagasaste (*Chamaecytisus* spp.) and Oldman Saltbush (*Atriplex nummularia*) are currently utilised *in situ* for livestock grazing on many farms in the region and potential exists for mechanical harvesting fodder shrubs to supply feedlots and stock feed manufacturing in the region.

There is an increasing interest and awareness of the potential for renewable energy sources to be used to generate electricity, offset the use of fossil fuels, and reduces greenhouse gas emissions and their influences on global climates (Stucley *et al.* 2004, Zorzetto and Chudleigh 1999, Hague *et al.* 2002). Electricity generation from biomass (bioenergy), especially when combined with co products of oil, charcoal, tannins or fodder provides an environmental friendly opportunity in many regions of

Australia (Zorzetto and Chudleigh 1999, Bennell *et al.* 2008, Bartle and Shea 2002, Olson *et al.* 2004, Enecon 2001). Stucley *et al.* (2004) have provided a recent review of *Biomass energy production in Australia - Status, costs and opportunities for major technologies*. It provides an excellent review of the technologies available of transforming biomass into energy and a variety of fuel types. However, they declare *"There is a general lack of information available on the growth of tree plantations in many parts of Australia."*

The purpose of this study in the SA Upper South East region was to:

- provide an evaluation of the annual productivity and product yields of native plant species suited to agroforestry and other woody biomass industries in the region;
- map and quantify the landscapes with potential for developing woody biomass industries;
- identify natural resource management issues that will benefit from revegetation activities;
- determine existing and potential broadscale industries and markets that can utilise woody biomass grown from the region; and
- undertake economic evaluations of proposed industry types.

Woody Crop Production

Growth data

The lack of productivity and yield data has hindered early attempts to evaluate the potential of biomass industries in the Upper South East (USE) region of South Australia. In the 1990's several small scale trial sites were established by Primary Industries and Resources SA as part of the *Farm Tree Improvement* and *Australian Low Rainfall Tree Improvement Group* projects (Fairlamb and Bulman 1994, Rural Solution SA 2003). The SA Department of Water, Land and Biodiversity Conservation contracted a re-measurement of many of these sites in 2003. This dataset, which we have now analysed, contains information on survival, heights and stem diameters from which we can deduce stemwood productivity per hectare rates. Additionally, Forestry SA has conducted a number of experimental trials in the USE region (predominantly *Hardwood Thinning Trials* focussed on the Bordertown area) and they have kindly allowed us access to that data (Joshua Driscoll, pers. comm. 2006).

To bolster existing trial site information from PIRSA and Forestry SA, and to provide information on species not grown in PIRSA/Forestry SA trials, FloraSearch targeted 35 new plantations in the region. All PIRSA, Forestry SA and FloraSearch trial site and survey productivity data was combined from sites within, and immediately neighbouring, the Upper South East (USE) region. Conversion of this data to stemwood productivity rates and application of allometric relationships (see Hobbs *et al.* 2009a, FloraSearch 3a report) were used to determine estimates of total plant productivity and yields of biomass components and totals for each species and site. Observed and estimated plant biomass productivity values for each species and location from the biometrics and productivity studies were standardised to an annual biomass accumulation rate to account for the different ages of the plant studied. The average annual rainfall for each sampled locality was extracted from spatial coverage of annual rainfall (CSIRO Land and Water 2001) using ArcGIS (ESRI 2005). Observed and modelled annual biomass accumulation rates for each species and locality was then standardised to an annual rainfall of 500mm using a simple linear relationship to permit a simple comparison of each species' relative biomass productivity. Summaries of the analyses and surveys and observations are presented the FloraSearch 3a report (Hobbs *et al.* 2009a).

Productivity data from the top 10% best performing plots for each species and trial/survey site location were extracted from the combined productivity dataset. These selections were aimed at identifying the best performing plant species, provenances and genetic choices suited to the local soil and climatic conditions and excluded plant germplasm that was either poorly suited to that site or plots which had suffered from poor management or a significant environmental event.

From the array of species contained within this combined productivity dataset FloraSearch has previously identified which species are suitable for each biomass industry class based on product testing results and published literature (Hobbs *et al.* 2008c). The four major *Biomass Industry* product groups and species suited to the Upper South East region are listed in Table 25. Bioclimatic distribution models for these species from climatic GIS data and natural and plantation location data; these are presented in Hobbs *et al.* (2006). A fifth group (*Habitat Species*) comprises native species which naturally occur within a given region. Fifteen species were selected to represent different lifeforms which are both productive and common to the region. These *USE Habitat Species* include Black Wattle (*Acacia mearnsii*), Blackwood (*Ac. melanoxylon*), Golden Wattle (*Ac. pycnantha*), Drooping Sheoak (*Allocasuarina verticillata*), River Redgum (*Eucalyptus camaldulensis*), Coastal White Mallee (*E. diversifolia*), White Mallee (*E. dumosa*), Pink or Hill Gum (*E. fasciculosa*), Ridge-fruited Mallee (*E. incrassata*), SA Bluegum (*E. leucoxylon*), Peppermint Box (*E. odorata*), Red Morrell Mallee (*E. oleosa*), Swamp Gum (*E. ovata*), SA Mallee Box (*E. porosa*), Red Mallee (*E. socialis*) and Rough-barked Manna Gum (*E. viminalis ssp. cygnetensis*). Productivity data for species within each of these five "*Biomass Industry Groups*" was extracted from the "*Top 10% Species Plots*" productivity dataset.

For developing productivity models the productivity of plots planted at a density of greater than 1000 trees or plants per hectare (tph) were proportionally reduced to the equivalent of 1000tph so not to bias per hectare productivity rates (1500tph rate for saltbush fodder species). The productivity of plots with less than 1000tph was <u>not</u> increased proportionally to their plant density. These rules were designed to create conservation models and estimates of plantation productivity.

Increased productivity rates per hectare could be expected for many, if not all, species observed in our study using higher planting densities. For species and plots with a crown area of less than 10m^2 it is likely that higher planting densities than 1000tph are possible. An indicative optimum planting rate per hectare for each species may be deduced from dividing the hectare area (i.e. 10,000m^2) by the crown area of the species. This 'crown' density of plants per hectare may be appropriate for short-cycle plantings but the optimum density to maximise biomass productivity per hectare will depend on the degree of plant competition for light, water and other nutrients.

Planting at rates higher than the 'crown' density rate may potentially increase productivity per hectare, however, this can only be accurately determined from more detailed trials and research. Where the observed planting density is lower than the calculated 'crown' density for a plantation it is likely that the productivity per hectare can be increased by planting at a higher rate than the observed rate. The 'crown' density data suggests that the minimum planting density for the short cycle biomass crops in the region is 1200 plants per hectare for trees and mallees and 1800 plants per hectare for saltbush fodder. A range of factors, including species selection, rainfall, topography, water table depth, soil types and fertility and crop management will influence the optimal planting rate in each paddock.

Table 25. Species suited to the four major biomass industry classes and climatic zones of the Upper South East region.

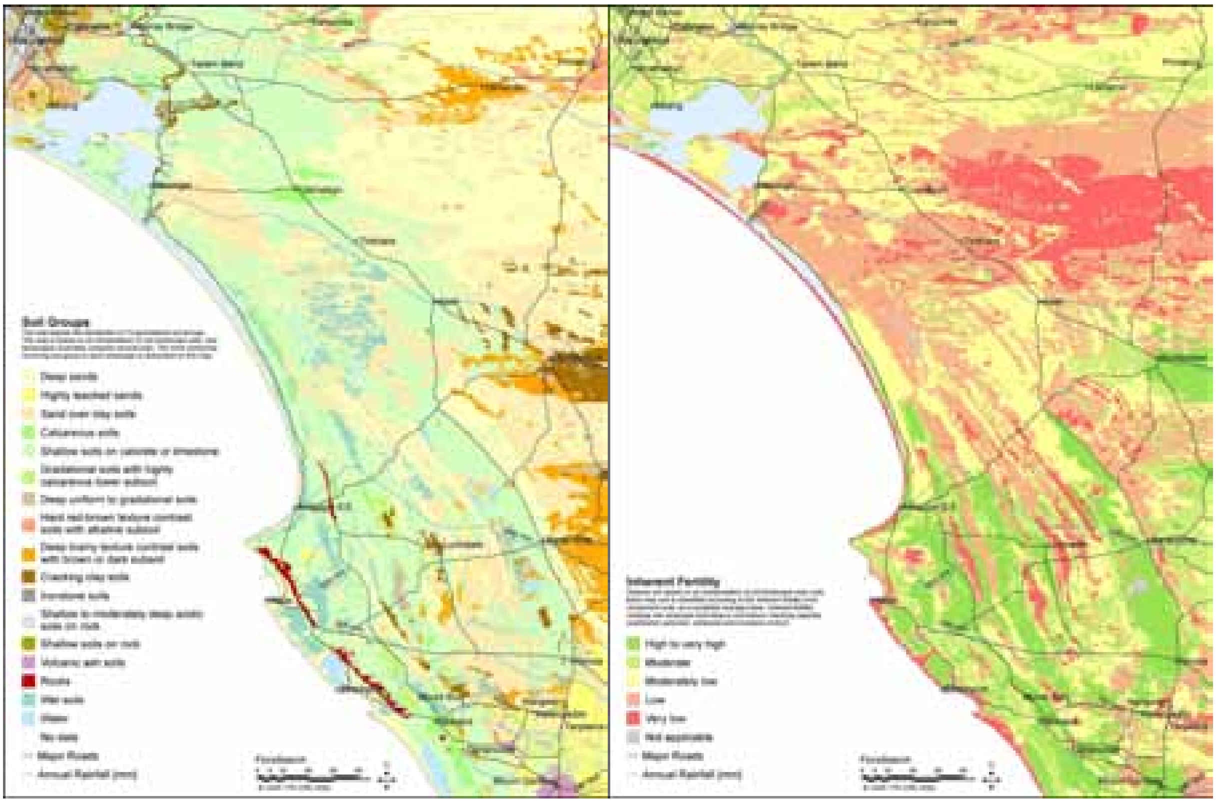
Species	Common Name	Biomass Industry Group			
		Pulp-wood	Bio-energy	Oil Mallee	Fodder
Acacia mearnsii	Black Wattle	✓	✓		
Acacia retinodes	Wirilda or Swamp Wattle	✓	✓		
Atriplex nummularia	Oldman Saltbush				✓
Eucalyptus aromaphloia	Scent Bark	✓	✓		
Eucalyptus camaldulensis	River Redgum		✓		
Eucalyptus cladocalyx	Sugargum		✓		
Eucalyptus globulus	Tasmanian Bluegum	✓	✓		
Eucalyptus gomphocephala	Tuart		✓		
Eucalyptus horistes	WA Oil Mallee			✓	
Eucalyptus leucoxylon	SA Bluegum		✓		
Eucalyptus occidentalis	Swamp Yate	✓	✓		
Eucalyptus odorata	Peppermint Box			✓	
Eucalyptus oleosa	Red Morrell Mallee			✓	
Eucalyptus ovata	Swamp Gum	✓	✓		
Eucalyptus petiolaris	Eyre Peninsula Bluegum	✓	✓		
Eucalyptus polybractea	Blue Mallee	✓		✓	
Eucalyptus porosa	SA Mallee Box	✓		✓	
Eucalyptus viminalis ssp. cygnetensis	Rough-barked Manna Gum	✓	✓		

Regional productivity predictions

The development of regional productivity models has been focussed on each of the *Biomass Industry Group* of species (ie. *Pulpwood Species*, *Bioenergy Species*, *Oil Mallee Species*, *Saltbush Fodder Species* and *Habitat Species*). The models have been based on relationships between our observations of plantation productivity in the region and soil-climate models. Raupach *et al.* (2001) developed the "*BiosEquil Model*" and created a national productivity surface coverage suitable for computer-based Geographic Information Systems (GIS). The *BiosEquil Model* coverage provides coarse resolution (~1km²) data for Australia. The high quality of soil mapping in South Australia (SA DWLBC Soil and Land Program 2006, Fig. 47) allows us to spatially refine the *BiosEquil Model* to a resolution less than one hectare (ie.100x100metres resolution). Relationships between BiosEquil Model data and SA maps of inherent fertility in the Upper South East (USE) region (see Fig. 47) and average annual rainfall were identified. From these relationships and high quality soil and rainfall maps we have created a high resolution (1 ha scale) equivalent of the *BiosEquil Model*, which we will refer to as the "*USE Productivity Index*" GIS coverage.

ArcGIS software was used to extract the corresponding *USE Productivity Index* value for each field trial or survey site location used for our plantation productivity study. Site and species productivity data was restricted to those species within the *Biomass Industry Species Groups* and the *Top 10% Species Plots* dataset. Strong linear regressions between *USE Productivity Index* values and restricted productivity data for each of the *Biomass Industry Species Groups* have allowed us to predict industry specific plantation productivities and yields across the USE region. A selection of model outputs for annual rates of stemwood production and green biomass production are presented in Fig. 48 and Fig. 49. More detailed summaries of estimated plantation productivity for each of the *Biomass Industry Species Groups* for each sub-division (Hundred) of the USE region are presented in Hobbs *et al.* 2006.

Fig. 47. Generalised soil groups and inherent fertility of soils in the Upper South East region.

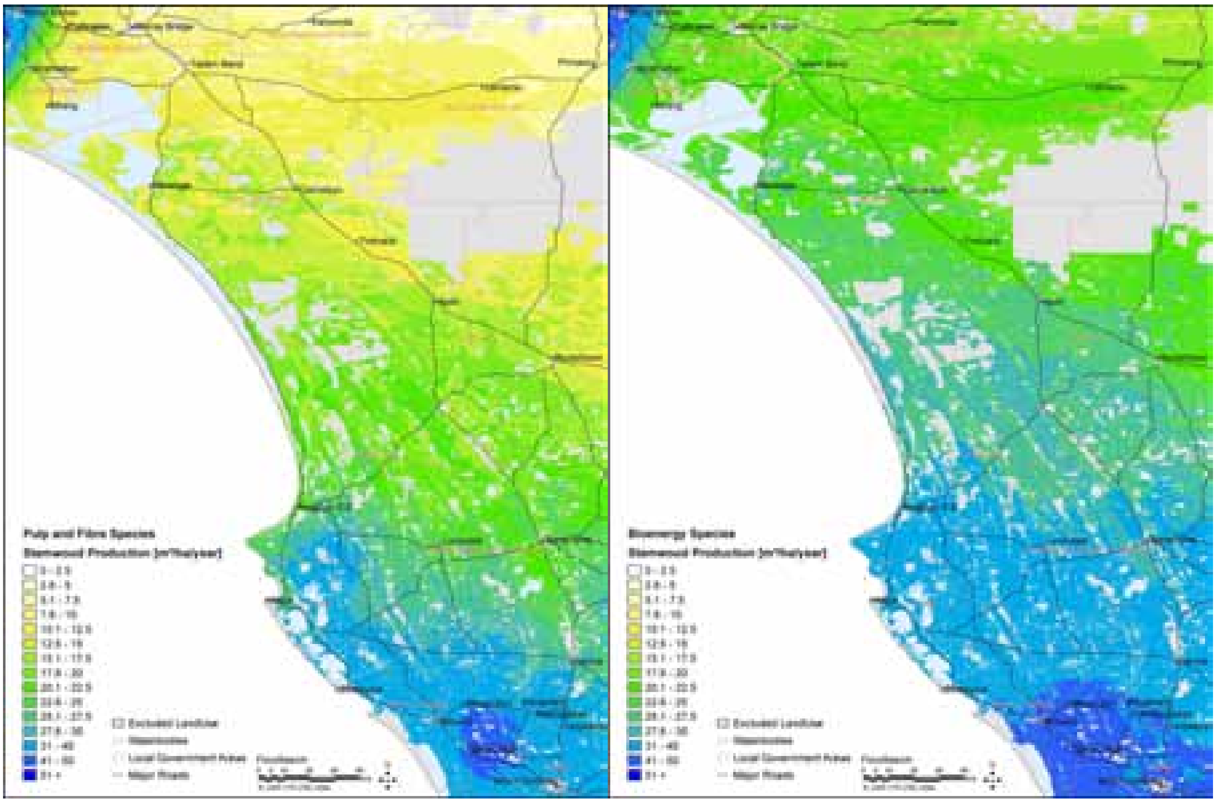


Source: SA DWLBC Soil and Land Program (2006)

Natural Resource Management Issues and Benefits of Revegetation

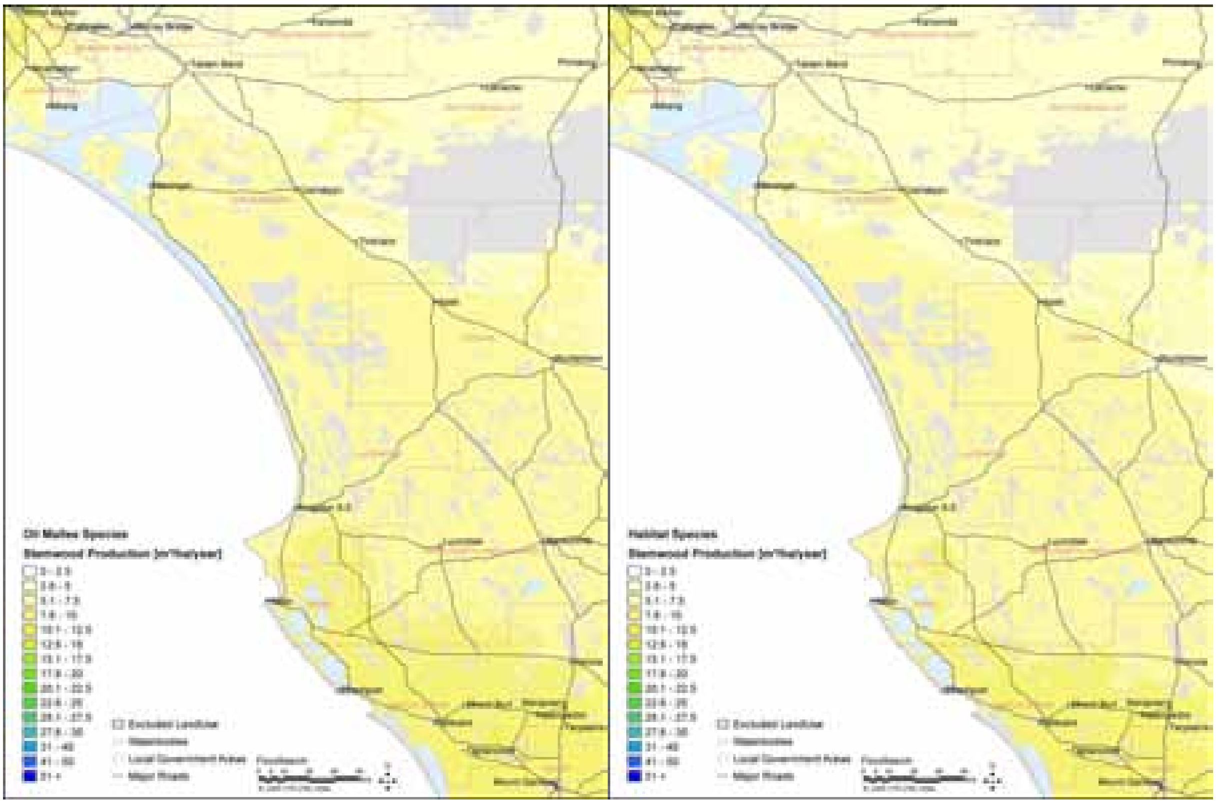
The natural environment and history of landuse in the Upper South East (USE) region has shaped many of the natural resource management issues that we currently face in the region. The natural environment has inherited, and commonly features, low topography, poor water drainage, high water tables, saline and low fertility soils and salty groundwater (see Fig. 47, Fig. 50). The clearance of approximately 75% of the native perennial vegetation in the USE region (see Fig. 50g) for predominately annual-based crops and pastures has substantially changed the hydrology of the area. Changes in the hydrology has generally accentuated soil salinity through the release of salt once stored in soil profiles and rising water tables in many areas (Fig. 50). Poor drainage and rising watertables result in unproductive waterlogged soils. The removal of native vegetation cover also exposes light sandy soils to a greater risk of wind erosion (Fig. 50g, e). Salinity, waterlogging and wind erosion reduces the productivity and sustainability of agricultural lands.

Fig. 48. Estimated annual stemwood production of Industry Species Groups in the SA Upper South East region.



