Joint Venture Agroforestry Program

Rural Industries Research & Development Corporation

Forest & Wood Products Research & Development Corporation

Land & Water Australia

An Australian Government Initiative

# The Bioeconomic Potential for Agroforestry in Northern Cattle Grazing Systems

*— An evaluation of tree alley scenarios in southern and central Queensland —*

RIRDC Publication No. 09/140

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# The Bioeconomic Potential for Agroforestry in Northern Cattle Grazing Systems

## An evaluation of tree alley scenarios in central Queensland

by Peter Donaghy, Steven Bray, Rebecca Gowen, John Rolfe, Michael Stephens, Sam Williams, Madonna Hoffman and Anne Stunzner

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# Foreword

There is a growing understanding of the bio-economic interactions driving plantation hardwoods and an increasing demand for hardwood timber products. However there is currently little known about the opportunity to establish complementary agroforestry and pastoral systems (silvopastoralism) in northern Australia.

The Rural Industries Research and Development Corporation (RIRDC) commissioned the CSIRO Livestock Industries to investigate the on-farm economics of silvopastoral systems, comparing them with conventional extensive grazing systems in northern Australia.

Previous rangelands grazing research has focused on the direct impacts of animal stocking rate and tree basal area (clearing) on pasture biomass and livestock production, with an emphasis on the competitive effects of tree density on pasture growth. The results presented here for alley belt systems suggest that encouraging natural regrowth and/or planted trees is a potentially valuable activity that includes not only the direct commercial benefits available from planted or natural regrowth, but also the combined NRM benefits associated with increased trees in the landscape.

This report provides detailed information on the key bio-physical factors influencing pasture and woodland growth and forestry outcomes for two widespread woodland communities (land types) in central Queensland. The analysis incorporates tradeoffs between tree and pasture growth, likely forest product yields, carbon sequestration and livestock methane emissions, to construct a bio-economic model of four potential silvopastoralism systems for comparison with conventional grazing systems.

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 & Water Australia (L&WA), 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**.

This report is an addition to RIRDC's diverse range of over 1900 research publications. It forms part of its 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
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[1] Now Forest & Wood Products Australia (FWPA)

# Abbreviations

| | |
|---|---|
| ABARE | Australian Bureau of Agricultural and Resource Economics |
| ALUM | Australian Land Use Mapping Classification |
| CPRS | Carbon Pollution Reduction Scheme |
| CQFA | Central Queensland Forestry Association |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| FWPA | Forest & Wood Products Australia |
| JVAP | Joint Venture Agroforestry Program |
| MLA | Meat and Livestock Australia |
| LWA | Land & Water Australia |
| NPV | Net Present Value |
| QPIF | Queensland Primary Industries and Fisheries |
| RIRDC | Rural Industries Research & Development Corporation |
| TRAPS | Transect Recording and Processing System |

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# Executive Summary

### *What the report is about*

Extensive land clearing for livestock production and associated land degradation has led to greater interest in the role of trees and revegetation practices such as agroforestry for achieving productivity and environmental outcomes in pastoral landscapes. RIRDC recently funded a national scale analysis (Polglase *et al.* 2008) of the potential to grow and profitably market wood products. Whilst there is now a growing understanding of the bio-economic interactions driving plantation hardwoods, there is little known about the economic outcomes of establishing complementary agroforestry and silvopastoralism in northern Australia's lower rainfall zones (600-750 mm annual rainfall) including central Queensland.

Silvopastoralism may offer landholders considerable advantages over traditional grazing systems in terms of income diversification, environmental benefits through increased woody vegetation cover and areas of stimulated versus constrained pasture growth. RIRDC commissioned this investigation to better understand whether an agro-forestry production system produces better financial and environmental outcomes than an extensive grazing system.

### *Report target audience*

This report is targeted primarily at industry leaders and landholders contemplating the integration of agroforestry and silvopastoralism into existing grazing systems. The report also has a wider audience including policy makers, natural resource management groups, agribusiness consultants and the research community interested in understanding the economic and biophysical tradeoffs of agroforestry systems in northern Australia. Of interest to those working on climate change is the report's analysis of avoided deforestation as a means of offsetting livestock methane emissions.

### *Aims/objectives*

Currently, little is known about the economic opportunities and risks associated with operating silvopastoral enterprises in central Queensland. This project seeks to evaluate the silvopastoralism potential of two widespread regrowth woodland communities (land types) in central Queensland, brigalow/blackbutt and poplar box with shrubby understorey. The key research tasks include:

- A literature review of silvopastoralism systems suitable to central Queensland;
- Spatial analysis of land suitability for agroforestry in the Fitzroy Basin;
- Collation of relevant (local where possible) tree growth and yield data for target land systems;
- A review and collation of regional marketing, costs and price data for forestry and livestock products relevant to central Queensland;
- Collation of modelled relationships between tree basal area, pasture production and carbon sequestration including the stimulatory and competitive impacts of woody vegetation strips in pastoral paddocks; and
- Construction of bio-economic models to evaluate conventional grazing systems against preferred silvopastoralism systems for two central Queensland land systems (brigalow and eucalypt).