Pulp and Fibre

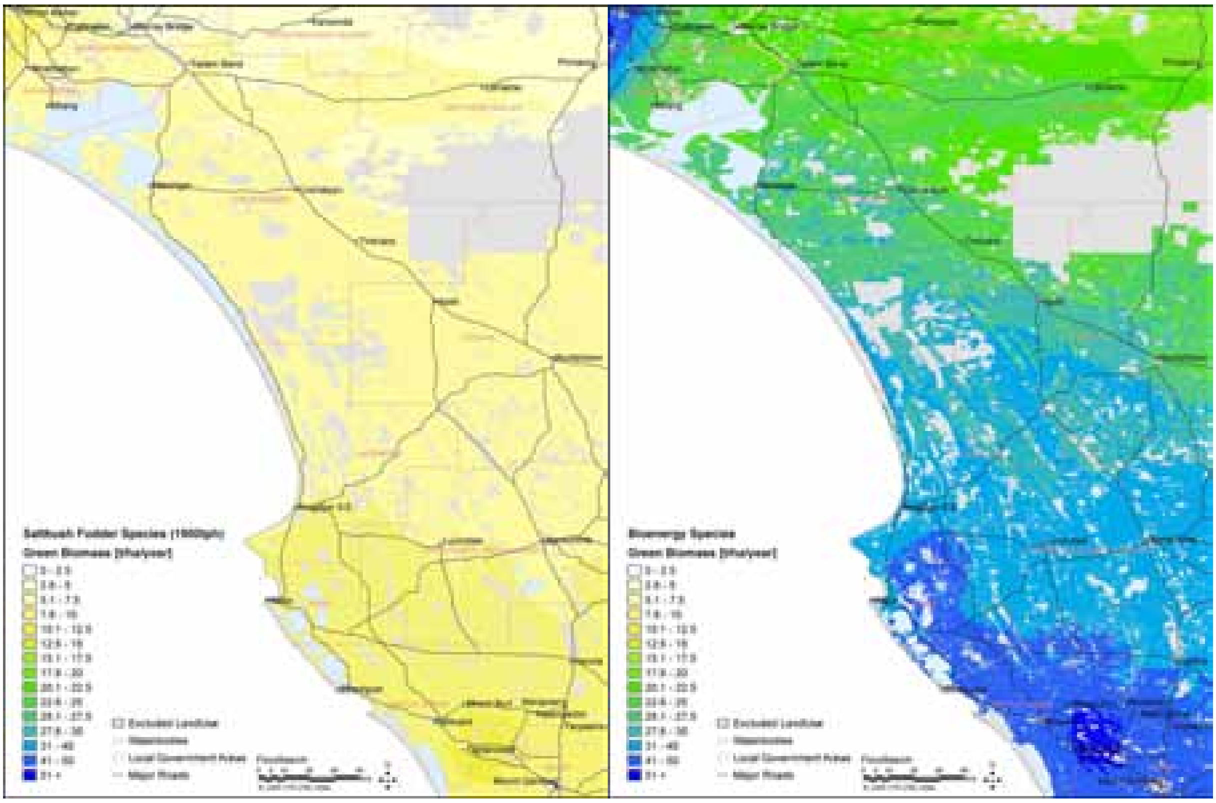
Bioenergy



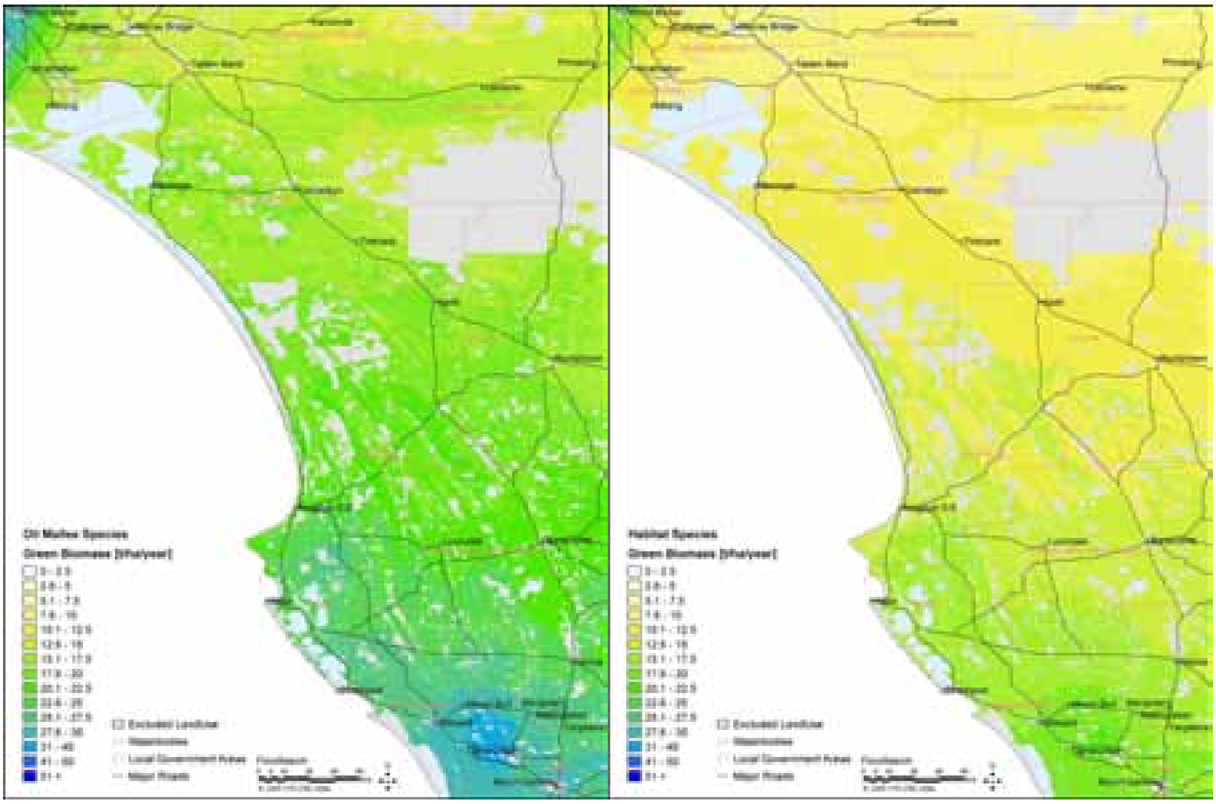
Oil Mallee

Habitat

Fig. 49. Estimated annual above-ground green biomass production of Industry Species Groups in the SA Upper South East region.



Saltbush Fodder **Bioenergy**



Oil Mallee **Habitat**

The natural resource management issues of dryland salinity, ecosystem fragmentation and degradation feature highly (and to a lesser extent, wind erosion, waterlogging and soil acidification) in the current *South East Natural Resource Management Plan* (SENRCC 2003) and will undoubtedly be core issues in the new *South East Regional Natural Resource Management Plan* (SENRMB 2006). It is well recognised that perennial revegetation, including commercial agroforestry, perennial farming systems and habitat re-creation can provide environmental and ecosystem services that may alleviate some of these NRM problems faced in the region (Australian Greenhouse Office and Murray Darling Basin Commission 2001, SENRCC 2003). New plantations of woody perennial species can reduce groundwater recharge, dryland salinity, saline river discharges, wind erosion and drought risk, and increase landscape sustainability, biodiversity, livestock production, economic diversification and stability of financial returns.

In the broader context of environmental services and climate change we have also conducted a series of analyses on the potential of five perennial revegetation types to sequester carbon dioxide from the atmosphere.

Soil salinity and wind erosion risk

To evaluate the extent and severity of soil salinity and wind erosion risk in the Upper South East (USE) region we have conducted spatial analyses of DWLBC Land and Soil Program's (2006) mapping of dry saline land, dryland salinity induced by water table and wind erosion risk (see Fig. 50a, d, e). This analysis is focussed on the annual cropping and grazing areas only. An index of extent and severity has been created by scaling the classes of dry saline land, salinity induced by water table and wind erosion risk between 0 and 1, where a value of 1 represents the most widespread and severely affected location. Then for each Hundred subdivision we have determined the average index value of each hectare under annual cropping and grazing. A high average index value highlights subdivisions which are most affected by salinity or erosion risk (see Table 26).

The main driver of dryland salinity in the Upper South East (USE) region is the leakage of water from the root zone of predominately annual crops and pastures. The resulting deep drainage contributes to the recharge of water tables in the region and increases the risk of dryland salinity. Every 1mm of deep drainage per hectare contributes 10,000 litres of water towards recharging the water table. Smettem (1998) predicts that deep drainage under annual crops and pastures in the 375 to 600mm rainfall zone is approximately 40 times that of native perennial vegetation. Smettem's work was conducted on similar landscapes to those found in the USE region. Using Smettem's models of deep drainage:

$$\textbf{Deep Drainage (Native Systems) [mm]} = \mathbf{0.0336e^{0.0059 * \text{Rainfall [mm]}}} \textbf{; and}$$

$$\textbf{Deep Drainage (Agricultural Systems) [mm]} = \mathbf{7.8619e^{0.0025 * \text{Rainfall [mm]}}}$$

and spatial coverages of rainfall and landuse we have mapped the spatial distribution of deep drainage for the USE region (see Fig. 50f). The spatial variation in deep drainage resulting from different landuses is tremendous. Average annual rates and volumes of deep drainage under annual crops and pastures for each local subdivision are presented in Table 26.

For every 1% of the annual cropping and grazing land revegetated with woody perennial crops or habitat will reduce the region's recharge by approximately 3.6 Gigalitres per year. Revegetation can contribute significantly to reducing one of the drivers of dryland salinity in the region. Conversely, in agricultural areas reliant on unconfined low salt aquifers careful planning of revegetation activities and water extraction will be required to ensure the persistence of the groundwater resource.

Ecosystem fragmentation and degradation

Approximately 75% of the Upper South East (USE) region has been cleared of native vegetation for the development of agricultural industries. Most of this clearance has been undertaken on the most fertile landscapes. Much of the remaining low fertility, saline and waterlogged soils, and wetlands are now formally conserved in our national estates. Other low productivity lands remain unused or opportunistically grazed by livestock. Government-managed National parks and reserves formally conserve 13.9% of the native landscapes of region. A further 3.9% of the region is conserved on private lands under formal Native Heritage Agreements with the state government with strong restriction on landuse and livestock grazing. Other native forests, woodlands, shrublands and heathlands (6.7% of the region) lie outside of formal conservation areas and are protected by legislation from any further clearing, however, these predominately privately owned lands are usually part of agricultural enterprises and still may be subject to the pressures of livestock grazing and other management that may degrade these relatively natural systems.

The coarse degree of ecosystem fragmentation is mapped in Fig. 50g. The formally conserved areas are focussed on the low fertility landscapes of the Ngarkat area in the northeast of the region and saline or waterlogging landscapes in the Coorong and adjacent wetland areas. Conservation areas or unconserved remnant native vegetation in other areas is highly dispersed and relatively unconnected vegetation structures and habitats. These areas have the greatest risk of biodiversity loss from the influence of high edge effects and isolation, particularly on small ground-based mammals and reptiles. In the greater South East Region 11 plant and 22 animal species have become regionally extinct, 333 plant species are considered threatened at the State level (63 endangered, 88 vulnerable, 180 rare and 2 not yet listed), and 27 of the 49 pre-European plant communities (55%) are considered rare or threatened (SENRCC 2003).

As an estimate of habitat loss and degradation in each Hundred subdivision we have combined the “Habitat Areas” of formal conservation on government and private lands with the currently remnant native vegetation which is not formally conserved. The total remaining “non-Habitat Areas” is then expressed as a proportion of the total subdivision area or a simplified index of ecosystem fragmentation and degradation; higher index values (~1) represent highly fragmented or degraded landscapes. Table 26 presents summaries of each regional conservation landuse type by Hundred for the USE region.

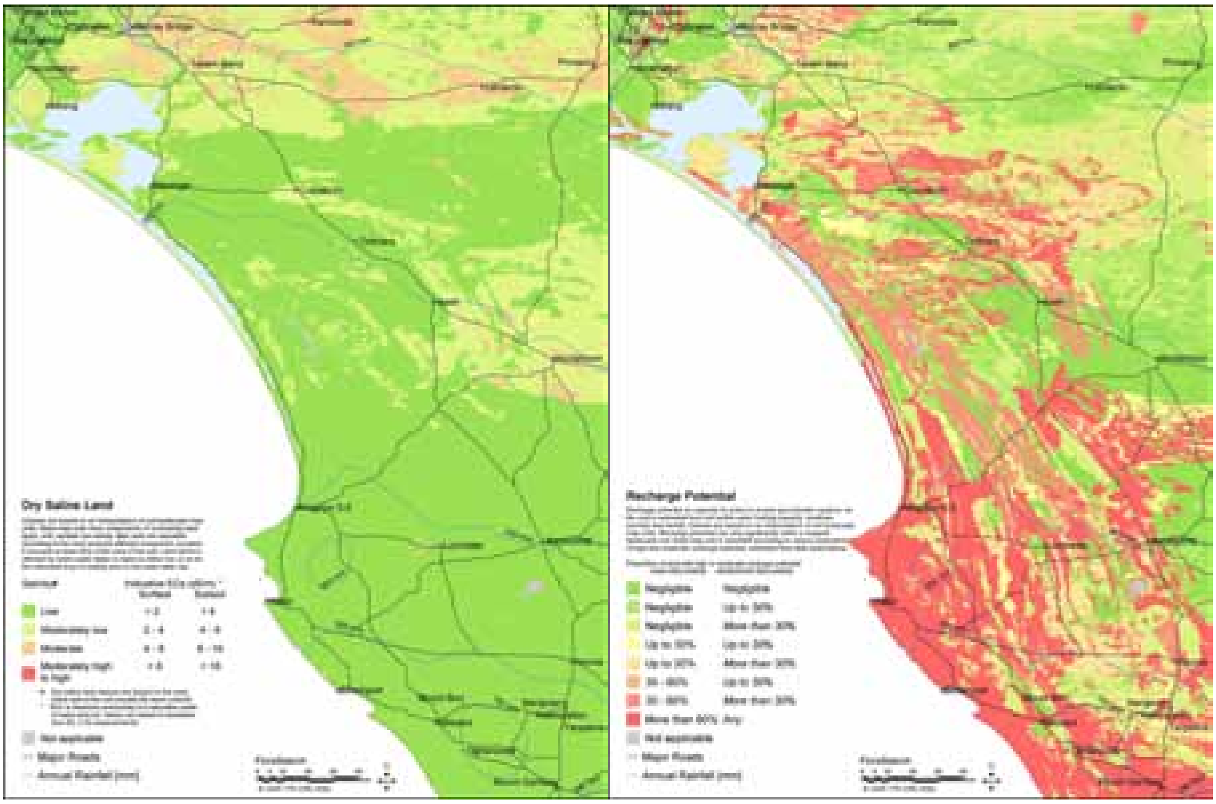
Overall environmental risk

To prioritise the Hundred subdivisions which will receive the most benefit from revegetation with woody perennial plants we have used the unweighted averaged of each Hundred’s dryland salinity, habitat loss and wind erosion risk indices. This information is presented at a broader scale (by Hundred subdivisions) so that regional and state planning and policy organisations may clearly identify and focus on management regions for priority activities and investments. These results are presented in Table 26 and graphically in Fig. 50h. These results highlight the need for revegetation in many areas, but especially the Hundreds of Richards, McNamara, Coombe and Laffer of the Tintinara district with their substantial vegetation clearance, high water tables and light sandy soils. Higher resolution mapping for within each subdivision may be utilised in the future to identify target properties for optimal natural resource management investments and on-ground activities. Extension of this environmental risk and natural resource management analysis can be used in regional case studies to explore the optimal arrangement of a range of landuses and environmental benefits (Bryan *et al.* 2007a, b).

Carbon sequestration potential

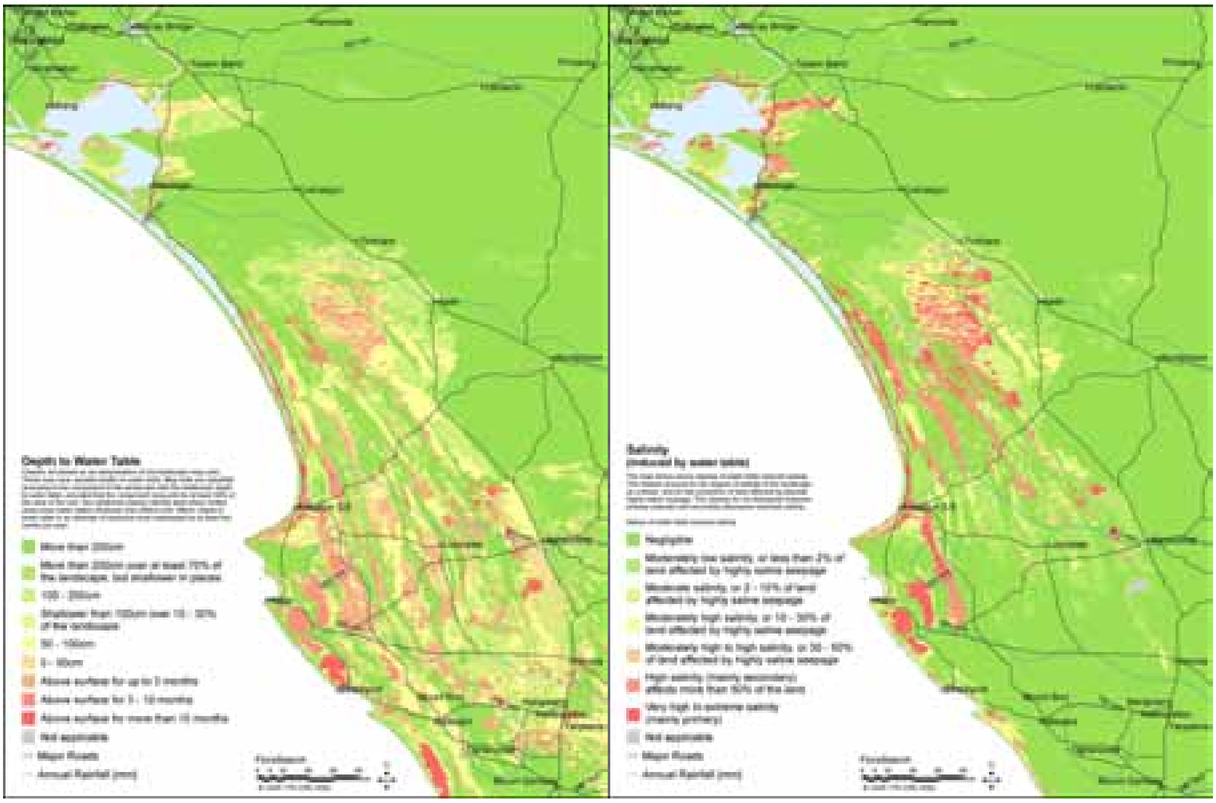
Revegetation using woody perennial vegetation can also provide additional environmental services by sequestering atmospheric carbon dioxide and reducing greenhouse gases that contribute to climate change. We have constructed spatial models of above-ground carbon sequestration based on the unharvested 20 year average plantation productivity data of the perennial *Biomass Industry Species Groups* (Fig. 51). Summaries presented in Table 27 show the expected rates of carbon sequestration of revegetation on the annual cropping and grazing land within each Hundred subdivision in the USE region.

Fig. 50. Natural resource management issues in the SA Upper South East region.



a) Naturally dry saline land

b) Recharge potential of soils



c) Depth to the water table

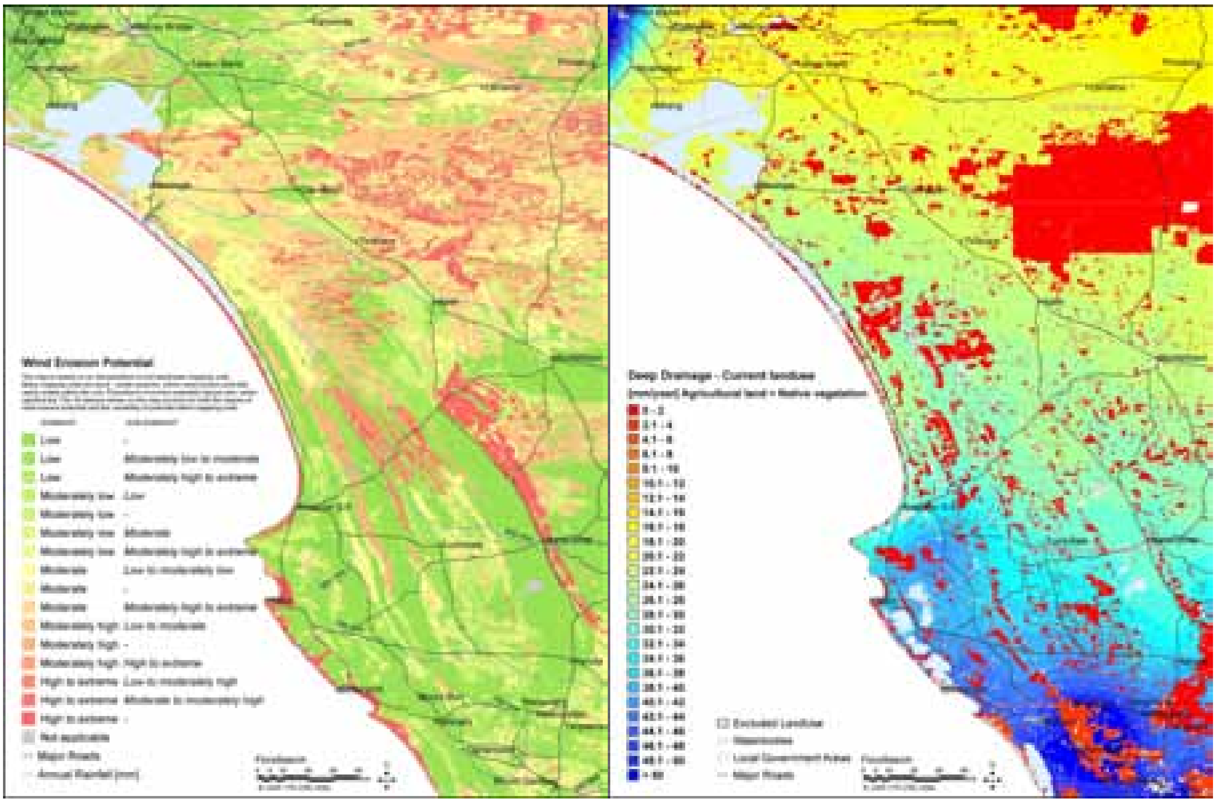
d) Salinity induced by water table

Sources: SA DWLBC Soil and Land Program (2006)

Fig. 50. Natural resource management issues in the SA Upper South East region (continued).

e) Wind erosion potential (SA DWLBC 2006)

f) Annual deep drainage rates (Hobbs *et al.* 2006)



g) Conservation areas and remnant native vegetation on private lands (Hobbs *et al.* 2006)

h) Overall environmental risk from dryland salinity, habitat loss and wind erosion risks (Hobbs *et al.* 2006)

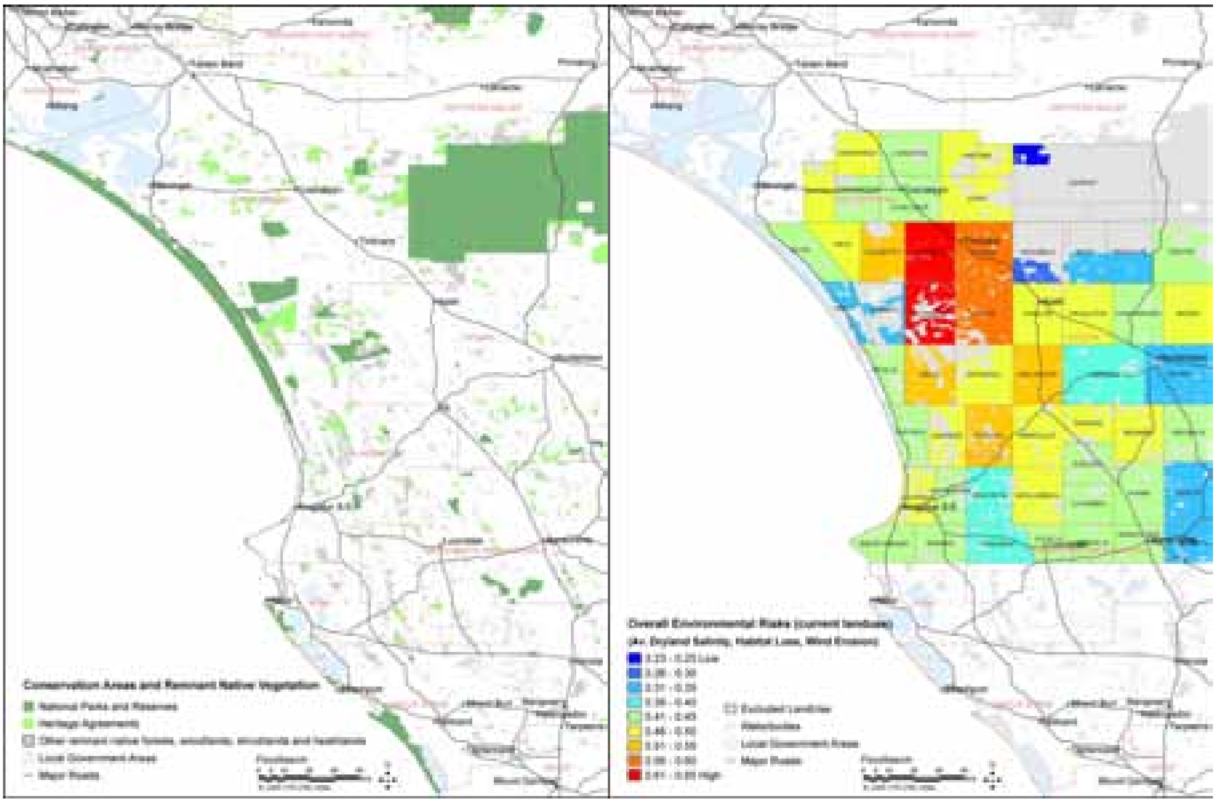


Table 26. Regional conservation and dryland agricultural lands (potential agroforestry) affected by deep drainage, salinity and wind erosion risk by land subdivision (Hundreds).

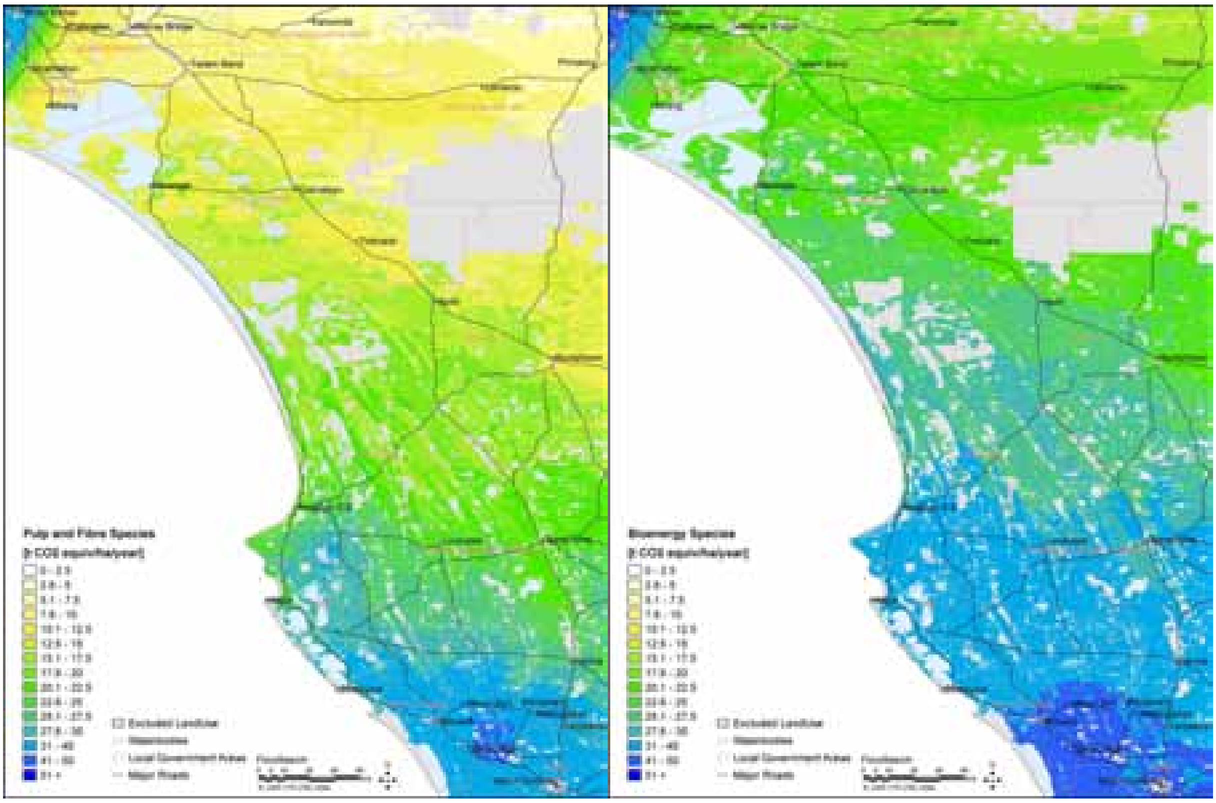
Hundred	**Parks and Reserves [ha]**	**Heritage Agreements [ha]**	**Native but Not Formally Conserved [ha]**	***All Habitat Areas [ha]***	**Index Habitat Areas #1**	**Dryland Agriculture [ha]**	**Rainfall [mm]**	**Deep Drainage [mm/ha/year]**	**Total Deep Drainage [GL/year]**	**Index Dry Saline Land**	**Index Salinity #2 - water table induced**	**Index Wind Erosion Risk #3**	**Index Overall (avg. #1, #2, #3)**
Archibald	25096	558	3641	*29295*	0.260	9850	443	22.1	2.2	0.136	0.052	0.520	0.278
Beeamma		2737	2808	*5545*	0.847	30388	507	26.6	8.1	0.000	0.000	0.554	0.467
Binnum	13	755	2031	*2799*	0.929	35965	527	28.6	10.3	0.000	0.000	0.101	0.343
Bowaka		691	2686	*3377*	0.864	20717	644	37.8	7.8	0.000	0.290	0.118	0.424
Cannawigara	5	1036	2705	*3746*	0.904	34640	445	23.0	8.0	0.191	0.015	0.409	0.443
Carcuma	2908	2487	4564	*9959*	0.719	25433	400	20.5	5.2	0.009	0.000	0.672	0.464
Colebatch	4948	5	1007	*5960*	0.825	28081	473	25.3	7.1	0.043	0.152	0.601	0.526
Coneybeer	2	2881	1877	*4760*	0.866	30525	427	22.1	6.7	0.103	0.012	0.351	0.410
Coombe		182	2157	*2339*	0.948	42515	441	23.3	9.9	0.048	0.189	0.552	0.563
Duffield	958	985	3505	*5448*	0.802	19462	509	26.2	5.1	0.000	0.318	0.209	0.443
Field		118	263	*381*	0.985	24233	472	25.4	6.2	0.021	0.045	0.441	0.490
Geegeela	1645	1502	3888	*7035*	0.802	27963	496	25.3	7.1	0.000	0.000	0.425	0.409
Glen Roy	494	347	978	*1819*	0.934	21780	512	27.2	5.9	0.000	0.072	0.318	0.441
Glyde	12525	146	2220	*14891*	0.635	24433	478	25.2	6.2	0.010	0.098	0.517	0.417
Hynam	16	2149	2993	*5158*	0.866	33077	532	28.8	9.5	0.000	0.032	0.409	0.436
Jeffries		3267	568	*3835*	0.844	20796	440	23.2	4.8	0.000	0.008	0.511	0.454
Jessie	21		306	*327*	0.987	21516	549	30.7	6.6	0.000	0.000	0.018	0.335
Joyce (North)		339	1667	*2006*	0.895	16378	567	31.1	5.1	0.003	0.112	0.228	0.412
Kirkpatrick		1291	1260	*2551*	0.900	23036	408	21.1	4.9	0.000	0.000	0.495	0.465
Lacepede	184	812	3070	*4066*	0.845	17272	557	30.1	5.2	0.000	0.350	0.202	0.466
Laffer	2274	1559	2172	*6005*	0.868	38493	473	25.0	9.6	0.048	0.453	0.341	0.554
Landseer		3604	6587	*10191*	0.658	18924	524	26.9	5.1	0.000	0.328	0.363	0.450
Lewis	13	8241	4300	*12554*	0.706	30160	418	21.2	6.4	0.077	0.003	0.654	0.454
Livingston		2246	1886	*4132*	0.879	29982	393	20.4	6.1	0.053	0.000	0.431	0.437
Lochaber	11	89	1075	*1175*	0.955	21317	534	29.1	6.2	0.000	0.180	0.129	0.421
Makin	18595	310	1886	*20791*	0.405	14153	428	21.8	3.1	0.133	0.008	0.593	0.335
Marcollat	937	123	2185	*3245*	0.918	34748	505	27.1	9.4	0.005	0.143	0.326	0.462
McCallum	18461		607	*19068*	0.469	16811	434	22.8	3.8	0.192	0.039	0.532	0.347
McNamara	1952	3283	5222	*10457*	0.735	26875	500	26.2	7.0	0.048	0.515	0.606	0.619
Messent	10873	8731	2571	*22175*	0.319	9421	507	25.6	2.4	0.008	0.136	0.479	0.311
Minecrow	3	846	4996	*5845*	0.827	26887	561	30.1	8.1	0.000	0.157	0.212	0.399
Mount Benson	268		835	*1103*	0.957	22305	601	26.7	6.0	0.000	0.137	0.212	0.435
Murrabinna	1269	722	2330	*4321*	0.803	16142	578	32.0	5.2	0.000	0.217	0.181	0.400
Naracoorte		4	1055	*1059*	0.957	20284	549	30.0	6.1	0.000	0.110	0.135	0.401
Neville	9447	807	2830	*13084*	0.559	15517	493	25.7	4.0	0.034	0.346	0.296	0.400
Ngarkat	127276	1214	1530	*130020*	0.055	7551	401	20.8	1.6	0.056	0.000	0.646	0.234
Parsons	982	1003	2296	*4281*	0.826	19066	508	26.5	5.1	0.020	0.000	0.659	0.495
Peacock	541	997	3921	*5459*	0.852	30706	519	27.2	8.4	0.003	0.222	0.480	0.518
Pendleton		479	1580	*2059*	0.947	36069	454	23.6	8.5	0.218	0.017	0.464	0.476
Petherick	3396	440	6163	*9999*	0.771	31951	503	26.8	8.6	0.034	0.406	0.294	0.491
Richards			906	*906*	0.977	37753	459	24.5	9.2	0.016	0.302	0.524	0.601
Santo	14239	1927	654	*16820*	0.400	10064	489	25.4	2.6	0.031	0.219	0.386	0.335
Senior		127	1422	*1549*	0.960	36751	438	23.1	8.5	0.237	0.000	0.415	0.458
Shaugh	3478	6444	3761	*13683*	0.716	34322	437	22.7	7.8	0.210	0.003	0.490	0.403
Spence (North)		1124	1100	*2224*	0.897	19019	558	30.6	5.8	0.000	0.108	0.235	0.413
Stirling	100	32	1350	*1482*	0.962	36320	459	24.3	8.8	0.082	0.106	0.336	0.468
Strawbridge		4722	2158	*6880*	0.743	19887	440	22.5	4.5	0.010	0.001	0.543	0.429
Tatiara	25	112	1747	*1884*	0.964	48028	462	24.4	11.7	0.278	0.000	0.066	0.343
Townsend		793	2824	*3617*	0.884	26681	597	33.5	8.9	0.013	0.105	0.194	0.394
Wells	3189	1383	4291	*8863*	0.770	26543	512	27.1	7.2	0.022	0.333	0.450	0.518
Willalooka	144	75	1411	*1630*	0.957	35928	492	26.4	9.5	0.100	0.233	0.389	0.526
Wirrega	76	1112	3292	*4480*	0.928	54898	481	25.4	13.9	0.156	0.005	0.265	0.399
Woolumbool	1384	607	2798	*4789*	0.868	30838	528	28.0	8.6	0.000	0.217	0.264	0.450
[Avg.] or Total	*267748*	*75444*	*127935*	*471127*	*[0.755]*	*1392454*	*[482]*	*[26.0]*	*359.5*	*[0.050]*	*[0.128]*	*[0.382]*	*[0.435]*

Table 27. Estimated unharvested above-ground carbon dioxide sequestration rates and district totals by land subdivision (Hundreds) and agroforestry species group.

Hundred	Rainfall [mm]	Potential Agroforestry Area [ha]	Carbon Dioxide Sequestration [t CO2 equiv./ha/year] by species group					Carbon Dioxide Sequestration [Kt CO2 equiv./Hundred/year] by species group				
			Pulpwood	Bioenergy	Oil Mallee	Saltbush Fodder	Habitat	Pulpwood	Bioenergy	Oil Mallee	Saltbush Fodder	Habitat
Archibald	443	9850	13.43	23.48	15.37	4.12	9.59	132	231	151	41	94
Beeamma	507	30388	17.51	26.90	17.27	4.62	10.77	532	818	525	141	327
Binnum	527	35965	19.81	28.83	18.34	4.91	11.43	713	1037	659	177	411
Bowaka	644	20717	28.32	35.97	22.29	5.97	13.90	587	745	462	124	288
Cannawigara	445	34640	13.43	23.47	15.37	4.12	9.58	465	813	532	143	332
Carcuma	400	25433	8.29	19.16	12.99	3.48	8.10	211	487	330	88	206
Colebatch	473	28081	14.21	24.14	15.74	4.21	9.81	399	678	442	118	276
Coneybeer	427	30525	12.70	22.87	15.03	4.03	9.38	388	698	459	123	286
Coombe	441	42515	11.71	22.03	14.57	3.90	9.09	498	937	620	166	386
Duffield	509	19462	17.91	27.24	17.46	4.67	10.88	349	530	340	91	212
Field	472	24233	14.21	24.14	15.74	4.21	9.81	344	585	381	102	238
Geegeela	496	27963	16.73	26.25	16.91	4.53	10.54	468	734	473	127	295
Glen Roy	512	21780	17.91	27.22	17.44	4.67	10.88	390	593	380	102	237
Glyde	478	24433	14.18	24.10	15.71	4.21	9.80	346	589	384	103	239
Hynam	532	33077	19.87	28.88	18.37	4.92	11.45	657	955	607	163	379
Jeffries	440	20796	12.81	22.96	15.09	4.04	9.41	266	477	314	84	196
Jessie	549	21516	22.00	30.67	19.35	5.18	12.07	473	660	416	111	260
Joyce (North)	567	16378	22.18	30.82	19.44	5.20	12.12	363	505	318	85	198
Kirkpatrick	408	23036	11.71	22.03	14.57	3.90	9.09	270	508	336	90	209
Lacepede	557	17272	22.32	30.93	19.50	5.22	12.16	385	534	337	90	210
Laffer	473	38493	15.98	25.61	16.55	4.43	10.32	615	986	637	171	397
Landseer	524	18924	19.15	28.28	18.03	4.83	11.24	362	535	341	91	213
Lewis	418	30160	10.01	20.61	13.79	3.69	8.60	302	622	416	111	259
Livingston	393	29982	10.49	21.01	14.01	3.75	8.74	315	630	420	112	262
Lochaber	534	21317	19.35	28.35	18.05	4.83	11.26	413	604	385	103	240
Makin	428	14153	10.52	21.04	14.02	3.76	8.75	149	298	198	53	124
Marcollat	505	34748	18.22	27.50	17.60	4.71	10.97	633	955	611	164	381
McCallum	434	16811	11.50	21.86	14.48	3.88	9.03	193	367	243	65	152
McNamara	500	26875	16.82	26.31	16.94	4.54	10.56	452	707	455	122	284
Messent	507	9421	16.10	25.63	16.55	4.43	10.32	152	241	156	42	97
Minecrow	561	26887	21.46	30.21	19.10	5.11	11.91	577	812	514	138	320
Mount Benson	601	22305	25.21	33.36	20.84	5.58	13.00	562	744	465	124	290
Murrabinna	578	16142	23.08	31.58	19.86	5.32	12.38	373	510	320	86	200
Naracoorte	549	20284	20.80	29.65	18.79	5.03	11.71	422	601	381	102	238
Neville	493	15517	18.07	27.37	17.53	4.69	10.93	280	425	272	73	170
Ngarkat	401	7551	8.59	19.42	13.13	3.52	8.19	65	147	99	27	62
Parsons	508	19066	17.17	26.61	17.11	4.58	10.67	327	507	326	87	203
Peacock	519	30706	18.46	27.70	17.71	4.74	11.04	567	851	544	146	339
Pendleton	454	36069	13.98	23.94	15.63	4.18	9.74	504	863	564	151	351
Petherick	503	31951	18.32	27.58	17.64	4.72	11.00	585	881	564	151	351
Richards	459	37753	12.83	22.98	15.10	4.04	9.41	485	868	570	153	355
Santo	489	10064	16.31	25.89	16.71	4.47	10.42	164	261	168	45	105
Senior	438	36751	12.31	22.53	14.85	3.98	9.26	452	828	546	146	340
Shaugh	437	34322	11.66	22.00	14.55	3.90	9.08	400	755	500	134	311
Spence (North)	558	19019	22.01	30.67	19.35	5.18	12.07	419	583	368	99	230
Stirling	459	36320	15.49	25.21	16.33	4.37	10.18	563	916	593	159	370
Strawbridge	440	19887	13.35	23.41	15.34	4.11	9.56	265	466	305	82	190
Tatiara	462	48028	13.16	23.23	15.24	4.08	9.50	632	1116	732	196	456
Townsend	597	26681	24.41	32.69	20.47	5.48	12.77	651	872	546	146	341
Wells	512	26543	18.01	27.26	17.46	4.67	10.88	478	724	463	124	289
Willalooka	492	35928	17.49	26.84	17.23	4.61	10.74	628	964	619	166	386
Wirrega	481	54898	16.93	26.36	16.96	4.54	10.58	929	1447	931	249	581