### *Methods used*

The economic feasibility of six agroforestry options was evaluated using discounted cash flow analysis, regional costs and prices for both livestock and forestry products, and a purpose built bioeconomic model calibrated for central Queensland. Tree growth data investigated included the TRAPS (Transect Recording and Processing System) woodland monitoring system, various plantation trials managed by Queensland Primary Industries and Fisheries (QPIF) and private industry, spatial tree cover and productivity indices from the National Forest Inventory and physiological growth models such as 3-PG (Landsberg & Waring 1997). These data were used to derive an indicative range of possible wood yields. Pasture yields for given tree basal areas were calculated or obtained from recent agroforestry scenarios using the GRASP/AussieGRASS pasture growth models either developed for central Queensland or observed from direct grazing trials.

The resultant measures of enterprise profitability (that is, net present value) were used to compare the silvopastoralism options compared to extensive grazing management systems. The modelling assumed each scenario was managed to maintain or enhance land condition utilising best management grazing and silvicultural practices.

Constructing the bioeconomic model and undertaking the economic comparisons reported here required seven steps.

1. spatially analyse agroforestry land suitability in central Queensland
2. design two business-as-usual and four silvopastoralism scenarios to be modelled
3. derive tree regrowth models
4. calculate pasture production and livestock carrying capacities
5. calculate tree biomass and timber products
6. incorporate the data obtained in steps 1 to 5 into an agroforestry bioeconomic model relevant to central Queensland
7. undertake economic analysis.

### *Results/key findings*

Central Queensland appears to have large areas of land suitable for agroforestry or silvopastoralism systems. Of the land identified as suitable for agroforestry purposes, 3.3 million hectares was within a 50 kilometre radius of existing timber mills, 4.5 Mha within 100 km, 4.8 Mha within 150 km and 4.9 Mha within a 200 km radius.

The decision to clear regrowth and retain timber strips as part of a silvopastoralism grazing system (timber strips 20 m wide every 60 m over a 1000 ha paddock) would have left the grazier marginally out of pocket (-$1701) on the eucalypt land and $14,732 worse off on brigalow land over 25 years.

The decision to clear brigalow regrowth and plant spotted gum strips 50 m wide every 150 m for the purposes of harvesting electrical transmission poles, whilst continuing to graze would have left the grazier $209,087 better off than clearing all the regrowth and continuing to graze only. If the grazier had instead opted to plant spotted gum for pulp production whilst continuing to graze, the NPV would have been $99,155. Whilst the timber pulp model provided a reasonable return to the grazier the sensitivity of the results to price and yield changes dramatically altered the outcomes and provided significant levels of down-side risk.

The inclusion of potential carbon sales dramatically alters the economic consequences of retaining regrowth strips. Excluding carbon released from the routine clearing of regrowth and methane emissions, the grazier would be $84,107 or $136,989 better off in the case of brigalow and eucalypt lands respectively by retaining regrowth strips and selling sequestered carbon when compared to conventional grazing systems. When methane emissions were included in the analysis, the decision to retain regrowth strips, continue to graze and sell sequestered carbon net of methane emissions left the grazier $48,820 better off in the case of brigalow and $112,876 better for eucalypt land.

### *Implications for relevant stakeholders:*

This project contributes directly to the goals of the Joint Venture Agroforestry Program (JVAP) through a better understanding of the bio-economic potential for agroforestry development in the low rainfall areas of central Queensland (e.g. 600-750 mm/yr). In particular, the project addresses some key long term strategies identified in the JVAP R&D Plan for 2004-2009, including:

- on a regional basis assess existing and potential volume and continuity of product supply from agroforestry and farm forestry, including planning and marketing needs; and

- address landholder and investor decision making needs in developing cost-effective multi-purpose agroforestry systems to meet commercial and environmental objectives, including whole-farm economics, farm forestry design options, and decision making tools.

These aspects are particularly relevant in a northern Queensland context since there is a perception amongst landowners that trees compete strongly with pasture and livestock production and are considered an economic liability rather than as a potential asset. The results of this research will help promote greater awareness of the economic value of trees in extensively grazed landscapes in northern Australia and should assist future investment decisions by landowners.

This research provides a "proof of concept" on the economic and environmental merits of silvopastoralism in northern Australia and in particular the potential contribution silvopastoralism may be able to make in meeting Australia’s carbon emission reduction targets via the CPRS.

The results of the research also suggest there is potential for silvopastoralism grazing systems to be used as a low cost land restoration tool in central Queensland. Replacing traditional grazing systems with silvopastoralism systems incorporating retained tree strips may provide an alternative land restoration strategy for brigalow and eucalypt lands in D or C condition[2] that has the added benefit of additional biodiversity and water quality outcomes.

### *Recommendations*

Given the positive economic viability of selected tree alley options under a range of cost and price scenarios, more detailed bioeconomic analysis is strongly recommended. This research should focus on key land types, tree species and market outlooks for carbon sequestration and forest products, including electricity poles, sawlogs, pulpwood and other emerging markets such as bioenergy. It should include carbon accounting frameworks that consider carbon stored in both trees and harvested wood products, given the potential for harvested products to increase the longer term pool of stored carbon and possible future commercial benefits.

Additional research is also needed into other technical and social constraints to larger scale adoption of silvopastoralism in central Queensland, such as availability of suitable tree stock, knowledge and awareness of silvopastoral systems, capital availability and regulatory requirements under proposed

[2] The Fitzroy Basin Association has identified significant areas of brigalow and eucalypt land types in central Queensland that have been classified as being in “D” or “C” condition using Queensland Primary Industry and Fisheries Stocktake grazing land condition scoring framework.

carbon trading schemes such as the CPRS (e.g. third party verification and accreditation of biosequestration; 100 year plus permanence requirements for reforestation projects).

As this project represents an initial “proof of concept” and first step in the adoption process of innovative silvopastoral systems such as alley belts, it is important that this information is disseminated through existing natural resource management and primary producer networks, as well as through the production of industry extension material outlining general principles and outcomes from this project.

A targeted workshop or series of seminars is needed with rural landowners and natural resource management agencies to encourage and promote the findings of the research and to support the adoption of silvopastoralism in the region. It is also suggested that CSIRO maintain its website outlining the project outcomes for at least two years as part of an integrated silvopastoralism and agroforestry extension strategy.

# Introduction

Extensive land clearing for livestock production and associated land degradation has led to greater interest in the role of trees and revegetation practices such as agroforestry for achieving productivity and environmental outcomes in pastoral landscapes. Over the past ten years, managed investment schemes have established large scale plantation hardwood estates across Queensland, and in particular around the centres of Mackay, Sarina and Miriam Vale. Polglase *et al.* (2008) conducted a national scale analysis of the potential to grow and profitably market wood products including central Queensland. Whilst there is now a growing understanding of the bio-economic interactions driving plantation hardwoods, there is currently little known about the opportunity to establish complementary agroforestry (including regrowth management and plantation) and pastoral systems (silvopastoralism) in northern Australia, particularly in lower rainfall (600-750 mm/yr) areas.

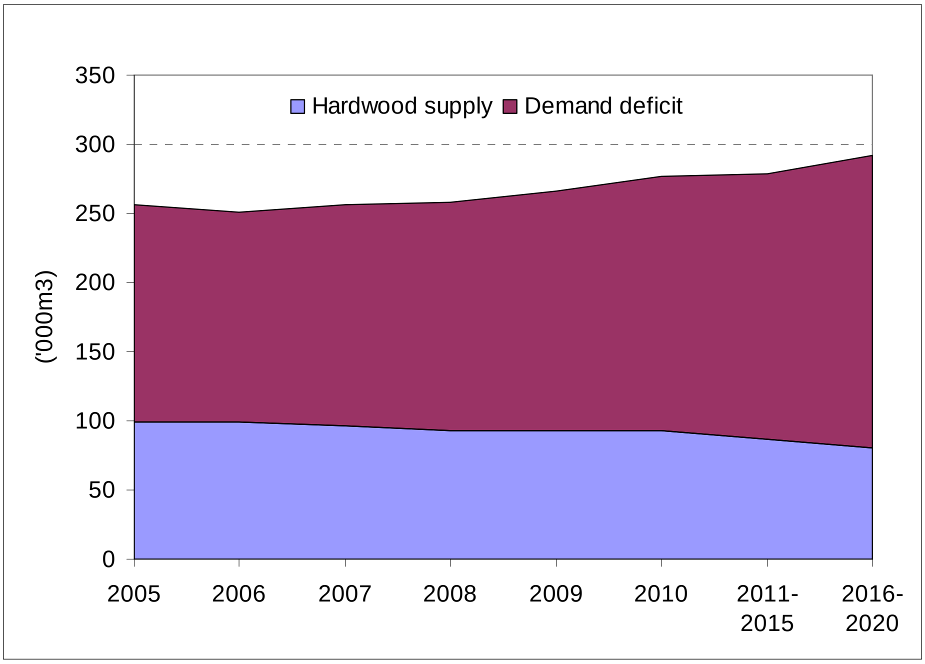
The rangelands of northern Australia provide a range of agricultural and ecosystem services. Extensive grazing systems for beef production represent a dominant land use, given the limited scope for alternative industries. Woodland clearing and grazing has resulted in a significant modification of the structure and composition of many vegetation communities in Australia's rangelands, with reported adverse soil, water and biodiversity impacts. Previous clearing and subsequent grazing management in the Fitzroy and Burdekin Basins has led to substantial soil loss and transfers of sediment and nutrients to the Great Barrier Reef lagoon.

Silvopastoralism, through the combined use of trees and pasture in an agroforestry system, may offer considerable benefits in terms of income diversification and environmental benefits through increased woody vegetation cover. Recently McKeon et al. (2008), investigated the impact of tree strips on the pasture productivity in the inter-strip areas. They identified zones within the inter-strip area of constrained and stimulated pasture growth depending on distance from the tree strip. The outcomes of this report have been used in the current analysis to improve the estimation of forage production in examining the trade-offs between pastoral production and retention or planting of trees.