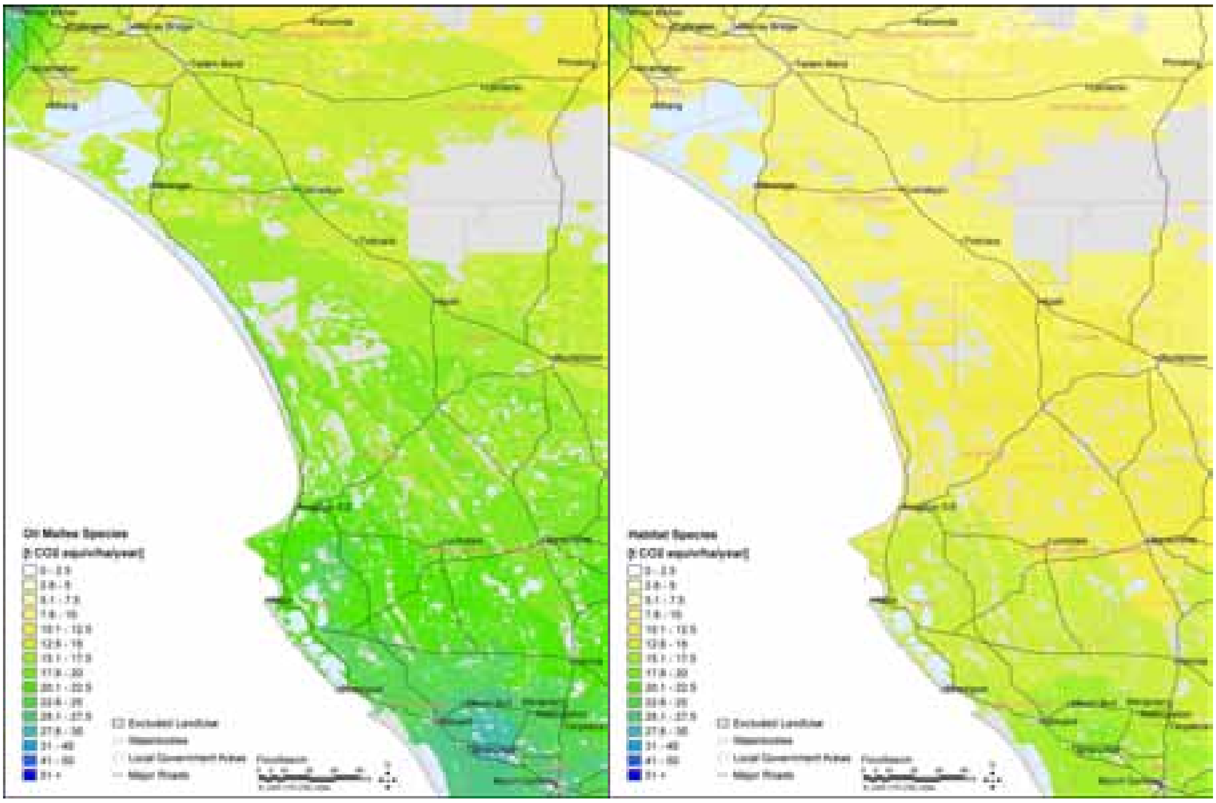
Woolumbool	528	30838	19.15	28.27	18.03	4.83	11.24	591	872	556	149	347
[Avg.] or Total	*[482]*	*1392454*	*[16.56]*	*[26.10]*	*[16.82]*	*[4.50]*	*[10.49]*	*22743*	*36072*	*23275*	*6233*	*14514*

Fig. 51. Estimated unharvested annual CO_2 sequestration rates of each Species Group in the SA Upper South East region.



Pulp and Fibre

Bioenergy



Oil Mallee

Habitat

High Priority Industry Types for the SA Upper South Region

FloraSearch and the WA Search reports (Hobbs *et al.* 2008c, Bennell *et al.* 2008, Olsen *et al.* 2004) identified the most prospective industry types for the wheat-sheep zone of southern Australia. They identify the high priority or "best bet" industries and detail some emerging industries that may be serviced by woody crop production in the mid-low rainfall areas of Australia. New biomass related markets are emerging from a world environment of higher fossil fuel costs, climate change, environmental awareness and advances in technology. The following sections provide a summary of high priority industries relevant to South Australia and the Upper South East region.

Wood fibre industries

Wood fibre industries are already an important landuse in the higher rainfall regions of the southeast of South Australia. Radiata Pine (*Pinus radiata*) and Tasmanian Bluegum (*Eucalyptus globulus ssp. globulus*) are widely planted in the 600+mm annual rainfall zone, predominantly south of Naracoorte. Wood pulp and paper products are currently produced at Kimberley-Clark Mills at Millicent and Tantanoola based on softwood fibres. Recently SA government development approvals have been given for a new pulp mill to be established near Penola and is planned to be operational by 2009. The consortium of companies developing this new mill include, Timbercorp, Orica, CellMark, Andritz and Silcar as Penola Pulp Pty Ltd, where they plan to produce hardwood pulp from Tasmanian Bluegum resources. Nearby in the western Victorian town of Heywood a further pulpwood mill is planned to utilise Australia hardwood species. Currently most hardwood chips are destined for export and transported to the deep water port of Portland in Victoria.

Firewood

There is already a great deal of interest in the production of firewood from the Upper South East region primarily to service the firewood markets in the Adelaide metropolitan and adjacent areas. Firewood is a moderately high value wood product and that can provide farmer returns within a relatively short period after initial investment. Firewood production systems can readily utilise the resprouting or coppicing nature of many Eucalyptus species and alleviates or minimise future woodlot establishment costs. Many of the currently preferred firewood species are well adapted to the Upper South East region, including Sugargum (*Eucalyptus cladocalyx*), Redgum (*E. camaldulensis*) and many mallee eucalypt species.

The commercial viability of firewood production in the Mount Lofty Ranges region of South Australia has been evaluated by several authors in recent years (eg. Bulman *et al.* 2002, Poynter and Borschmann 2002, Geddes Management 2003, Mt Lofty Ranges Private Forestry 2006). They indicate that the Adelaide and outer metropolitan market consumes around 150,000 - 180,000 tonnes of firewood per annum, of which approximately 65,000-90,000 tonnes is acquired through commercial vendors. Modest markets also exist in major regional centres, notably Mount Gambier, Murray Bridge and Naracoorte.

Bioenergy for electricity generation

As outlined in the Section 4 of this report (*Woody Bioenergy Crops for Lower Rainfall Regions of Southern Australia*) there is significant demand for renewable electricity generation across Australia. The SA Upper South East region is no different to the rest of the country. In fact, heat and electricity generation already occurs in the Lower South East regions from forestry waste streams in the Mount Gambier / Millicent areas. A new pulp mill proposed at Penola also intends to generate electricity from pulpwood wastes and Babcock and Brown have investigated the development of purpose-build wood-fired power plants for the Green Triangle region in recent years.

Eucalyptus oil and integrated wood processing

Eucalypt mallee species dominate the native vegetation communities of the northern part of the Upper South East study area. Nearby regions in Victoria (eg. Nhill) have a past history of harvesting *Eucalyptus viridis* ssp. *wimmerensis* and other mallees for oil productions. Several rural communities in the 'mallee districts' of South Australia and Victoria have shown considerable interest in both markets for Eucalypt oil and energy production. As much of the region is remote from existing large power generation facilities and environmentally-friendly (but part-time) windfarming is generally supported in the region there is considerable potential to develop these industries in the SA Upper South East region.

Fodder industries

Livestock grazing is already a major industry across the South Australia's south east. Some of the SA's most productive and profitable grazing enterprises occur in this region. These industries require a primary resource of livestock fodder, which is presently based on predominantly annual crops of pasture and cereals. However, some herbaceous perennial plant species (predominantly lucerne) are widely utilised, and highly valued, for their provision of green feed or nutritious hay for dry season fodder in the paddock or as a feedlot resource. However, lucerne often fails to perform as a dryland crop in some drier areas and on soils that are shallow, acidic, high in exchangeable aluminium or sodium salt, or with hostile subsoils. Several robust fodder shrubs could provide an easily propagated, fast growing, readily managed and grazing tolerant option for livestock industries in this region.

Old Man Saltbush (*Atriplex nummularia*) and the introduced Tagasaste or Lucerne Tree (*Chamaecytisus* spp.) is currently widely used in the South East region of Southern Australia as fodder shrub crops over the last decade. These fodder shrubs can provide valuable green feed resource during summer and autumn when other typically annual fodder species are desiccated making its livestock value higher and more equivalent to that of lucerne.

Carbon sequestration

The potential for carbon trading has become a significant factor in evaluating the economics of long-term perennial vegetation as permanent sinks but there is also increasing interest in the carbon stores held in harvested perennial crop systems such as classical forestry and other shorter rotation agroforestry crops. European carbon dioxide trading has been active since early 2005. In Australia, the carbon trading market is a near future prospect (proposed for 2010) with state governments and private corporations are already gearing up for carbon trading.

The current European price suggests that carbon sequestration alone may be economically viable for revegetation in some landscapes and regions. Additionally, commercial woody crops may also include the average standing biomass of these crops as a carbon sequestration value, or even the long term carbon stored in the roots and accumulated soil carbon of these crops, as a contributor to the economic value of these perennial farming systems.

Regional Industry Potential Analysis 2006

The *Regional Industry Potential Analysis* (*RIPA*) is a methodology for evaluating the potential plantation productivity and industry product yields, economically optimum harvest intervals of woody crops, landholder annual equivalent returns (AER) from each industry type and location, and sensitivity analyses. The methodology of the *Regional Industry Potential Analysis* is detailed in the FloraSearch 1a and 2 reports (Bennell *et al.* 2008, Hobbs *et al.* 2008c) and should be read prior to reviewing the current outputs. The following sections are based on that methodology, but have expanded to include additional industry types and economic models. Current models include updated transportation costs and delivered feedstock values based on recent price increases and better estimates of product yields and values. *RIPA* allows spatial and economic comparisons between existing agricultural systems, new industries based on existing infrastructure, and hypothetical explorations of new investments in infrastructure or highly prospective industry types.

Existing Dryland Annual Cropping and Livestock Industries

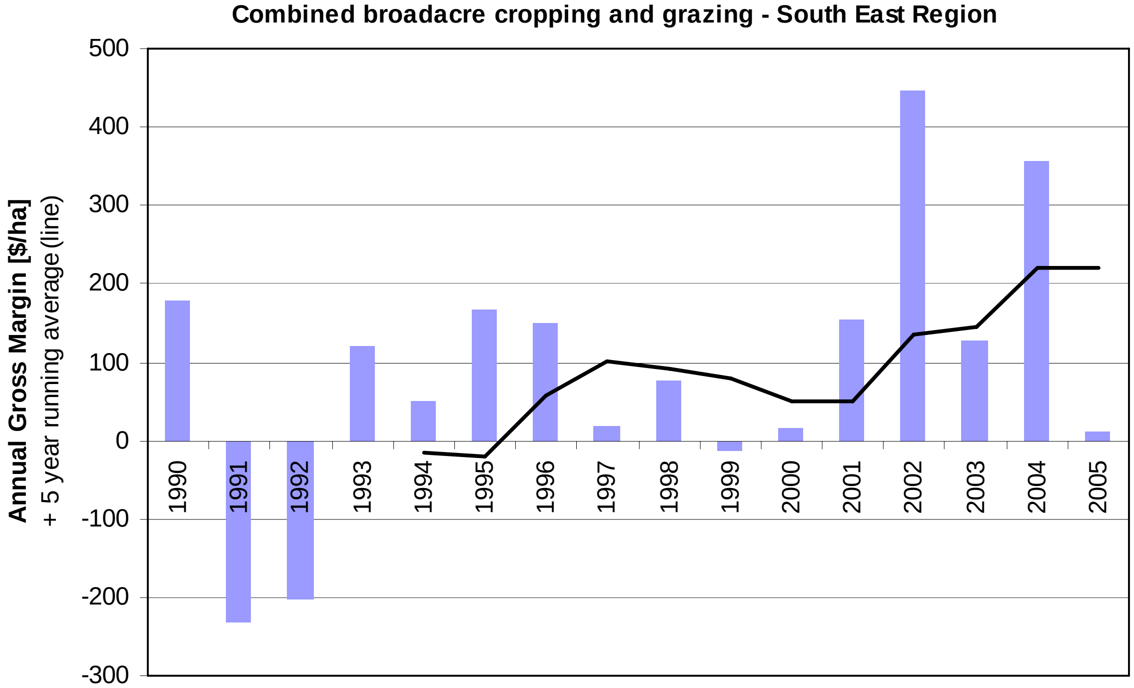
Livestock production is a major existing industry in the South East Region. As of June 30, 2005, 32% of sheep and lambs in South Australia (4,013,400 head), and 54% of meat cattle (65,000head) were found in the South East Statistical Division (ABS 2006). The majority of these livestock graze on improved pastures, annual crop residues, and to a lesser extent on native grasslands. Other herds are managed in substantial feedlots at Meningie and Naracoorte, with smaller lots at Tintinara, Lameroo, Parrakie and Frances. In 2004-05, 4.9% (96,900 tonnes) of all barley produced in South Australia and 3.6% (94,500 tonnes) of all wheat produced in South Australia came from the South East Statistical Division. The region also produced significant quantities of grain legumes (~37,000t) and oilseeds (mainly canola, ~28,000t).

Australian Bureau of Agricultural and Resource Economics *AgSurf* farm survey statistics for the South East Region (ABARE 2006, see Fig. 52) illustrate the variability of farmer economic returns from dryland cropping and grazing. Seasonal variations significantly influence crop yields and pasture growth for livestock meat and fibre production. To estimate the gross margin returns in the Upper South East (USE) region we have mapped all annual cropping and grazing lands for the greater South East region, extracted their inherent climate-soil productivity values from CSIRO productivity surfaces (Raupach *et al.* 2001) and projected their proportional contribution to the South East region’s 10 year average of gross margins for combined broadacre cropping and grazing. Fig. 53a illustrates the likely spatial variation in gross margin returns in existing annual cropping and grazing lands. Following an identical process we have also mapped the 10 year maximum gross margin return for the region (Fig. 53a). Hobbs *et al.* 2006 provides more detailed summaries of these values for each Hundred subdivision.

New Industry Modelling Approach

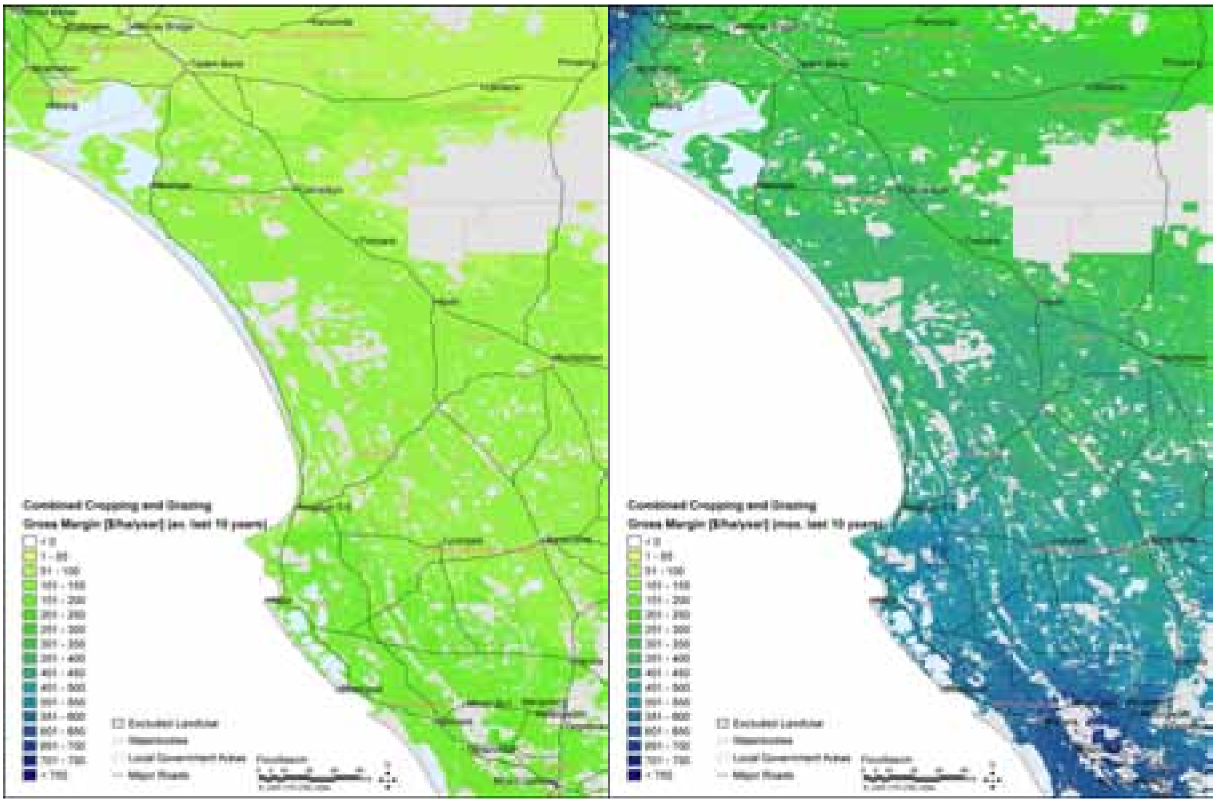
Regional Industry Potential Analysis (*RIPA*) methodologies and national economic evaluations are described in detail in Bennell *et al.* (2008) and Hobbs *et al.* (2008c). In summary, the *RIPA* model consists of a series of models predicting potential spatial distributions of individual species based on bioclimatic relationships, spatial plantation productivities and yields of biomass components, point-based economic models of optimised annual equivalent returns from short cycle woody perennial woody crops, and transportation network models for each industry type. Finally, the *RIPA* integrates point-based economic models with spatial information to predict agroforestry equivalents to gross margin analyses (used to evaluate the short-term economic performance of crops and livestock). The integrated *RIPA* model is not scale dependant - early versions undertook broadscale analyses at a one kilometre resolution. In the Upper South East (USE) region landuse, vegetation and soil mapping is available at a scale of one hectare and this is the native resolution of the *RIPA* predictions in this region. ArcGIS 9.1 (ESRI 2005) geographic information system software is used for these spatial models and analyses.

Fig. 52. Average gross margins per hectare (2005 dollars) of combined cropping and livestock grazing enterprises for years 1990 to 2005.



Source: ABARE AgSurf (2006)

Fig. 53. Estimated gross margin (2005 dollars) of combined cropping and livestock grazing enterprises.



a) 10 year average for 1996 to 2005

b) 10 year maximum for 1996 to 2005

The first step in this process is to determine which agroforestry, fodder shrub or other woody biomass industry is to be evaluated. Species are then selected that match the product specifications of that industry type (eg. from laboratory pulp yields test for pulpwood species). Bioclimatic models predict the regional suitability of the species chosen, and observations of plantation productivities from field trials and agroforestry plots used to predicted growth rates and yields across the study area (as described earlier in this report). Coppicing species have a 30% increase in total biomass productivity resulting from having effectively more stems per hectare and established investments in root biomass. For unharvested carbon sequestration biomass crops we have incorporated an estimate of below ground biomass as a proportion of above ground biomass (ie. mallees +20%, tree and shrubs +10%, +15% average for habitat species).

We have mapped existing infrastructure which may be utilised for each potential industry type (eg. roads, processing plants, ports etc.; see Fig. 55) and geographically placed hypothetical new infrastructure to support prospective new industry type (eg. hypothetical Integrated Tree Processing plant at Keith). Transport paths and associated freight costs have been mapped and evaluated between each hectare of land potentially available for new woody biomass industries and each existing or hypothetical facility.

Freight costs are a significant contributor to the economics of biomass commodity industries, especially for producers of high volume / relatively low value product that need to be transported to distant mills and processing plants (Bennell *et al.* 2008, Hobbs *et al.* 2008c). Transport costs are dependant on vehicle travel speeds and are variable in their proportion of running costs and driver salaries. To increase the accuracy of spatial economic models we detailed different road types and surfaces, speed restrictions on all roads and tracks servicing the Upper South East and transport routes to Port Adelaide. The following equation was used in our models to account for transport costs by road networks:

$$\textbf{Transport cost multiplier} = \mathbf{0.0002466 * Road\ Speed^2 - 0.04553 * Road\ Speed + 3.092}$$

Using the base cost of $0.115/t/km return trip included, and road speed information Fig. 54 demonstrates the range of freight costs from highway to farm tracks.