Furthermore, the relative value of trees may rise in the future with respect to carbon sequestration (e.g. emissions trading and carbon offset schemes), renewable energy (e.g. biomass), projected shortfalls in timber supply (Figure 1) and global forest product markets (e.g. pulp and paper). The net effect of increases in public native forest reserves across Queensland has been a reduction in public hardwood availability and industry restructuring through the government buy out of crown log allocations. Current projections suggest that hardwood sawlog demand in Queensland will exceed local production from existing sources by between 120,000 and 170,000 cubic metres per year over the next 10-15 years (Timber Queensland, 2007). Opportunities therefore exist for forest product substitution from private native forests and plantations in the medium to longer term (Stephens & Stunzner, 2008).

In 2008 the Australian Government set a long-term target of a 60 per cent reduction in greenhouse gas emissions produced in 2000 by 2050. To achieve this target, the Government plans to implement a nationwide carbon pollution reduction scheme (CPRS) in 2010. In the recently published *Carbon Pollution Reduction Scheme White Paper*, the Government indicated that while agriculture will not be included in the CPRS before 2015, the ultimate inclusion of agriculture will be reviewed by 2012. Under current carbon accounting conventions, agriculture and landuse, landuse change and forestry are significant emitters of greenhouse gases, with agriculture currently accounting for 16 per cent of national emissions and landuse, landuse change and forestry currently accounting for 6 per cent of national emissions (Jiang et al., 2009). The methane emitted by the livestock industries account for 11 per cent of Australia’s total greenhouse emissions making it one of the largest industry emitters.

**Figure 1 Projected wood shortfall: Queensland *Source*: Timber Queensland 2008**




RIRDC commissioned CSIRO Livestock Industries to investigate the on-farm economics of silvopastoral systems versus conventional grazing systems. Given the possible inclusion of agriculture in the CPRS and growing interest in understanding the economics of avoided deforestation as a means of offsetting livestock methane emissions, carbon sequestration and $CO_2$-e sales are included in the economic modelling.

This project evaluates the regional feasibility of silvopastoralism in the low annual rainfall areas (600-750 mm) of central Queensland. The report documents what is known about the key bio-physical factors influencing pasture and woodland growth and forestry outcomes using local data where possible for two widespread woodland communities (land types) in central Queensland. The analysis incorporates the dynamic tradeoffs between tree and pasture growth, likely forest product yields, carbon sequestration and livestock methane emissions. This knowledge is then used to construct a bio-economic model of four potential silvopastoralism systems (based on regrowth retention and planting of trees) that are compared with conventional grazing systems.

# Literature Review

A short review is provided of key biophysical and economic factors influencing agroforestry potential and profitability for grassy woodland types in Queensland. The review also includes some broader R&D priorities and general findings relevant to agroforestry development in northern Australia, including results from previous projects funded under the Joint Venture Agroforestry Program (JVAP).

From a broad Australian context, Prinsley (1992) provided an overview of the potential benefits and underpinning science of agroforestry development, taken to include:

- rehabilitation of land from degradation (e.g. soil erosion, salinity, acidification);
- improved productivity (e.g. windbreaks for plant and animal shade and shelter);
- timber production; and
- higher farm income and income diversification.

Silvopastoralism, which combines trees, pasture and livestock within a single agricultural system, has also been identified as the dominant form of agroforestry practised in Australia and New Zealand (Mead, 1995). In the mid 1990s, Wilson *et al*. (1995) reported on the percentage of Australian farms with planted trees with respect to the main planting designs. These were: tree belts and corridors (35%); tree blocks (14%); widely spaced trees (6%) and alley belts (6%). The three major functions of planted trees were for provision of shade and shelter, rehabilitation of degraded land or protection of land from future degradation, and the conservation of native vegetation and wildlife. The production of wood and wood products was a relatively minor function at a national level. The main functions for planting trees on farms were similar in the late 1990s, with the number of Australian farms with planted trees increasing from 48% to 68% between 1993-94 and 1998-99 (Alexander *et al*., 2000).

However, agroforestry development in the lower rainfall and subtropical regions of northern Australia is in an early developmental phase, with a number of impediments and research and development (R&D) priorities to be further investigated in order to ascertain its full potential. From a broad sustainability perspective, agroforestry research is identified as a priority in the northern savannahs given its relevance to vegetation rehabilitation, biodiversity and enterprise profitability in light of issues such as land degradation and declining terms of trade for beef production (MacLeod & McIvor, 2006). From a timber production perspective, some of the key research gaps include a lack of published data on establishment of agroforestry trees for timber in the dry tropics; wood quality and wood processing for native and exotic timber species and a lack of information on the marketing of wood products on domestic and international markets (Turvey & Larsen, 2001). These issues have been addressed to some extent in subsequent JVAP reports outlined below).