The economic module of the *RIPA* model incorporates all plantation establishment and maintenance costs for each biomass industry group of species. Planting densities are set at 1000 plants per hectare for all biomass industry species groups except for Saltbush Fodder Species Group which uses 1500 shrubs per hectare. Establishment costs are based on those reported by Hobbs *et al.* (2008c) for broadacre biomass industries and Bulman (2002) and Mt Lofty Ranges Private Forestry (2006) for farm forestry woodlots in the Adelaide Hills. For this study we have used a generous establishment cost of $875/ha for trees and mallees and $825/ha for fodder shrubs. However, broadacre agroforestry establishment costs in flat, simple and sandy landscapes are likely to be around 15% less than this figure. Average annual maintenance costs have been set at $10/ha/year to include occasional and sporadic activities such as firebreak control, supplementary fertilisers, follow-up weed and pest control. Harvest cost varies depending on each industry type and the degree of biomass sorting and product quality controls. For wood fibre, bioenergy and oil mallee costs are based on continuous flow in-field biomass chipping technologies described by Enecon Pty Ltd (2001) or in-field log chippers used in existing Tasmanian Bluegum (*Eucalyptus globulus*) industries (Timbercorp 2006). Firewood harvest costs are based on small and medium scale harvesting systems described by Poynter and Borschmann (2002) and Mt Lofty Ranges Private Forestry (2006). Off-farm fodder harvest costs are based on forage harvesters. A summary of establishment, harvest and transport costs are presented in Table 28.

The economics module then combines information on plantation productivities, changes in plantation product component yields (ie. biomass fractions) with plant age, establishment costs, maintenance costs, harvest costs and delivered feedstock values (see Table 12), a financial discount rate of 7%, and conducts sensitivity analyses to determine economically optimal harvest cycles for each industry type.

Spatial economics models are constructed for each industry type and applied to spatial surfaces of plantation productivities and road transport costs (where applicable) for every hectare of land potentially available to revegetation industries in the region. Cash flows over the first 20 years of each production system (under a financial discount rate of 7%) are converted to *Annual Equivalent Returns* (AER) which allows direct comparisons with annual gross margin analyses for existing annual agricultural.

Fig. 54. Influence of road speed on 2006 freight costs used in spatial economic models.

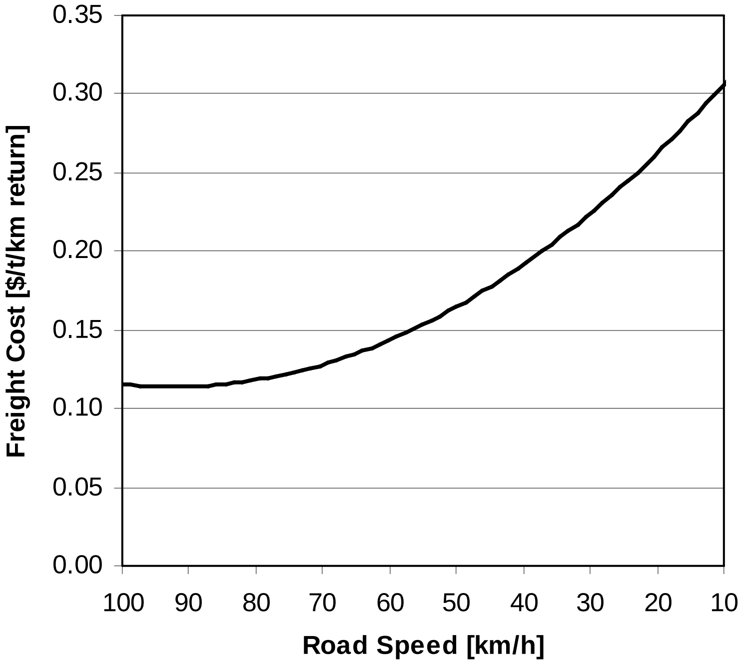


Table 28. Primary production, freight costs and discount rate used in regional industry potential analysis.

Primary Production Costs ($/ha) by Plantation Type	**Planting density**	**Site planning, setup and land preparation**	**Seedlings, planting, fertiliser and watering**	**Weed/Pest management and control**	**Total Establishment costs [$/ha]**
Agroforestry/Biomass	1,000 trees/ha	290	510	75	875
Fodder Shrubs	1,500 shrubs/ha	270	480	75	825
Average Maintenance Costs ($/ha/year)	10				
Harvest Costs ($/freshweight tonne of total biomass)	**Wood Fibres**	**Bioenergy/ ITP Oil Mallee**	**In-field Eucalyptus Oil[#1]**	**Off-farm Harvested Fodder**	**Grazed Fodder / CO2 Seq.**
	20	10	28	5	0
Freight costs – includes truck return trip ($/t/km)	base of 0.115 (depending on road/track surface, see Fig. 54)				
Discount rate	7%				

[#1] includes oil extraction, based on Abadi *et al.* (2006)

Table 29. Economically optimum harvest cycles, delivery locations and estimated 2006 delivered feedstock values by industry used in regional industry potential analysis.

Industry and Commodity Type	Optimum Harvest Cycle (First, Subsequent)	Delivery Location	Delivered Feedstock Value [$/freshweight tonne]
Export pulp - woodchip	11, 9	Port	90
Australian pulp - woodchip	11, 9	Mill	85
Australian particleboard - woodchip	14, 12	Mill	43
Firewood (bulk supply) - cut and split billets	14, 12	Distribution Centre	100
Electricity generation - whole plant biomass	7, 4	Power Plant	28
Eucalyptus bulk oil - leaf	4, 3	Mobile Processing Plant	80
Integrated wood processing - whole plant biomass	7, 4	Processing Plant	36
Fodder - Saltbush leaf (Autumn)	3, 2	In situ/ Paddock/Feedlot /Mill	65
Fodder - Saltbush leaf (Spring)	3, 2	In situ/ Paddock	45
Carbon Sequestration - all biomass	Not Harvested	In situ	20

New Industry Economic and Spatial Evaluations

Regional Industry Potential Analysis (*RIPA*) models have been applied for the most prospective woody biomass industries type in the Upper South East. Model outputs include parts of neighbouring Lower South East and Southern Mallee regions. However, our productivity models have not been calibrated for higher rainfall regions (eg. >700mm) and greater caution is required in interpreting economic results for these high rainfall areas. The *RIPA* model outputs of *Annual Equivalent Returns* for each biomass industry type are present in Fig. 56a-o. Summaries of predicted farmer returns for each Hundred subdivision in the Upper South East region are presented in Table 30.

Overall, many new biomass industries can bring substantial financial returns to many districts in the Upper South East (USE) depending on farmer access to existing and potential markets or corporate/government/cooperative investment in new infrastructure. Immediate access can be gained to livestock fodder (see Fig. 56g-i) and firewood industry markets (see Fig. 56e, f) which are reflected in existing farm diversification in the region. Low to medium rainfall pulpwood industries for export or delivery to the new pulp mill planned for Penola are feasible over much of the region (see Fig. 56a-c) and are likely to create the greatest return per hectare in many districts. Delivery of feedstock to the particleboard mill at Mount Gambier (see Fig. 56d) is not viable anywhere in the USE region due to relatively low feedstock values and modest transportation costs. Prospective bioenergy and oil mallee systems (Integrated Tree Processing, see Fig. 56k, l) could provide substantial returns in the region but these require a reasonable investment in new infrastructure to be viable. In-field mallee harvesting and distillation of Eucalyptus oil could also provide significant returns in landscapes suited to oil mallee species with minimal investments in infrastructure (see Fig. 56j).

Carbon sequestration in unharvested habitat or oil mallee revegetation using low planting density (1000tph) and high-cost establishment techniques (tubestock plantings used in our analysis cf. cheaper direct seeding) provide minimal returns for farmers at present without co investment from governments (see Fig. 56m, n). Carbon sequestration using unharvested *Bioenergy* species and current world carbon prices could provide reasonable returns to land holders when carbon trading is available in South Australia (see Fig. 56o). Equally, if the average standing biomass and root biomass of harvested woody crops was included in carbon sequestration trading it could provide additional income streams to extractive agroforestry enterprises in the region.

Fig. 55. Existing infrastructure relating to biomass industries in the region.

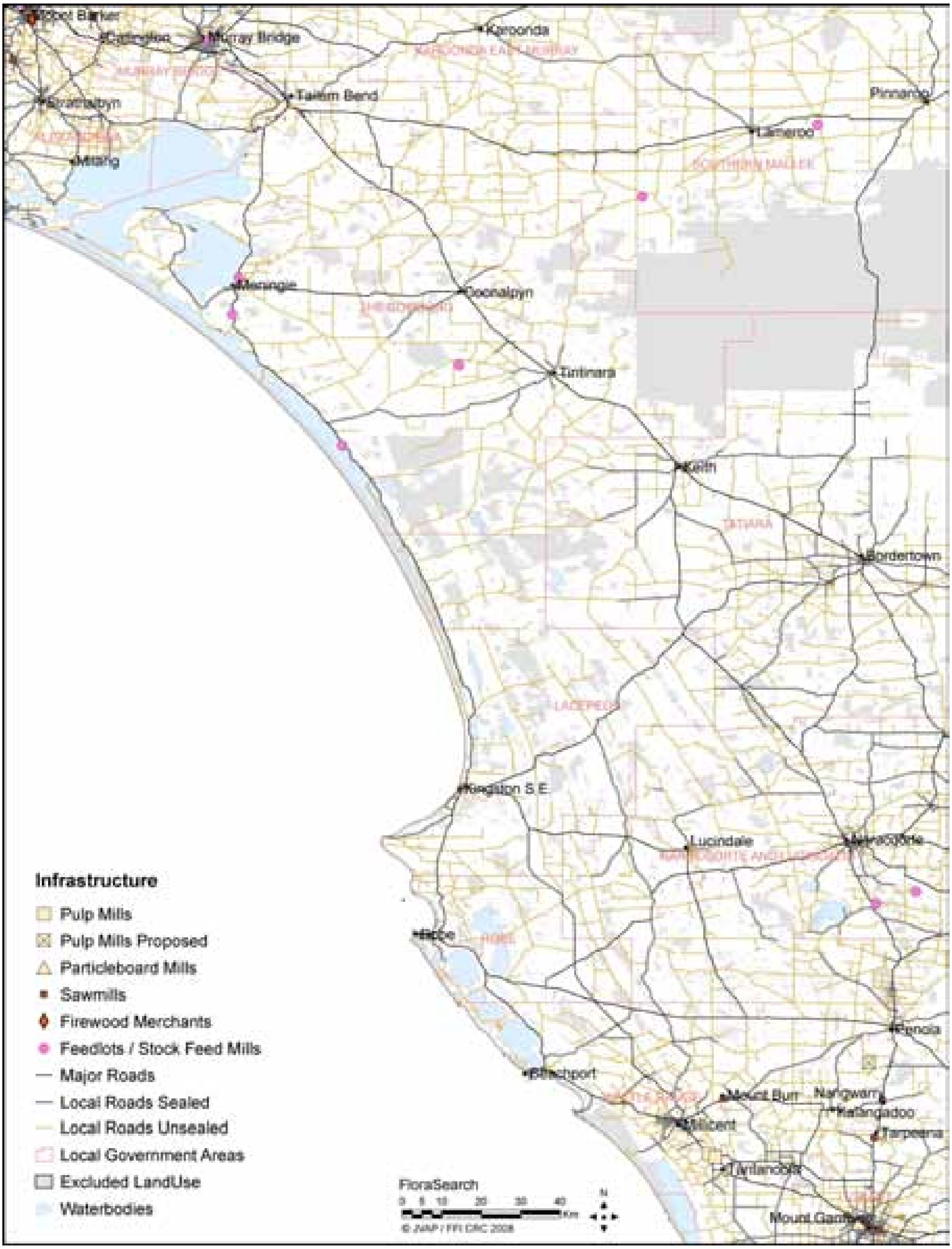
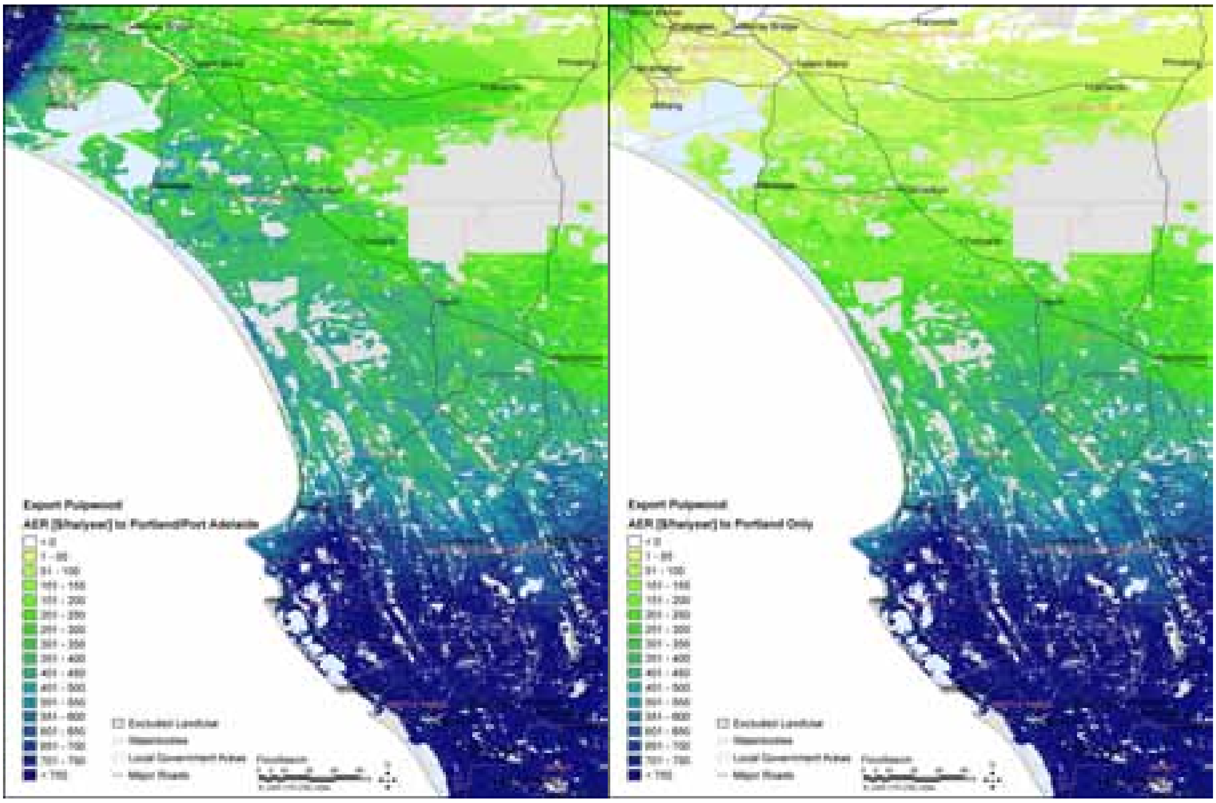


Fig. 56. Estimated primary producer returns from a range of Regional Industry Potential Analysis scenarios in the Upper South East region.

a) Export Pulpwood - Port Adelaide and Portland **b) Export Pulpwood - Portland Only**



c) Australian Pulpwood - Existing pulp mills at Millicent and Tantanoola, and proposed at Penola **d) Particleboard - Existing at Mount Gambier**

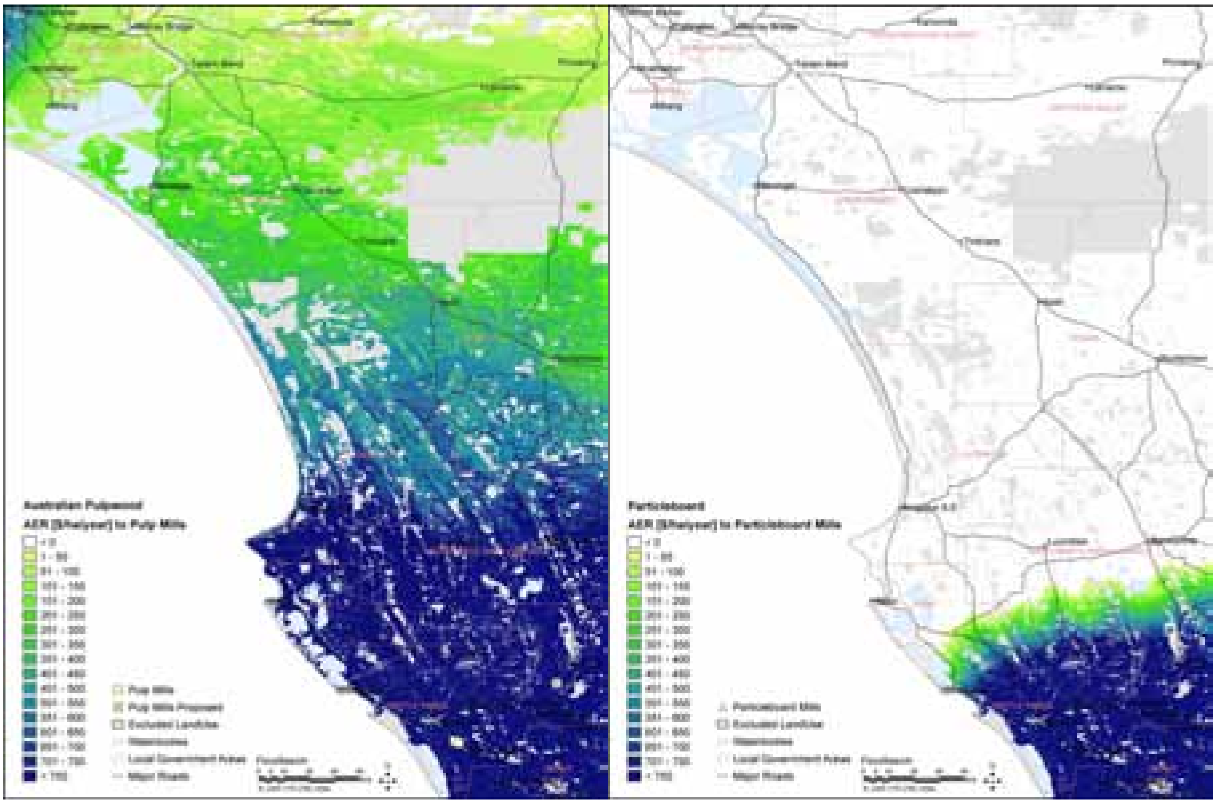
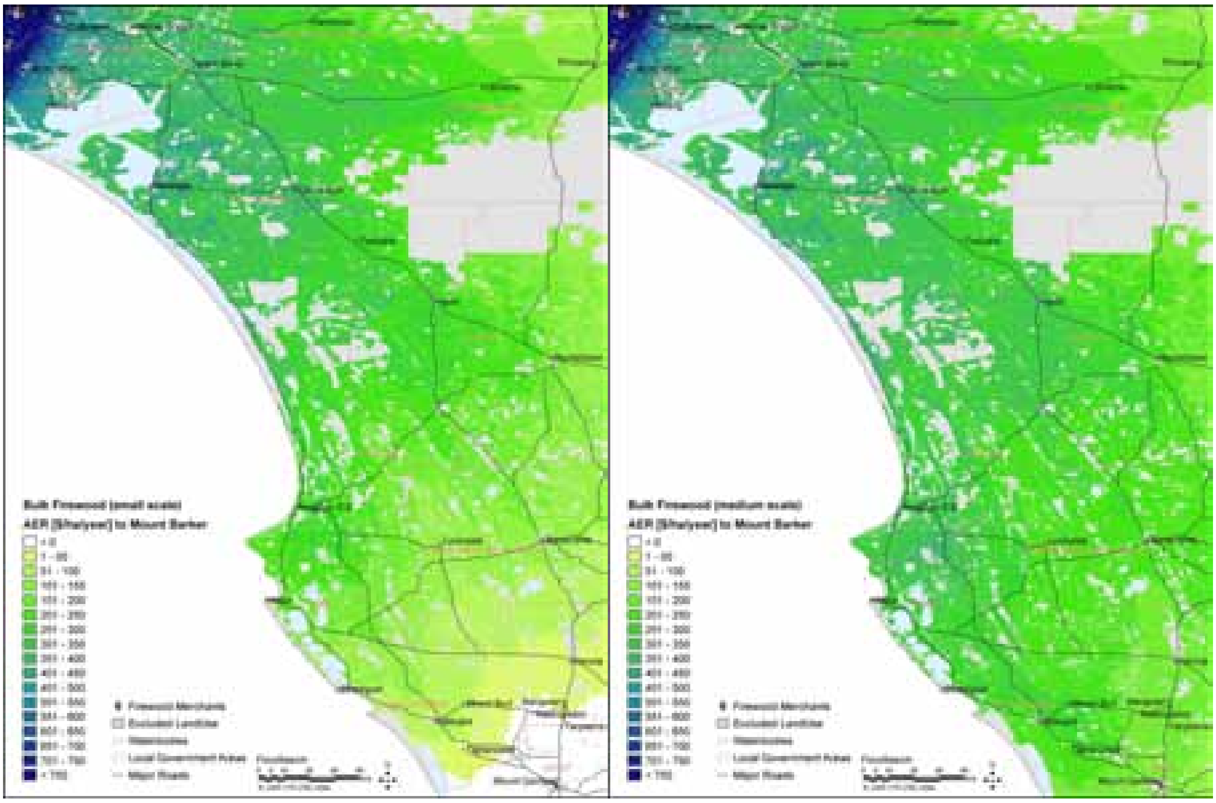


Fig. 56. Estimated primary producer returns from a range of Regional Industry Potential Analysis scenarios in the Upper South East region. (continued)

e) Bulk firewood to Mount Barker - Small scale harvesting methods

f) Bulk firewood to Mount Barker - Medium scale harvesting methods



g) In situ Farm Fodder Saltbush (Autumn value)

h) In situ Farm Fodder Saltbush (Spring value)

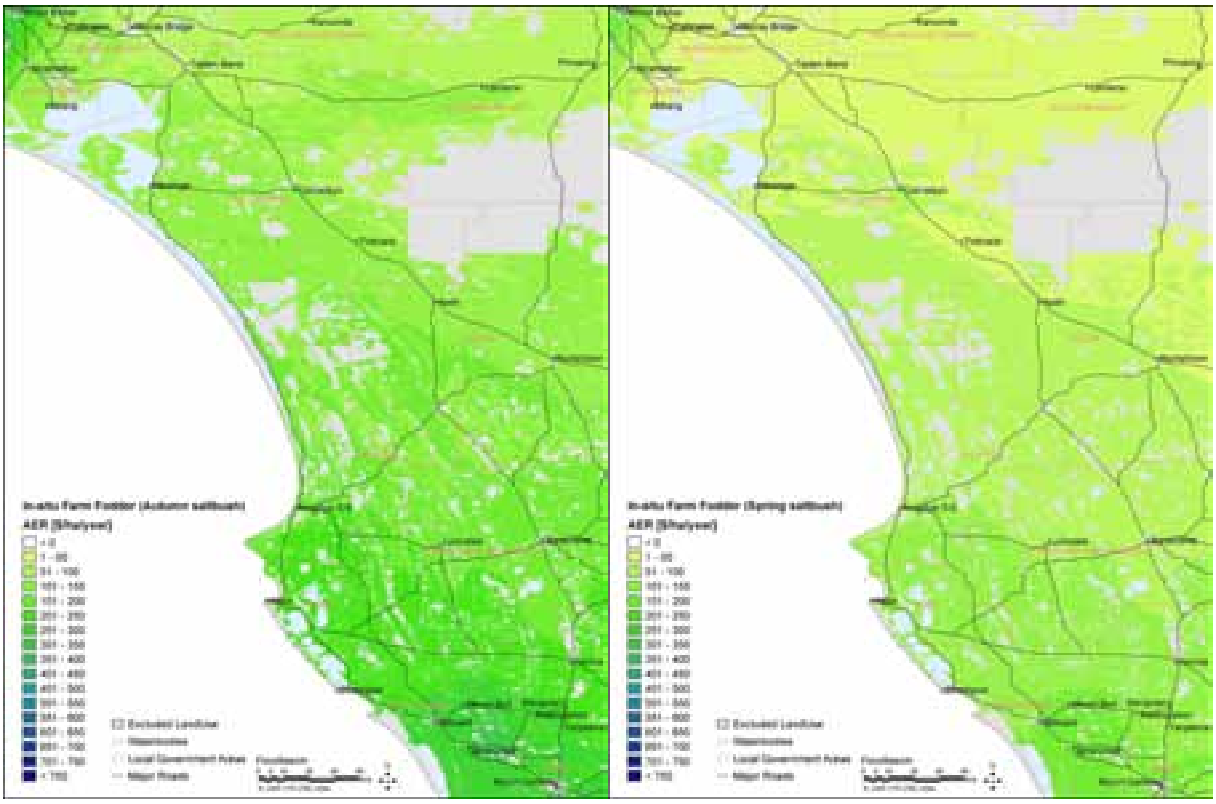
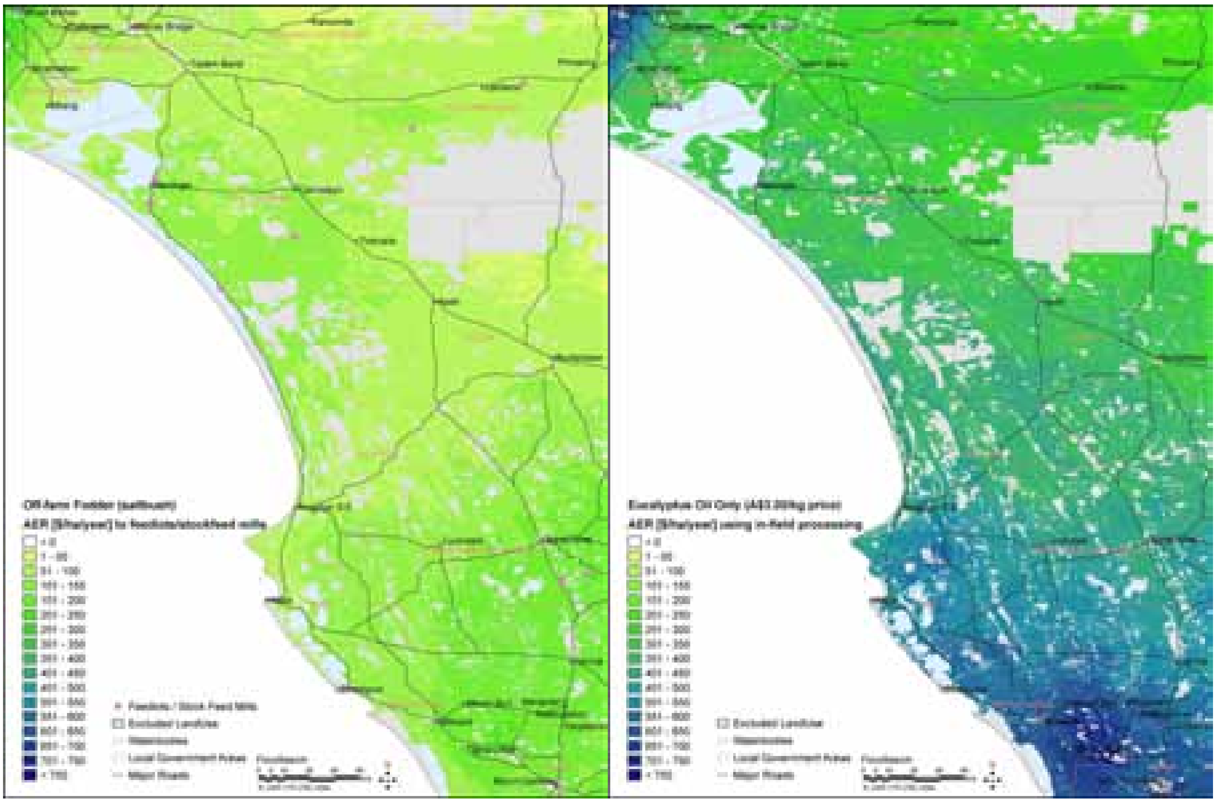


Fig. 56. Estimated primary producer returns from a range of Regional Industry Potential Analysis scenarios in the Upper South East region. (continued)

i) Off-farm Fodder (saltbush) - Feedlots and stockfeed manufacturing facilities

j) Eucalyptus Oil Only - mobile oil distillation plants ($3.00/kg price) with product freighted to ports



k) Bioenergy Only scenario delivered to a new bioenergy plant located at Keith

l) Integrated Tree Processing scenario delivered to a new ITP plant located at Keith

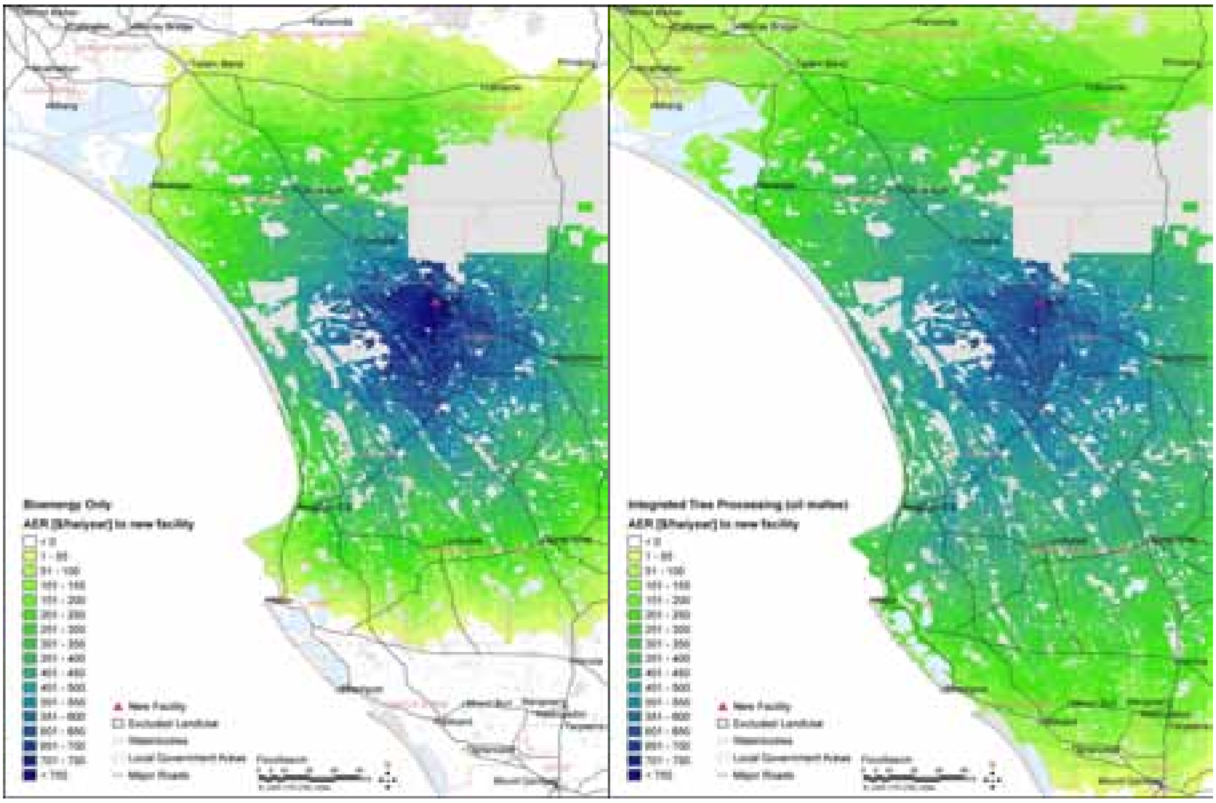
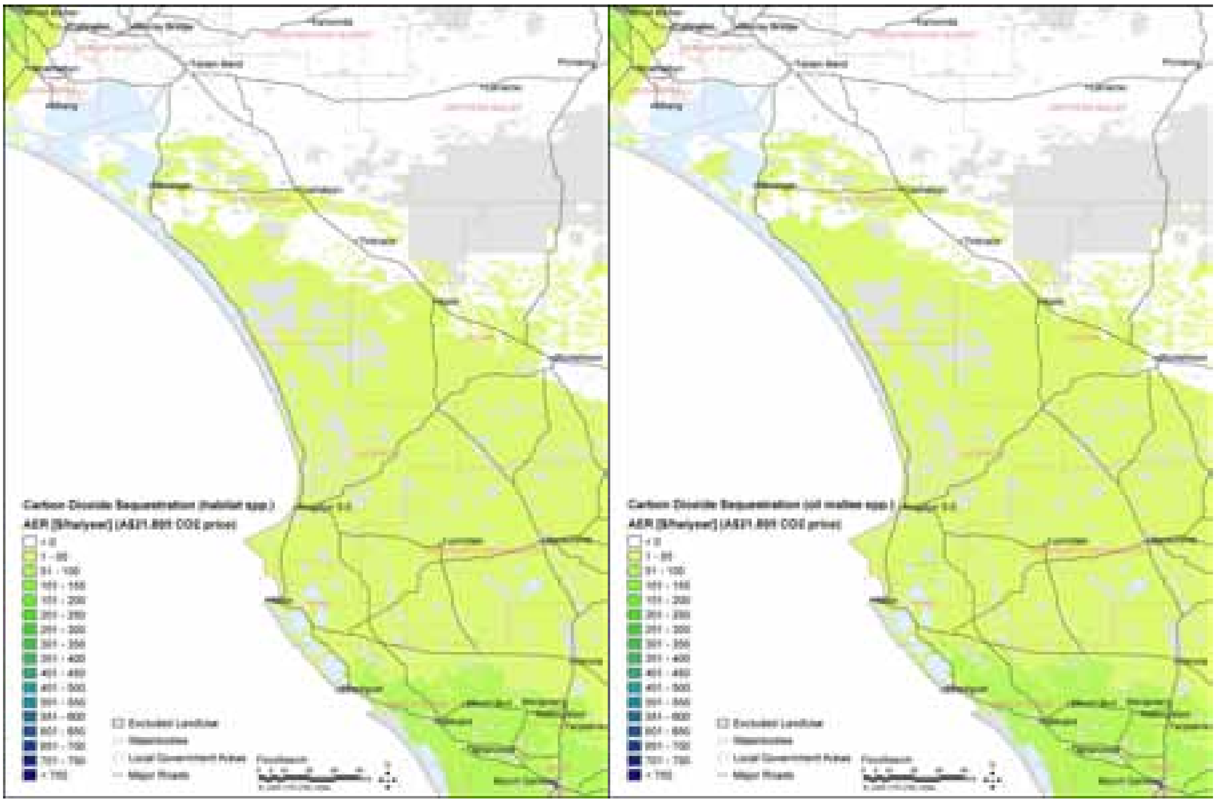


Fig. 56. Estimated primary producer returns from a range of Regional Industry Potential Analysis scenarios in the Upper South East region. (continued)



m) Carbon sequestration - Habitat Species (above-ground biomass +15% root biomass)

n) Carbon sequestration - Oil Mallee Species (above-ground biomass +20% root biomass)

o) Carbon sequestration - Bioenergy Species (above-ground biomass +10% root biomass)

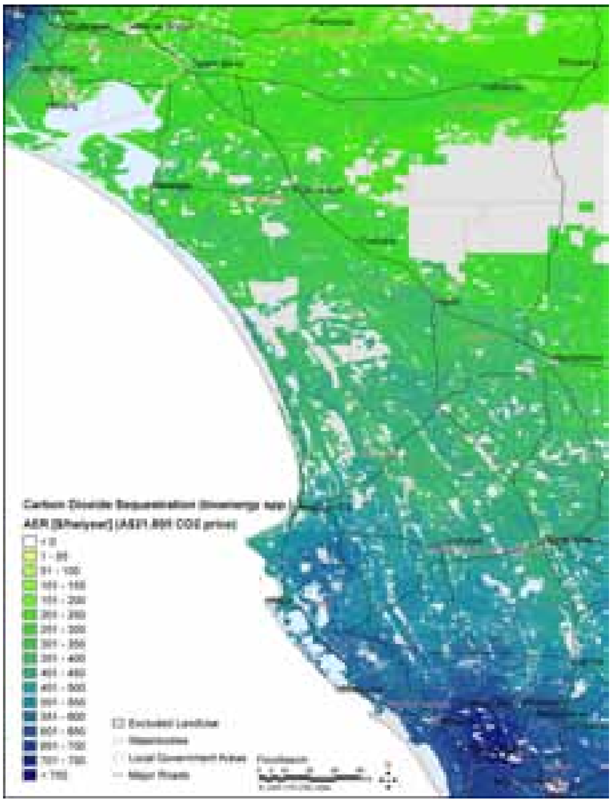


Table 30. Summaries of expected annual equivalent returns [$/ha/yr] from existing cropping and grazing industries, and new agroforestry industries by subdivision.

Hundred	Rainfall [mm]	Potential Agroforestry Area [ha]	Gross Margin Cropping - Grazing Avg Last 10 years	Gross margin Cropping - Grazing Max Last 10 years	Export Pulpwood All Ports	Export Pulpwood Portland Only	Australian Pulpwood	Particleboard	Firewood (small scale)	Firewood (medium scale)	In situ Fodder (Autumn)	In situ Fodder (Spring)	Off farm Fodder
Archibald	443	9850	110	368	318	232	329	-2023	259	287	126	57	83
Beeamma	507	30388	124	413	434	434	553	-1208	162	237	153	76	114
Binnum	527	35965	132	439	565	565	682	-722	118	216	168	86	150
Bowaka	644	20717	160	533	764	764	1006	-831	246	346	224	125	114
Cannawigara	445	34640	110	368	277	272	350	-1779	185	234	126	57	65
Carcuma	400	25433	93	310	186	62	122	-2181	244	253	92	34	78
Colebatch	473	28081	113	376	375	189	302	-2732	317	332	131	61	122
Coneybeer	427	30525	108	360	351	162	254	-2568	335	338	121	54	108
Coombe	441	42515	105	349	284	174	259	-2088	267	285	115	49	88
Duffield	509	19462	125	417	411	381	535	-1702	257	306	156	77	99
Field	472	24233	113	376	392	177	299	-2793	342	350	131	61	113
Geegeela	496	27963	121	404	433	433	526	-1183	141	218	148	72	126
Glen Roy	512	21780	125	417	454	454	586	-1031	173	247	155	77	108
Glyde	478	24433	113	376	396	185	307	-2685	349	355	131	60	121
Hynam	532	33077	132	439	548	548	687	-689	146	236	168	86	139
Jeffries	440	20796	108	361	369	131	236	-2900	360	356	122	54	103
Jessie	549	21516	139	463	671	671	806	-239	100	213	182	96	169
Joyce (North)	567	16378	140	465	613	613	787	-483	128	234	183	97	130
Kirkpatrick	408	23036	105	348	339	117	202	-2745	358	350	115	49	86
Lacepede	557	17272	140	466	543	543	735	-1323	249	321	184	97	96
Laffer	473	38493	119	396	390	295	410	-2188	282	316	143	69	94
Landseer	524	18924	130	431	431	423	582	-1635	237	297	164	83	90
Lewis	418	30160	99	330	239	115	187	-2174	260	272	104	42	82
Livingston	393	29982	101	335	284	102	178	-2489	318	316	107	44	81
Lochaber	534	21317	130	432	512	512	663	-835	149	236	164	83	122
Makin	428	14153	101	335	207	167	231	-1900	183	220	107	44	49
Marcollat	505	34748	127	421	428	428	568	-1405	203	269	158	79	87
McCallum	434	16811	104	346	217	198	264	-1932	166	212	114	48	49
McNamara	500	26875	122	405	422	285	416	-2540	302	334	148	72	111
Messent	507	9421	119	396	402	261	399	-2472	295	325	143	69	116
Minecrow	561	26887	137	457	536	536	709	-1124	189	274	179	93	92
Mount Benson	601	22305	150	499	635	635	851	-1251	234	323	203	110	90
Murrabinna	578	16142	143	475	577	577	775	-1200	236	315	189	101	94
Naracoorte	549	20284	135	449	604	604	757	-315	121	223	174	90	157
Neville	493	15517	126	419	450	343	498	-2198	304	341	157	78	121
Ngarkat	401	7551	94	314	183	70	132	-2205	223	239	94	35	86
Parsons	508	19066	123	409	409	409	533	-1289	187	253	151	74	94
Peacock	519	30706	127	424	412	411	559	-1556	202	270	159	80	74
Pendleton	454	36069	112	374	305	275	362	-1883	221	263	130	60	67
Petherick	503	31951	127	422	410	381	519	-1968	244	299	158	79	82
Richards	459	37753	108	361	331	181	276	-2393	301	314	122	54	109
Santo	489	10064	120	400	436	265	405	-2493	336	356	145	70	136
Senior	438	36751	107	355	245	245	313	-1725	140	197	119	52	65
Shaugh	437	34322	105	348	206	203	268	-1965	134	190	115	49	55
Spence (North)	558	19019	139	463	615	615	792	-515	128	233	182	96	146
Stirling	459	36320	117	391	367	303	415	-1930	265	301	140	66	85
Strawbridge	440	19887	110	367	378	157	257	-2848	352	353	126	57	106
Tatiara	462	48028	109	364	297	297	370	-1434	148	206	124	56	88
Townsend	597	26681	147	490	663	663	861	-663	175	278	198	107	121
Wells	512	26543	125	417	420	350	501	-2111	266	313	156	77	102
Willalooka	492	35928	124	412	397	384	511	-1689	244	295	152	75	77
Wirrega	481	54898	122	406	383	381	494	-1630	213	270	149	73	88
Woolumbool	528	30838	130	431	483	483	633	-981	151	236	164	83	100
Avg. or [Total]	***482***	***1392454***	***121***	***402***	***415***	***352***	***476***	***-1714***	***229***	***280***	***147***	***71***	***101***

Table 30. Summaries of expected annual equivalent returns [$/ha/yr] from existing cropping and grazing industries, and new agroforestry industries by subdivision. (cont.)