## R&D priorities in subtropical northern landscapes: JVAP supported research

Zorzetto and Chudleigh (1999) reviewed commercial prospects for agroforestry in the low to medium rainfall zone (400-600 mm). Enterprises considered included sawn timber, wood panel products, posts/poles, specialty timber, biomass for electricity and ethanol, firewood, charcoal and activated carbon, eucalyptus oil, fodder and a range of niche markets (e.g. bushfood, olives, jojoba). Full investment analyses were conducted for four of these enterprises: sawn timber, firewood, biomass for electricity, and eucalyptus oil production. Other enterprises were handled in a descriptive manner. Three prospects that emerged favourably from the assessment were: fodder; eucalyptus oil; and electricity produced from by-products and residues.

In an attempt to narrow the focus of prospective industries and drawing on the earlier study by Zorzetto and Chudleigh (1999), Hague *et a*l. (2007) adopted a similar approach in evaluating market prospects for six forestry based products in the low to medium rainfall zone. The products fell into two distinct categories: traditional or emerging forest products industries (appearance grade timber, fibreboard and wood-plastic composites) and energy and chemical industries products (electricity from woody biomass, ethanol and methanol, pyrolytic bio-oil). Appearance grade timber was selected on the basis that, for the immediate future, revegetation of low rainfall areas will be dominated by conventional forestry approaches; hardwood sawlogs grown in these areas are likely to be too high density for structural lumber but are ideally suited for appearance grade timbers. The dry formed fibreboard and wood-plastic composites industries were also considered to have good future growth prospects, the products potentially being manufactured from a wide range of woody raw materials.

The products and processes concerning bioenergy and chemicals were selected primarily on the basis of large potential market sizes, with significant penetration of markets requiring vast quantities of woody biomass feed-stocks. For the forest products, the main challenge identified was competition from conventional forestry operations based on the more productive, higher rainfall zones. However, within the sphere of the energy and chemical based industries greater challenges were identified. Dry zone woody feed-stocks would not only have to compete with their higher rainfall counterparts, but also other naturally derived raw materials (e.g. starch and sugar) and fossil fuels (Hague *et al*., 2007).

Venn *et al*. (2004) evaluated niche markets for semi-arid western Queensland hardwoods and concluded that while domestic market volumes were low (~200 $m^3$/a), there was considerable interest in North America and Europe for high quality western hardwood boards. Financial analyses based on portable sawmilling technology and the utilisation of *Acacia aneura* (mulga) and *A. cambagei* (gidgee) found that hardwood production scenarios may be more competitive than grazing options for selected high value markets (e.g. dried and dressed boards, parquetry flooring). It was concluded there was considerable scope for future investigations into the western Queensland hardood industry, focusing on resource assessment of woodland regeneration and stand volumes, opportunities for agroforestry and appropriate processing techniques.

Within the geographic locale of the tropical savannas of northern Australia, Bristow (2004) collated information on relevant agroforestry and forestry trials to date. Poor soils, high evapotranspiration, medium to low rainfall and an often extended dry season characterise the region. Despite such challenges, plantation forestry was considered to have promising early growth rates of potentially high-value timber and non-timber species. Thirteen projects consisting of 74 plantings were considered. Each project was short-term (1-4 years) and focused on identifying species suitable for northern Australia conditions. In order for the potential of the region to be fully evaluated, the author recommended the need for long-term, strategic approaches to R&D including land suitability investigations; economic feasibility; species-site matching; targeted genetic improvement; establishment silviculture; utilisation and value-adding of products from both plantations and native forests.

From a silvopastoral perspective, several studies have reviewed the potential of various non-eucalypt tree species for wood and animal (forage) production in northern Australia. Lowry and Seebeck (1997) concluded there was good evidence that some species did promote higher quality pasture below the canopy, and with less assurance, that fallen leaf from a number of trees could be a dry-season feed. The best candidate considered was the siris tree (*Albizia lebbeck*). This was followed by a further evaluation of native non-sclerophyll trees, many of which were found to promote grass production below the canopy with potential for supporting wood and animal production in open plantings (Lowry 2000).

Given a common perception that productive pasture cannot be maintained under tree canopies, Congdon and Addison (2003) sought to identify pasture legume species capable of tolerating different levels of shading under tree plantations in the Australian tropics. The potential benefits from such species include improved forage quality and productivity for grazing in agroforestry situations, improved soil fertility and lower fertiliser costs through nitrogen fixation. From a total of 35 species and cultivars of tropical pasture legumes tested, 16 were identified as potentially useful, shade-tolerant species that showed promise for use under trees in both the wet and seasonally dry tropics. Research priorities were identified with respect to controlling the climbing habit of many legume species through grazing management (which would broaden the range of legume species available for use); examining the longer term persistence and productivity of the identified species as trees age and shade levels increase; and investigating shade tolerant grasses in addition to the legume component of the pasture.

The economic viability of incorporating woody crops with conventional agriculture in the dryland cropping zones of Western Australia and New South Wales was evaluated by Abadi *et al*. (2006). Seven prospective case studies were evaluated using discounted cash flow analysis and an analytical spreadsheet tool known as *Imagine*. While confined to the dryland cropping zones, the low rainfall (325-450 mm/yr) aspects and planting systems (alley belts, phase farming and plantations) are relevant to the subtropics. It was found that oil mallee had the greatest potential for further development in the WA cropping zone, while jojoba and blue mallee were the most promising commercial prospects for the NSW cropping zone. The *Imagine* modelling tool enabled temporal and spatial interactions between woody crops, herbaceous crops and pastures to be captured as well as sensitivity analyses of key variables influencing the viability of each enterprise. Discounted cash flow analysis was used to compare agricultural gross margins with annuity equivalents of the net present value of forestry returns.

From a broader landscape perspective, Polgalse *et al*. (2008) conducted a spatial assessment of opportunities for agroforestry systems across the major geoclimatic zones of Australia. Taking into account wood processing infrastructure, land opportunity costs for agriculture, cost and price scenarios and growth and yield predictions based on the 3-PG2 model (Landsberg & Waring, 1997), they assessed the relative profitability of 5 major types of plantings: traditional forestry systems (hardwood sawlog, softwood sawlog and pulpwood), bioenergy; integrated tree processing (chipped mallee systems to produce electricity, activated carbon and eucalyptus oil), in-situ fodder and carbon plantings. The main conclusions were that agroforestry can be competitive for some regions, particularly:

- pulpwood and hardwood sawlogs due to the often fast rates of growth and relatively higher prices for hardwood compared to softwood products;
- northern Australia, where expansion of agroforestry may be promising due to the often low profitability of agriculture and potential fast rates of tree growth; and
- carbon farming, due to relatively low cost of production with no harvesting or processing costs and multiple environmental benefits.

Major recommendations to explore this potential included:

- research into growth data and prediction for dryland species and environmental plantings;
- carbon accounting and prediction; and
- breeding and silviculture to maximise growth.

**Selected reports from the Joint Venture Agroforestry Program: low rainfall and/or northern Australia**

Abadi, A, Lefroy, T, Cooper, D, Hean, R & Davies, C 2006, '*Profitability of agroforestry in the medium to low rainfall cropping zone*', RIRDC Publication 05/181, Canberra.

Bristow, M 2004, '*Review of agroforestry in tropical savanna regions of northern Australia*', RIRDC Publication 04/025, Canberra.

Congdon, B & Addison, H 2003, '*Optimising nutrition for productive and sustainable farm forestry systems – pasture legumes under shade*', RIRDC Publication 03/113, Canberra.

Hague, J, Freischmidt, G, Pongracic, S & Fung, P 2007, '*Six best bet products from agroforestry biomass grown in low rainfall areas*', RIRDC Publication 05/179, Canberra.

Lowry, JB 2000, '*Trees for wood and animal production in northern Australia*', RIRDC Project CSC-58A, Canberra.

Lowry, B & Seebeck, J 1997, '*The potential for tropical agroforestry in wood and animal feed production*', RIRDC Publication 97/073, Canberra.

Polglase, P, Paul, K, Hawkins, C, Siggins, A, Turner, J, Booth, T, Crawford, D, Jovanovic, T, Hobbs, T, Opie, K, Almeida, A & Carter, J 2008, '*Regional Opportunities for Agoforestry Systems in Australia*', RIRDC Publication 08/176, Canberra.

Turvey, N & Larsen, P 2001, '*Agroforestry R&D priorities for northern Australia*', RIRDC Publication 01/142, Canberra.

Venn, TJ, McGavin, RL & Leggate, WW 2004, 'U*tilisation of western Queensland hardwoods as specialty timbers*', RIRDC Publication 04/130, Canberra.

Zorzetto, A & Chudleigh, P 1999, '*Commercial prospects for low rainfall agroforestry*', RIRDC Publication 99/152, Canberra.

## Tree grass interactions: productivity and multi-functionality

Given the specific focus of silvopastoralism on integrating trees, pastures and livestock in an agricultural land use system, the interactions between trees and pasture are a key factor influencing the dynamics of total production and economic viability of such enterprises. The review highlighted the various competitive and stimulatory effects of trees on pasture production and the importance of tree density (that is basal area) and tree design factors (e.g. use of alleys and windbreaks, geographic orientation) on yields, as well as the multi-functionality of these systems for a range of benefits. These multiple benefits can include income diversification, improved biodiversity and water and soil function, bio-sequestration of carbon and increased livestock productivity from changes in forage quality and provision of shade and shelter. These aspects are summarised below.

### *Competitive effects and costs*

Generally, early tree/pasture based research in Queensland focused on the competitive effects of tree density on pasture production for key woodland types, including *Eucalyptus* spp. and *Acacia harpophylla* (Walker *et al*., 1971; Walker *et al*., 1986; Scanlan & Burrows, 1990; Scanlan, 1991; McIvor & Gardener, 1995). Pasture production benefits of tree removal were identified through higher documented pasture yields on sites with lower tree stocking, reflecting direct competition between trees and pasture for water, nutrients and light. Trees and grass compete more strongly for water followed by nutrients, while competition for light is thought to be low (McIvor & Gardener, 1995;

McIntyre *et al*., 2002). In northern regions where wet season rainfall is generally reliable, there is less competition between trees and grasses for soil moisture compared to temperate southern areas where competition for soil water is more significant (Jackson & Ash 1998). The higher the overall productivity of a site the more linear (as opposed to concave) the competitive effect of trees on pasture yield (McIntyre *et al*., 2002). Trees generally have less impact on grass production in sites with high potential productivity (Scanlan, 2002).