Hundred	Rainfall [mm]	Potential Agroforestry Area [ha]	Gross Margin Cropping Grazing Avg Last 10 years	Gross margin Cropping Grazing Max Last 10 years	Eucalyptus Oil Only	Bioenergy Only @ Keith	Integrated Tree Processing @ Keith	CO2 Sequestration Bioenergy Spp	CO2 Sequestration Oil Mallee Spp	CO2 Sequestration Habitat Spp
Archibald	443	9850	110	368	340	641	570	324	3	1
Beeamma	507	30388	124	413	393	400	448	385	14	12
Binnum	527	35965	132	439	425	242	368	419	21	19
Bowaka	644	20717	160	533	534	248	424	546	45	43
Cannawigara	445	34640	110	368	337	508	491	324	3	1
Carcuma	400	25433	93	310	274	226	293	247	-11	-13
Colebatch	473	28081	113	376	352	373	413	335	5	3
Coneybeer	427	30525	108	360	333	372	405	313	1	-1
Coombe	441	42515	105	349	318	513	486	298	-2	-4
Duffield	509	19462	125	417	396	305	394	391	15	13
Field	472	24233	113	376	352	275	355	335	5	3
Geegeela	496	27963	121	404	383	344	410	373	12	10
Glen Roy	512	21780	125	417	398	433	469	390	15	13
Glyde	478	24433	113	376	352	201	310	335	5	3
Hynam	532	33077	132	439	425	329	419	420	21	19
Jeffries	440	20796	108	361	335	207	306	315	1	-1
Jessie	549	21516	139	463	455	168	338	451	27	25
Joyce (North)	567	16378	140	465	455	231	376	454	28	25
Kirkpatrick	408	23036	105	348	321	225	311	298	-2	-4
Lacepede	557	17272	140	466	454	261	394	456	28	26
Laffer	473	38493	119	396	373	652	589	362	10	8
Landseer	524	18924	130	431	412	387	449	409	19	17
Lewis	418	30160	99	330	297	360	385	273	-7	-8
Livingston	393	29982	101	335	305	249	319	280	-5	-7
Lochaber	534	21317	130	432	415	347	425	410	19	17
Makin	428	14153	101	335	300	506	476	280	-5	-7
Marcollat	505	34748	127	421	401	523	523	395	16	14
McCallum	434	16811	104	346	312	446	444	295	-2	-4
McNamara	500	26875	122	405	384	534	523	374	12	10
Messent	507	9421	119	396	373	408	443	362	10	8
Minecrow	561	26887	137	457	443	378	457	443	26	23
Mount Benson	601	22305	150	499	492	135	339	499	36	34
Murrabinna	578	16142	143	475	464	343	446	468	30	28
Naracoorte	549	20284	135	449	438	245	376	433	24	21
Neville	493	15517	126	419	400	398	450	393	16	14
Ngarkat	401	7551	94	314	277	238	302	252	-11	-12
Parsons	508	19066	123	409	387	483	495	379	13	11
Peacock	519	30706	127	424	403	473	496	399	17	15
Pendleton	454	36069	112	374	345	616	558	332	4	2
Petherick	503	31951	127	422	401	605	573	397	17	14
Richards	459	37753	108	361	334	446	451	315	1	-1
Santo	489	10064	120	400	379	314	390	367	11	9
Senior	438	36751	107	355	323	379	408	307	0	-2
Shaugh	437	34322	105	348	313	351	387	297	-2	-4
Spence (North)	558	19019	139	463	453	255	389	451	27	25
Stirling	459	36320	117	391	366	722	628	354	9	7
Strawbridge	440	19887	110	367	342	295	362	323	3	1
Tatiara	462	48028	109	364	335	397	422	319	2	0
Townsend	597	26681	147	490	483	262	407	487	34	32
Wells	512	26543	125	417	397	459	484	391	15	13
Willalooka	492	35928	124	412	390	650	594	383	14	12
Wirrega	481	54898	122	406	382	566	542	375	12	10
Woolumbool	528	30838	130	431	414	349	427	409	19	17
Avg. or [Total]	*482*	*1392454*	*121*	*402*	*380*	*382*	*433*	*370*	*12*	*10*

Discussion

Any woody biomass industry development is underpinned by the selection of the appropriate species to match the product and yield specifications of each industry type. Once the selected species (or groups of species) have proven to meet elementary industry requirements the primary driver towards economic development is the ability to produce sufficient economic volumes of biomass.

The specific green biomass productivity rates and above ground carbon accumulation rates reported in this study should be considered conservative estimates only, as optimum planting rates for each species and site has not been determined. Using higher planting rates is likely to increase plantation total biomass production by ~50% or more in the Upper South East. The above-ground biomass from dryland plantations of local native "habitat species" can sequester around 10.5 tonnes of carbon dioxide per hectare per year in the region with higher average values for "bioenergy species" of around 26 tonnes of carbon dioxide per hectare per year (see Table 31). A further component of annual carbon dioxide sequestration rates (but not accurately quantified in our study) is the additional biomass within plantation root systems (Gifford 2000).

Dryland plantations of native species can provide many environmental services and economic opportunities in the Upper South East region. The value of perennial plant systems to reduce salinity and carbon sequestration is well recognised, with correctly managed and designed planting providing an additional positive contribution to ecosystems, habitats and biodiversity. A number of commercial opportunities exist for extending existing biomass industries in the Upper South East (USE) region. Biomass production rates and infrastructure support the expansion of livestock fodder industries, firewood for Adelaide metropolitan and surrounding markets, and pulpwood industries.

Fodder shrubs are already a part of the existing livestock industries in the Upper South East region and much potential exists for further expansion of fodder shrubs to both increase livestock production and provide greater income stability when rainfall is less reliable. Firewood markets, especially to service our major population centres, are currently attractive to farmers in the region. Reasonable profits can be expected from firewood sales especially when landholders access the additional margins that can be gained from more mechanised harvesting systems. Pulpwood industries are extensive in the Lower South East region and much of the existing infrastructure can support expansion of these industries into lower rainfall regions in the neighbouring Upper South East. The planned new pulp mill at Penola will provide further opportunities for expansion. New industries based on bioenergy and *Eucalyptus* oil or combined in an *Integrated Tree Processing* plant (eg. Narrogin WA oil mallee based plant) would deliver economic returns to farmers in the region if there was a significant investment in the necessary infrastructure in the central part of the USE region.

Existing broadacre annual cropping and livestock grazing provide an average gross margin return of around $121 per hectare (based on average returns 1996-2005, see Table 31). As could be expected with annual-based crops and pastures these returns are highly variable over time, ranging from losses of over $-200/ha to profits of over $400/ha in good seasons. Woody perennial crops provide more consistent returns as the robust woody crops generally survive droughted conditions and can make the most of unseasonal rainfalls. Our integrated spatial analysis of plantation productivity and farm economics (Regional Industry Potential Analysis) for several industry types show that expanded pulpwood industries could provide annual equivalent returns of between $132 - 1006/ha (region average range = $415 - 476/ha). Firewood industry average annual returns for the region would be in the vicinity $229 - 280/ha, and fodder shrubs in Autumn would be worth $147/ha. The prospective industries of bioenergy and Eucalyptus oil extraction based on new infrastructure at Keith would provide annual returns of around $380 - 433/ha, and single purpose carbon sequestration planting would create annual returns up to $43/ha (average $10 - 12/ha) for habitat and oil mallee plantings but could be higher than $500/ha (average $370/ha) for permanent woodlots of Sugargum (*Eucalyptus cladocalyx*) or similar species.

Several of the woody biomass industries analysed here could provide economic returns which are competitive with existing cropping and grazing landuses in the region. Rather than a total displacement of existing annual cropping and grazing systems in the Upper South East region, we envisage these new woody biomass industries will provide new options and opportunities for farmers and existing industries of the region. These new options can be strategically placed to become an integral part of a healthy mosaic of new woody perennial-based and existing annual-based primary industries. In our landscapes that are subject to the risks of rising water tables, dryland salinity, soil erosion, habitat loss, climate change, and economic and community sustainability, there appears to be a sound future for woody perennial cropping in the Upper South East region.

Table 31. Summaries of expected plantation productivities, environmental risks and landholder annual equivalent returns from existing and potential biomass industries (minimum, maximum and average values for 53 Hundred subdivisions).

Plantation Productivity	**Min.**	**Max.**	**Average**
Stemwood Productivity [m³/ha/year]			
Pulpwood Species	8.79	30.06	17.57
Bioenergy Species	19.29	36.21	26.27
Oil Mallee Species	4.52	7.76	5.85
Saltbush Fodder Species	2.35	4.03	3.04
Habitat Species	4.29	7.36	5.55
Green Biomass Productivity [t/ha/year]			
Pulpwood Species	9.65	33.00	19.29
Bioenergy Species	21.53	40.40	29.31
Oil Mallee Species	14.33	24.59	18.56
Saltbush Fodder Species	4.92	8.44	6.37
Habitat Species	9.19	15.77	11.91
Carbon Dioxide Sequestration [t CO_2 equiv/ha/year]			
Pulpwood Species	8.29	28.32	16.56
Bioenergy Species	19.16	35.97	26.10
Oil Mallee Species	12.99	22.29	16.82
Saltbush Fodder Species	3.48	5.97	4.50
Habitat Species	8.10	13.90	10.49
Environment	**Min.**	**Max.**	**Average**
Rainfall [mm]	393	644	482
Deep Drainage [mm/ha/year]	20.4	37.8	26.0
Risk Indices (0=low, 1=high)			
Index Dry Saline Land	0.00	0.28	0.05
Index Habitat Areas [#1]	0.06	0.99	0.76
Index Salinity [#2] - water table induced	0.00	0.52	0.13
Index Wind Erosion Risk [#3]	0.02	0.67	0.38
Index Overall (average [#1],[#2],[#3])	0.23	0.62	0.44
Industry Annual Returns ($/ha)	**Min.**	**Max.**	**Average**
Cropping/Grazing - Avg Last 10 years	93	160	121
Cropping/Grazing - Max Last 10 years	310	533	402
Export Pulpwood All Ports	183	764	415
Export Pulpwood Portland Only	62	764	352
Australian Pulpwood	122	1006	476
Particleboard	-2900	-239	-1714
Firewood (small scale)	100	360	229
Firewood (medium scale)	190	356	280
In situ Fodder (Autumn)	92	224	147
In situ Fodder (Spring)	34	125	71
Off farm Fodder	49	169	101
Eucalyptus Oil Only	274	534	380
Bioenergy Only at Keith	135	722	382
Integrated Tree Processing at Keith	293	628	433
CO_2 Sequestration Bioenergy Species	247	546	370
CO_2 Sequestration Oil Mallee Species	-11	45	12
CO_2 Sequestration Habitat Species	-13	43	10

6. Conclusions and Future Directions

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Industry Priorities, Economics and Spatial Analyses

In recent years Climate change has emerged as a significant driver to the greater adoption of renewable energies and carbon sequestration industries. The opportunities for renewable energy from biomass are expanding as the world realises that agricultural production systems of the future need to account for the risk of increased climate variability. Robust and productive perennial plant species can make an important contribution to the resilience of future farming systems. Wood products (pulp and paper, fibreboard and particle board) remain a high priority biomass industry with continued high level policy comment on the huge net import of wood fibre products into Australia (in the order of $ 2 billion annually), major new infrastructure developments (pulp mills) proposed for southeastern Australia, recent short falls in fibreboard feedstock availability in southern New South Wales and emerging MDF industries in Western Australia.

Energy and metal refining and production industries face increasing pressure to reduce emissions of greenhouse gases (GHG) from the consumption of fossil fuels. The substitution of fossil fuels by renewable biomass has the potential to radically reduce the net carbon emissions from energy and metallurgical processing.

Australia currently consumes >5500 Petajoules (1 PJ = 10^{15} joules) of energy ever year across our industrial, mining, agricultural, commercial and residential sectors. The trend and prices of energy is continuing to increase. In Australia electricity generation is predominantly based on black and brown coal deposits. Opportunities exist for greater use of woody biomass to generate electricity either as a coal replacement (or blend) in existing solid fuel plants or a co-product in a Narrogin style integrated wood processing facility. World oil prices have escalated from around US$25 in 2001 to over US$100/barrel in 2008 and although initially predictions that the current high price is only a short term prospect there are no clear indicators to suggest that oil will return to below the US$75 a barrel experienced in 2007.

The Australian Government has recently renewed and expanded its commitment to developing and promoting renewable energy sources in Australia and is supported by market forces for Renewable Energy Certificates and currently high fossil-fuel energy feedstock prices. Biofuels are currently competitive with fossil fuels and should remain so even after current government excise assistance diminishes in 2015. The potential of lignocellulosic feedstocks for ethanol production is rapidly developing and will be encouraged by recent proposals to develop an Australian-first demonstration plant in northern NSW to use woody biomass to generate ethanol using lignocellulosic conversion. Technological developments in North American and Europe in the production of ethanol from wood through lignocellulosic processes is raising the profile of biomass as an important source of transport fuel within a 10 - 20 year time frame for large scale adoption.

Woody cropping systems in the lower rainfall regions of southern Australia provide numerous opportunities for commercial development of bioenergy, carbon sequestration, wood fibres and livestock production industries. These systems can also provide a wide range of environmental and community benefit across Australia. The scale of this potential is immense with over 57 million hectares in the lower rainfall regions of southern Australia currently used for cropping and grazing that could potentially be used to develop new sustainable woody crop industries.

Factors Affecting the Economic Performance of Mallee Production Systems illustrates there are numerous influences on the viability of woody crop production systems in Australia. Using oil mallee production systems in Western Australia we have shown the need to maximise productivity for commercial viability through better plant selections, and crop designs that can harvest excess water from the landscape. We are also aware of the need to balance woody crop production with other landuses, and that the goal is an optimal overall farming system that has components of new woody crops and existing industry types to be successful. Establishment, silvicultural, harvest and land management practices are highly important in optimising returns from these systems. Where additional (and often off-site) environmental benefits can be valued, these can potentially provide a new income stream to enhance these new crop systems.

The *Regional Industry Potential Analysis* (RIPA) methodologies combine geographic information system (GIS) data with economic models to evaluate the potential commercial viability of the woody crop industries. This report highlights the full potential of this analytical technique through 2 case studies on The RIPA methodology was first described in the FloraSearch Phase 1 report (Bennell *et al.* 2008) using early estimates of productivity and preliminary models to illustrate the concept. This work has progressed and is becoming a sophisticated tool, able to support the systematic regional evaluation of perennial crop options at a range of scales. It incorporates improved species knowledge (eg. productivity estimates), industry developments, updated costs and returns and refinements in the modelling process. The methodology has been recently adopted and modified to undertake other spatio-economic analyses for other industries and regions across Australia (eg. JVAP *Regional opportunities for agroforestry* project, Polglase *et al.* 2008) and used to perform analyses for the Garnaut Climate Change Review (Garnaut 2008, Chapter 22 Transforming Rural Land Use).

Case Study 1: Woody Bioenergy Crops for Lower Rainfall Regions of Southern Australia demonstrates there is immense potential to develop new woody bioenergy crops in southern Australia. Although prices of these new feedstocks are still tenuous, by comparing these product streams with internationally and Australian marketed commodities we can approximate likely feedstock values of woody biomass for these energy markets. The analyses do highlight the sensitivity of commodity prices and production rates on industry feasibility due to the cost of growing, harvesting and transporting a currently low-valued product especially in remote and less productive landscapes.

Increasing energy (electricity, heat and transport liquid fuels) demands and prices, and emerging conversion and harvest technologies suggest that bioenergy crops will soon play an important role in Australian agricultural landscapes.

Case Study 2: Woody Crop Potential in the Upper South East Region of South Australia identifies a region with significant potential for a wide range of woody crop industry types. It is in a region that borders a higher rainfall zone containing existing woodfibre industries (pulp, paper, particleboard production, woodchip export) and within contains existing interest and use fodder shrubs for livestock and firewood. New bioenergy industries and carbon sequestration potential offer new opportunities for landholder in this region and are likely to provide significant symbiotic (and perhaps competitive) economic returns to current cereal cropping and livestock grazing enterprises in the region. This study also explores the environmental benefits of woody crop systems and revegetation in the region. It has been used to identify specific districts that would most benefit from these new industry options.

The current analyses presented in this report shows that many short-cycle woody crops and biomass industries are profitable across vast regions of southern Australia. The economic returns of several industry types in the region are complimentary or alternatives to existing land uses. The current and potential profitability and sustainability of perennial woody crops can provide landholders with alternative into the future.

Future directions

The evaluation of species will continue at a reduced level and be focused on evaluating provenance variability and also matching development species to emerging industry types with the greatest potential. The assessment of fodder value of selected woody species will continue and be expanded in conjunction with project work on grazing systems based on woody perennials in the Enrich project. We are also liaising on a project to evaluate charcoal use in metal smelting and an evaluation of the value of feedstock for lignocellulosic ethanol production may be considered.

The growth of woody crops and product yields are critical for the commercial reality of FloraSearch industries. Work on productivity evaluations will be continued and, with additional collections of plant growth data, the accuracy of biomass productivity and yield models will improve and economic evaluations will become more robust.

Economic evaluation and spatial analysis of farm and industry economics will be refined as new data becomes available, such as improved industry and market knowledge flowing from related projects, and improved understanding of the effects of biophysical factors on woody crop productivity, especially water movement and capture. Estimated farm returns from new industries will be compared to current land use options. This component of FloraSearch will have strong links with, and draw on results from the CRC’s New Industry and Marketing project. Utilising the economic and spatial tools described above to undertake a case study of pilot industry development option(s) in conjunction with an industry partner.

Research into the domestication of selected focus and development species will be a central area of work. This includes germplasm collection and establishment of plant improvement trials for focus species. Multiple provenances will be collected for development species and included in the trials to collect field performance data. Feedstock characteristics will be identified that are appropriate targets for improvement by selection of germplasm to ensure product attributes are incorporated into germplasm selection. Future species development evaluations will also include weed and genetic pollution risks assessed in collaboration with related CRC programs and projects

Agronomic experimentation on focus species to develop methods for production of short-cycle phase and coppice crops. Important aspects include system design, site selection, establishment techniques, the impact of planting density on productivity, nutrient response, coppice and sucker management, and susceptibility to herbicides, grazing and pests.

Optimising Productivity Through Landuse Planning, Agronomic Designs and Wateruse

The woody crop research described in this report will provide improved genetic material, plant production systems and industry understanding for biomass crops that will meet emerging market demand. However the questions remain as to where to place these new systems in highly variable landscapes, what methods are available to predict and measure productivity and how to optimise returns taking into account the land resource, existing land-uses and new crop options.

The approaches to planting system design in the study area can be broadly considered in the following ways:

1. Coppicing trees planted in belts within the productive cropping areas.

Cooper *et al.* (2005) present a conceptual model for estimating the maximum scale of biomass processing industry that may be supported by woody crops grown in the medium and low rainfall agricultural regions of southern Australia. Based on the assumptions quoted, the analysis concludes that significant gains in productivity (20%) are required to achieve yields that will enable break-even with the reduced annual crop yields resulting from land lost to production and tree – crop interactions (competition for water). The rate of converting water to biomass, the capacity to capture excess water in the landscape and biomass price are key determinants of the returns possible and potential scale of biomass crops and processing industries in the southern Australian wheat/sheep belt. Re-introducing trees into agricultural landscapes as agroforestry systems establishes a tension between long-term objectives, such as increasing shelter, water use, nature conservation and harvesting tree products, and the short-term objective of maximising crop and pasture profitability (Sudmeyer and Flugge, 2005).

Severing lateral tree roots (root-pruning), harvesting mallees and allowing them to coppice, or thinning trees for sawlog regimes increased the yield of crops and pastures in the competition zone (Sudmeyer and Flugge, 2005). In some instances, these increases were significant: root-pruning increased the annual return from crops grown in the competition zone of *Pinus radiata* by up to $548/km of the tree line at 1 site. Conversely, root-pruning reduced tree growth by 14–43% across all sites. Therefore, where trees provide benefits, such as shelter from damaging winds, the benefits of reduced tree–crop competition may not offset the consequent reduction in rate of tree growth. For mallee–crop alley systems on agriculturally productive soils, mallee growth rates must be high enough to compensate for crop losses in the competition zone. However, where management outcomes for dryland salinity are critical maximising water use in the landscape will be a critical outcome.

2. Block plantings of trees and shrubs – long term coppicing species and phase cropping

On less agriculturally productive soils, block-planting trees and shrubs may be more profitable than alley systems or crops without competition. Woody species can be highly robust and reliable in areas that are poorly suited to annual crops and pastures and therefore do not need to offset the lost production from traditional crops. An example of this approach receiving close attention is the establishment of shrubs with forage value (Oldman Saltbush) in mixed planting with other perennial species to provide livestock feed when pasture species are unproductive due to climatic pressure. An alternative approach is to use fast growing, deep rooted tree species in a short term phase (3 – 5 years) to utilise water stored in the soil profile after which the trees are harvested and the land returned to annual crop production.

Yield mapping from precision agriculture has shown that significant proportions of cropland effectively produce low to negative returns. There is potential for adaptation of current farming systems by targeting those sites with low returns and exploring the potential of better returns via woody biomass crop options. By understanding the optimal productive arrangement of annual and woody crops (belts or blocks) in a farming enterprise, issues of competition between new and traditional crop options can be systematically analysed to reduce opportunity costs to existing land uses. It is crucial to estimate economic returns of new systems with those from existing annual crops/pastures, accounting for additional risk, so that the most profitable option is applied at any point. Fig. 57 shows predicted economic return patterns across wheat paddocks with large areas that are potentially loss making indicating location options for land-use change. Maps like this will allow land managers to identify the extent of areas that are suboptimal for the current farming regime. Quantitative estimates will provide the baseline against which any new system will be measured.

Future research needs to improve the capacity for informed decision making through farm level economic analysis for optimal arrangements of traditional and new crops including the net carbon sequestration of such arrangements to prepare farmers for participation in future carbon emissions trading or offset schemes. Some goals of the next generation of research include:

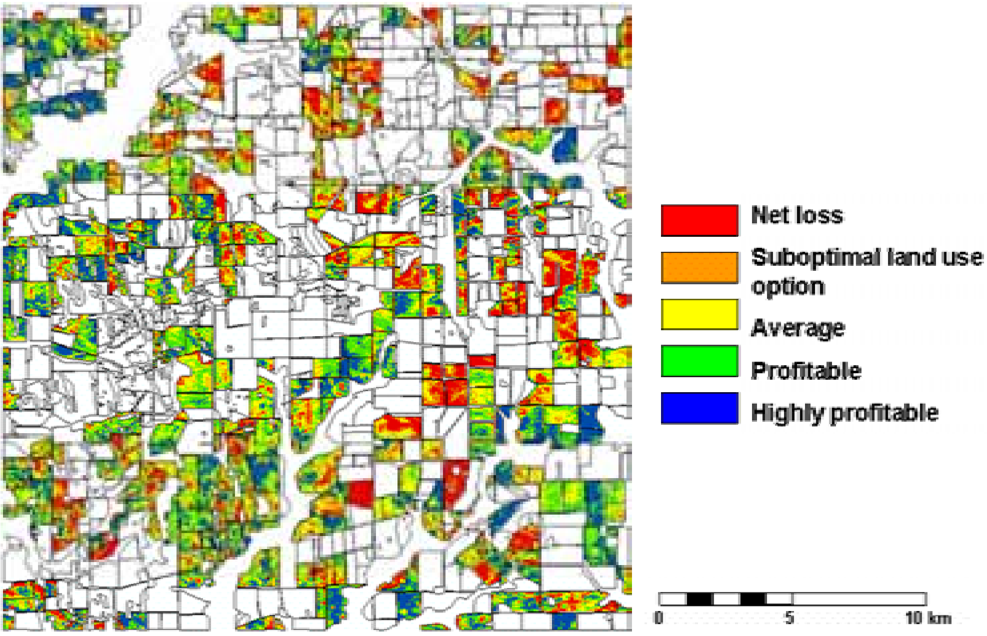
1. Identification of modelling needs and data availability for estimating spatial and temporal scales for productivity of key biomass species including forage. Leading to decision tools for location specific economic analyses of woody crop options based on yield predictions under a range of climate change, market and policy scenarios as compared with a range of other future and traditional farm options.

2. Test profitability and feasibility of spatial mix of different land, including insights on soil and climatic constraints that influence the suitability of plant species selected for development

as new woody crops. Woody crop performance may be affected by different soil attributes to annual crops.

3. Fundamental understanding of carbon dynamics of woody perennial ecosystems in low rainfall regions. The almost certain farmer participation in national emissions trading or carbon offsets will demand carbon metrics to support accounting procedures.

Fig. 57. Regional prediction of economic return from wheat paddocks.



Source: Bertram Ostendorf, University of Adelaide (pers. comm. 2008).

More accurate information regarding the accumulation of carbon in plant roots, the sequestration of carbon in labile and non-labile C pools in soil, and any losses incurred via microbial turnover or root respiration is required if we are to link productivity of these woody systems with a capacity to sequester carbon.

The impact of water availability in the landscape will have a major impact on plant productivity. Linking a growth model in the context of the three dimensional hydrological model will provide a tool for analysis of the growth and yield of tree crops in specified arrangements and locations in an agricultural landscape. There is considerable uncertainty about the likely rates of carbon sequestration and bioenergy production from reforestation in areas where farm-forestry has not been traditionally practiced. Improved woody crop yields by active water harvest are a potential mean of increasing yield in particular environments i.e. diverting water by low cost, paddock scale surface water engineering methods from source areas to woody crop sinks. Future work will develop the capability to design water harvest systems, estimate quantity and costs of water delivered to sinks, and predict yield response in terms of above and below ground biomass production. Potential outcomes of this approach include:

1. Demonstrate that water harvest systems for woody crops can be successfully integrated into farming systems with precision agriculture practices, reliable farm water supply, water erosion management and whole farm planning.

2. Experimental confirmation of the extent to which water capture can improve yield. A dataset suitable for validation of growth models incorporating enhanced water inputs.

3. Process based prediction of the systems design and water supplied by water harvest systems. A GIS based water harvest design tool suitable for use by extension specialists to design woody crop planting configurations for farmers.

Future directions

Apart from farm system development and profitability, adoption of new landuse options will need to take into consideration the emerging concerns of climate change adaptation and mitigation. Current agricultural enterprises and future woody crop production models must account for changes in the productive potential of our landscapes due climate changes that will influence rainfall, seasonality, temperatures and ultimately crop growth in the future. Community concerns about the reduction of food production capacity may also become important as more land is committed to biomass crops and carbon sequestration.

New farming systems metrics will include:

- Assumptions that climate change adaptation is fundamental to future of agriculture - building soil carbon may be important in a drying climate for reasons of soil moisture storage and plant water relations

- Measurement of key farming systems under development for water, carbon and energy ‘life cycles’ – this must include an understanding of the fate of new carbon

- Taking a systems approach that includes the soil component and its potential to sequester carbon

The Australian Government has indicated that it will introduce an emissions trading scheme in 2010, and this is likely to allow the sequestration of carbon in trees, and possibly agricultural soils, to be counted as an offset against fossil fuel emissions. Similarly, there will be a national renewable energy target of 20% by 2020. Contracts to delivery certain amounts of carbon by a specific date will have to be underpinned by solid analysis and technologies to ensure delivery. Such predictions are not available for many of the tree species that are likely to provide carbon sinks in dryland farming areas.

Likely products from the system include sequestered carbon and bioenergy. An Australian Emissions Trading Scheme will be implemented in 2010 (Wong 2008), and both industry and Governments are committed to making real reductions in their net greenhouse emissions. Farm forestry, through biosequestration and bioenergy projects, offers an immediate means of mitigating climate change by reducing carbon dioxide levels in a cost effective manner.

Prior to the development of clean emissions technology, sequestration in farm-forestry based projects, and the substitution of fossil fuel emissions using biomass combustion provide a real and immediate opportunity to reduce net greenhouse gas emissions. Biosequestration thus forms a major component in both national and state climate change policies in reducing net greenhouse gas emissions. Reforestation is also a means of restoring catchment water quality, the protection of land from salinity and erosion, the enhancement of remnant biodiversity and opportunities for rural development. The carbon sequestration potential has been estimated, for forestry and agricultural options (Harper *et al.* 2003, Harper *et al.* 2007). For landholders, carbon investment thus provides a very real prospect of financing revegetation to increase farm sustainability (Harper *et al.* 2007, Shea *et al.* 1998).

Climate change policy is particularly relevant as woody perennial systems can accumulate and store significant quantities of carbon in both living plant biomass and soil profiles. Economic evaluation of new crop opportunities requires reliable estimates of productivity (harvestable yield and carbon accumulation in plant biomass and soil profiles). Whilst there is a long tradition of forest growth modelling, accurate predictions in the agricultural belt are still difficult to make because existing models were developed for climate zones with high rainfall and higher average yield prospects than expected in the wheat/sheep zone. In lower rainfall regions the spatial variations of climate, soils and hydrological processes may have great influence on woody crop productivity.

Harvester Technologies

The absence of large-scale harvest systems for short cycle woody crop species is a significant requirement for developing new biomass industries. Conventional forestry harvesting techniques based on single stem harvesting are too expensive when applied to short cycle woody crops. Short cycle coppice tree harvesters in the northern hemisphere have limited suitability for transfer to Australia because they have been developed to handle low density tree growth eg willow, of small stem diameter and consequently are neither robust enough nor appropriately configured for the branched form and dense wood of Australian species. The possibility of a dispersed layout of these crops in a low rainfall agricultural environment also creates significant challenges for cost-efficient transport of biomass from the harvester to the roadside. The sequence of steps to develop a suitable supply chain is a complex engineering task and the cost and risk of the exercise will limit private investment by a machinery manufacturer or any single aspiring commercial biomass production/processing industry while the industry in the current “start-up” stage of development. Significant government support is needed to advance the development of new industries until new technologies that create large-scale demand of biomass are in place.

The principal products required by a development program will be a pre-commercial prototype harvester, a complete proven design for a supply chain for low rainfall tree crops, and commercial designs for the manufacture of the machinery required by the supply chain. This work is planned to be undertaken within the Future Farm Industries – CRC. Intellectual property will be managed by the CRC to ensure that these designs have value for a commercial manufacturer. This supply chain capability will enable low rainfall tree crops and their associated processing industries to expand to commercial scale.

The three sub-projects will be:

- Supply chain analysis and logistics to ensure that the scale of the supply chain components is appropriate and work efficiently as an integrated system.
- Harvester design, prototype development and field testing. This sub-project may also be required to design and fabricate some other supply chain machinery as required to enable proper testing of the prototype harvesters and supply chain logistics.
- Analysis of global biomass industry prospects, including engaging with other developments in the oil mallee industry and investigation of the commercial prospects of the harvester in other short rotation woody crops in Australia and overseas.

Economic Feasibility

There is renewed interest in large-scale production of biomass from woody crops reinforced by the growing national and global resolve to reduce fossil carbon emissions, impose fundamental restructuring on the energy sector and support the adaptation of farming systems. Current national activities indicating progress include the successful conclusion of Verve Energy’s IWP (Integrated Wood Processing) demonstration in WA, the recent investment by Willmott Forests in second-generation ethanol Research and Development in NSW and the large body of knowledge and experience now available on woody crop biomass production demonstrated by the Salinity CRC FloraSearch and related projects. However, private investment in growing and processing biomass is still uncertain and considered risky. Woody crops need further technology development and ongoing emergence of large-scale market demand to improve actual and perceived economic viability.

The opportunities exist for the development of a business analyses capacity based on the skills and knowledge accumulated in various aspects of the FloraSearch and related project work. In the future this can supply services in the following areas:

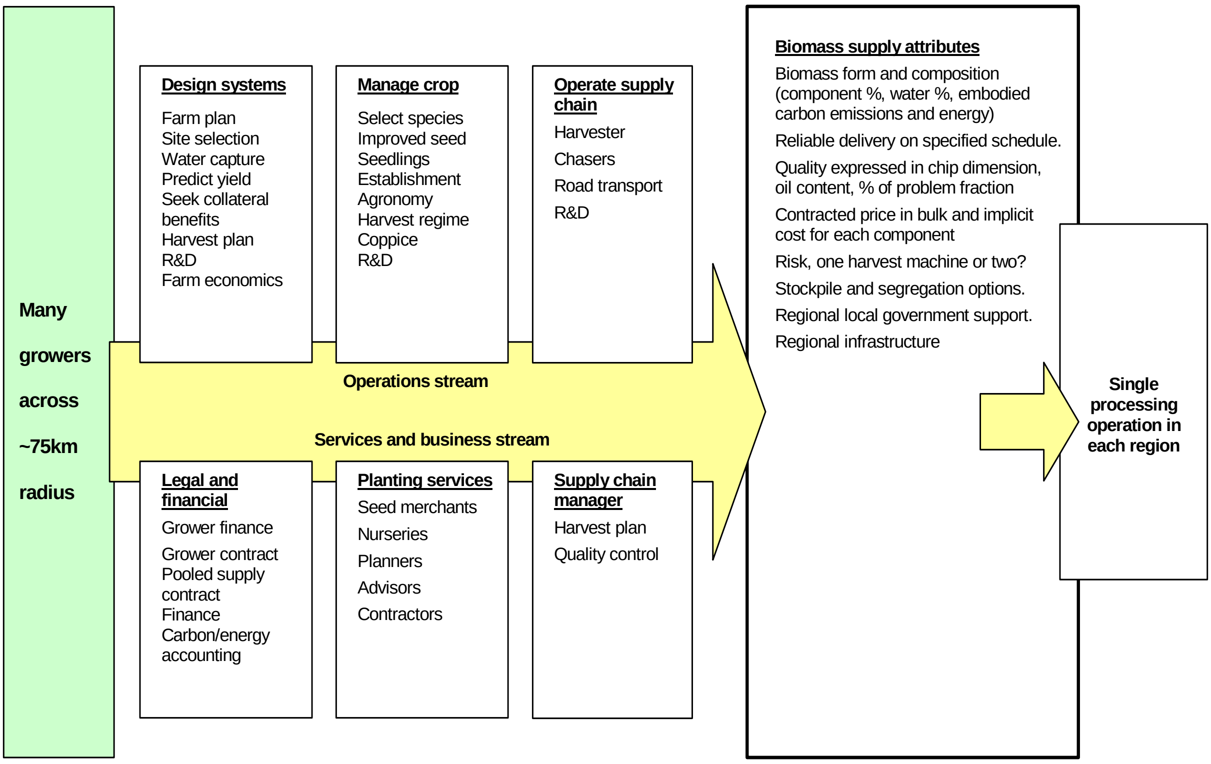
- Support production and business development on the supply side at the farm level.
- Analysis at a regional scale to provide a service to aspiring processors needing high quality information as an input to their feasibility assessments.
- Investigate policy questions related to emerging biomass industries i.e. "What should the public policy emphasis be in the production of transport fuels using emerging second generation technologies given the current imperatives of climate change mitigation?” A discussion paper will focus on the policy issues as well as some of the implications for farming areas within Australia.

Feasibility assessment will highlight the need to develop the services and business stream in industry development (see Fig. 58). There appears to be promising economic prospects for both biomass production and processing to proceed but commercial operations have been slow to emerge in Australia.

Public-good outcomes, not only in GHG emissions control, renewable energy targets and climate change will be important to the future success of new crops and also in managing the external costs of environmental damage arising from annual plant agriculture in Australia. Pannell (2008) presents a theoretical treatment of how to deal with this mix of public and private benefits in encouraging environmentally beneficial land-use change. He proposes that public investment in technology improvement should be applied where ‘public net benefits of land use change are positive and private net benefits are (currently) negative, but not highly negative’. Future work should retain the objective that public investment in new industry development will achieve technology advance and that the economic viability of the new technology will deliver public and private benefit.

In the context of ‘supply side development’ future programs can deliver project specific biomass supply feasibility assessment to major aspiring processors and, based on this experience, inform across-industry coordination of biomass supply development and progressively build a generic assessment capability suitable for any woody biomass industry nationwide. This experience will enable the evaluation of options and stimulate development of service industry participants for new biomass supply industries.

Fig. 58. Biomass supply flow chart.



A Growers' model may be used to run scenarios (using Imagine from the MIDAS stable; Imagine is a discounted cash flow analysis extended over the appropriate term for any project usually 20 years) to compare equivalent returns of woody crop and annual crop/pasture activities and to determine the economically viable extent of biomass production for a typical farm. There are now sufficient WA based data for mallee crop management, systems design and supply chain operation to enable modelling of production, cash flow and profitability of this crop. However, with careful judgement by experienced researchers these data are adequate to guide estimation of likely performance parameters across a wide range of wheatbelt woody crop types and regions. The Buyer's model can be developed to analyse the buyer’s perspective on supply side issues. This feasibility assessment will generate information on biomass supply parameters pertaining to quantity, quality, price and risk associated with this new production system. The model would enable evaluation of the relative importance of these supply parameters from the perspective of the buyer as well as the seller of biomass.

Currently Australian policy is focussing on a preliminary development of 'what should be done' - in this case renewable fuels. The reasons for government assisting in the development of biofuels industries are varied and with mixed outcomes. Issues such as: energy security; climate mitigation; health; and regional development are considered but often not explicitly addressed. The development of policies that specifically address environmental aspects of biofuel production is limited. There are significant policy positions that have been developed by the EU and the US in relation to production and trade. Within Australia some policy instruments are in place but there is an expectation that the interest will significantly increase in relation to climate change.

One of the main advantages of biomass to energy systems is that they are flexible in their delivery. This, however, can lead to confusion as systems are put in place that may not meet policy outcomes (e.g., a corn to ethanol systems is unlikely to contribute to climate mitigation strategies). This leads to confusion within the market as the public are not confident in the products that they consume meet their expectations (e.g., ethanol is good for the environment).

There are significant policy developments occurring internationally (e.g., climate change and post Kyoto negotiations) that could be addressed if the specific policy instruments are in place to meet the goals (eg. mitigation of climate change). There are also policies in place within Australia (eg. the NSW Biofuel Act 2007) and internationally (eg. EU directive of a target of 5.75% renewables by 2010, Commission of the European Communities 2008) that look to meet some of the opportunities for biofuels. The links between some of the key policy issues (i.e., climate change and biofuel production) need to be more clearly defined. This would lead to a much clearer understanding of what instruments could be developed to meet the nominated goals.

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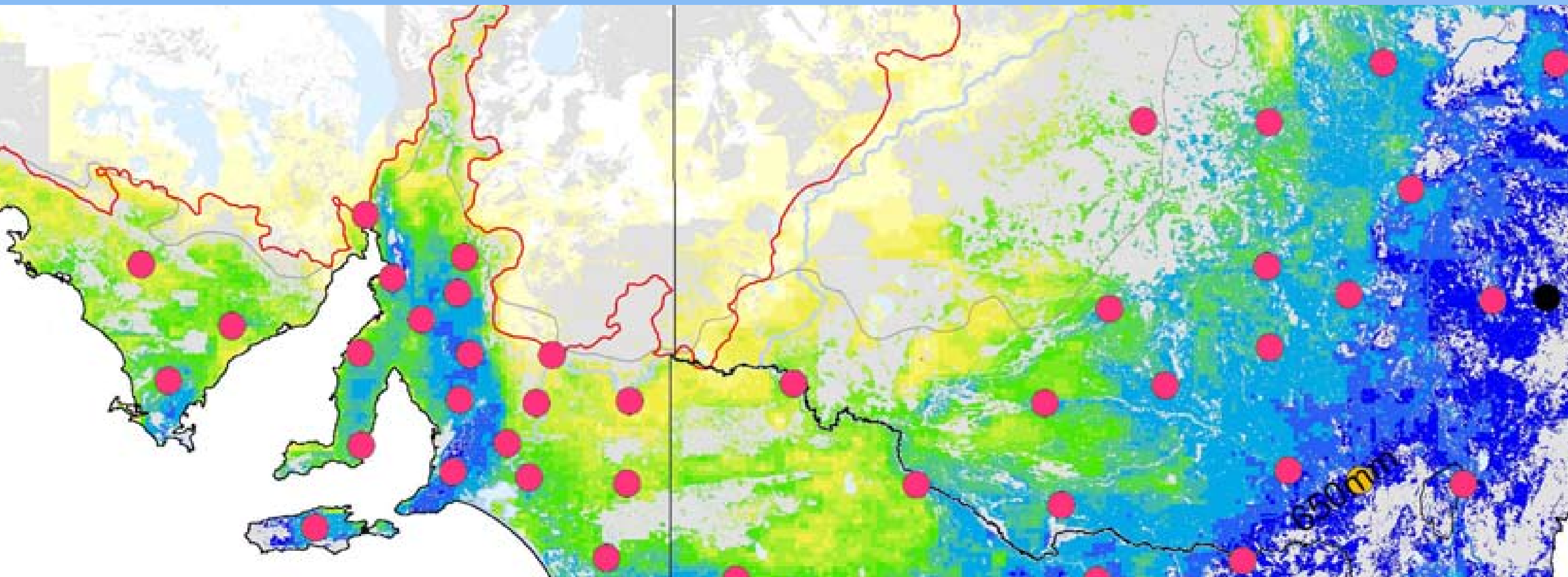
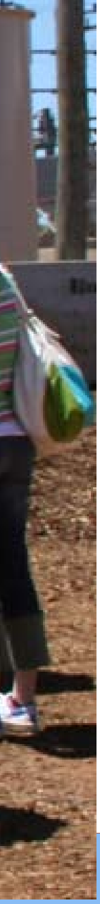
Joint Venture Agroforestry Program

Edited by by Trevor J. Hobbs

August 2009





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