Other ecological studies have focused on the adverse impacts (or costs) of tree and vegetation clearing on a range of ecosystem services, either through on-site (paddock) or off-site (catchment) processes. These impacts are summarised in a Queensland landscape context through a series of articles in The Rangeland Journal (2002). The main ecological impacts included: biodiversity loss (McAlpine *et al*., 2002); increased greenhouse gas emissions (Henry *et al*., 2002); declines in nutrient availability and cycling (Schmidt & Lamble, 2002); soil and water erosion (Ludwig and Tongway, 2002) and higher soil and water salinity (Thorburn *et al*., 2002). The importance of balancing these broader ecological impacts and costs with the benefits from vegetation clearing for agricultural production is recognised from a resource economics perspective in terms of optimising the net societal benefits from such systems (Rolfe, 2002).

In particular, there is recognition that following initial clearing and pasture growth brought about by the release of accumulated nutrients, pasture tends to decline over time in terms of pasture yield and/or grass species diversity (Myers & Robbins, 1991; Kaur *et al.*, 2006; Radford *et al*., 2007). Sangha *et al*., (2005) documented a depletion of nutrients and plant diversity from long-term cleared sites compared to uncleared remnants for selected communities of *Eucalyptus populnea*, *E. melanophloia* and *Acacia harpophylla* in central Queensland. This run down in pasture productivity is commonly attributed to an immobilisation of soil N in the process of degradation of high C:N litter (Wilson, 1996). This implies that the longer term aspects of nutrient dynamics should be taken into account when evaluating tree clearing or revegetation/tree planting activities.

### *Joint production*

One of the earliest trials to evaluate the specific feasibility and productivity of silvopastoral systems in the subtropics was that undertaken by Cameron *et al*. (1989) as part of Project STAG (the acronym stands for Soil, Trees and Grass). *Eucalyptus grandis* (flooded gum) was planted in a Nelder fan design in a *Setaria* dominated pasture in south-east Queensland with tree densities ranging from 42 to 3580 stems per hectare. The experiment was run over 4.6 years and growth of pasture was not significantly influenced by tree densities less than 158 stems/ha. At high tree densities, pasture productivity tended to decline which became more severe over time. They concluded that trees and pasture could be successfully grown together to provide substantial production from each. They identified tree stocking densities of greater than 1000 stems/ha for maximum above ground tree biomass with smaller sized stems and virtually no pasture; medium densities of around 300-600 stems/ha suitable for round timber, pulpwood and sawlogs, with some pasture production and thinning practices down to a final stand density of 20-50 stems/ha; and lower density plantings of less than 100 stems/ha that could be used for stock shelter without seriously affecting pasture production. There was also some evidence that pasture quality was improved by shading, as a higher portion of yield under trees was allocated to green leaf with higher nitrogen content than more exposed pasture (Cameron *et al*., 1989).

### *Stimulatory effects and benefits*

The benefits of trees in silvopastoral systems are linked with specific design features to capture a range of stimulatory and/or complementary effects on total output. In addition to widely spaced/scattered trees and tree blocks, the most common designs involve rows of trees described as tree strips, alley belts, shelterbelts and/or windbreaks. These types of tree strips are used by land managers to reduce wind speeds and erosion, provide shelter and beneficial microclimate and increase soil moisture and plant growth (McKeon *et al.*, 2008). Woodlands with mature, scattered trees have also been shown to reduce wind speeds by up to 50% (McIntyre *et al.*, 2002).

The general effects of windbreaks on microclimate and crop and pasture yields are summarised in Cleugh *et al.* (2002), drawing on tunnel experiments and Australian field studies such as Bird (1998) and Cleugh and Hughes (2002). In general, two broad areas of crop and pasture response can be identified: a zone of reduced yield associated with tree competition that extends 1H to 3H (where H is windbreak tree height), and a zone of unchanged or slightly increased yield stretching downwind from 10 to 20H (Cleugh *et al.*, 2002). However, these impacts will vary according to a range of climatic and soil conditions and other design factors. As identified by McKeon *et al,* (2008), important parameters influencing the performance and function of tree strips include:

- tree height;
- optical porosity (that is ratio of open areas to that of vegetated obstructions);
- upwind turbulence;
- length of tree strips;
- orientation;
- extent of multiple arrays of tree strips; and
- types of trees and understorey plants used.

The direct bio-physical processes by which trees used for shelter can enhance pasture and plant production are documented by Bird *et al*. (1992). These processes can include:

- reducing water loss, as a result of reducing wind speed and/or shading, which can also prolong pasture growth and improve water use efficiency;
- protecting plants from frost;
- promoting mineralisation of soil nitrogen as a result of shading pasture or soil;
- contributing to soil organic matter (leaf and twig litter forming humus) and improved soil moisture retention; and
- trapping or recycling nutrients over time (that is nutrient cycling).

Trees used strategically in the landscape can also provide direct benefits for animal production through provision of shade and shelter, particularly during periods of climatic stress and calving (Roberts 1984; Daly 1984; Bird *et al.*, 1992). As summarised by Bird *et al.* (1992), trees may affect animals in the following ways:

- by providing additional leaf foliage or fruit as a supplement to pasture, particularly in times of drought;
- by reducing livestock maintenance requirements due to shelter, as energy expended is increased by excessive heat or cold;
- by reducing climatic stress due to shelter and improving numbers of calves and intervals between calves;

- by increasing provision of shade and survival rates of newborns, particularly in hot and humid conditions.

From a tropical perspective, a number of studies have evaluated the impacts of tree shading on nutrient cycling and pasture quality in northern and central Queensland. Based on artificial shade experiments, Wilson (1996) concluded that shade did enhance organic matter breakdown and N cycling at a pastoral research site near Munduberra. Jackson and Ash (1998) similarly identified higher soil N concentration and pasture quality (that is higher dry matter digestibility for ruminants) under trees compared to more open inter-tree areas at two woodland sites in northeast Queensland. While total dry matter yields were higher in more open areas, the benefits were partially offset by a reduction in pasture quality in these areas. Other grassy woodland studies have identified improved soil fertility and forage N under the tree canopy for shade tolerant grasses (Ash & McIvor, 1998; Jackson & Ash, 2001).

### *Economics and emerging carbon markets*

The emergence of the carbon economy and market trading of offsets for bio-sequestration of carbon on agricultural land represents a potential economic driver for silvopastoral development. This opportunity arises from the potential for trees to sequester $CO_2$ from the atmosphere and store carbon in the various biotic and abiotic components of the land use system (e.g. soils, tree roots, litter, woody stems, branches and foliage). While ‘carbon farming’ has the potential for direct offset payments to farmers from other parties (e.g. net emitters from fossil fuel intensive sectors), forestry activities may also help reduce on-farm emissions. This on-farm component may be equally important should a broader range of agricultural activities, such as livestock emissions, be included in any future carbon trading scheme (Stephens & Stunzner, 2008).

Ford-Robertson *et al.* (1999) describe a carbon stock and flow model and compare the net carbon balance over 80 years for grazing, agroforestry and afforestation land uses in New Zealand. The net carbon stock for a typical pasture system was substantially lower than for agroforestry and afforestation scenarios based on planting *Pinus radiati*, due mainly to ongoing methane emissions from livestock. For the agroforestry systems, the gains in total carbon stocks were lower than for afforestation due to methane emissions and lower accumulated biomass carbon over time. However, there may be a range of economic and social reasons for adopting some forms of agroforestry compared to broad scale afforestation, such as food security, cash flow implications and limits to the amount of available land at low cost. Shively *et al.* (2004) looked at the incremental costs of increasing carbon sequestration across the Manupali watershed in the Philippines using agroforestry and afforestation systems based on *Paraserianthes falcataria*. They found that the costs of carbon storage (or prices needed to compensate farmers for conversion to forestry based on the opportunity costs of the land for cropping) varied between $3.30 per tonne on fallow land to $62.50/t on higher value cropping land. Importantly, carbon storage through agroforestry was less costly than afforestation due to the addition of annual crops to compensate for some of the opportunity costs of land conversion.

In their assessment of the national windbreaks program, Cleugh *et al.* (2002) observed that economic analyses that accounted for the costs of tree establishment, losses due to competition and gains as a result of shelter either produced small financial gains or were cost neutral. These analyses were conducted in the absence of potential carbon sequestration benefits. This implies there is scope for enhanced net returns from carbon sequestration outputs although this would depend upon such factors as future carbon prices, emissions trading rules and relative trade-offs between outputs.

From a forest products perspective, Venn (2005) looked at the financial and economic potential for plantations across Queensland for hardwood sawlog production. Where high growth rates are achievable (20-25 $m^3$/ha/yr), such as along the high rainfall coastal fringes of northern and southern Queensland, long rotation hardwood plantations were found to be profitable compared to agricultural land values. At intermediate (15 $m^3$/ha/yr) or lower growth rates (5-10 $m^3$/ha/yr), hardwood sawlog plantations were either viable under optimistic assumptions or marginal. However, the inclusion of broader social benefits such as carbon sequestration, salinity amelioration and other ecosystem services justified the establishment of plantations for most regions.

### *Broader landscape impacts/opportunities*

It is also important to recognise the significance of broader design factors of silvopastoral systems on pasture production and ecological functions across a landscape. Scanlan (1992, 2002) initially described spatial simulation models for community level relationships between trees and understorey grasses relevant to Queensland’s grazing lands. These modelling studies, with selected field validation, showed that herbaceous production in response to increasing tree density (relative to that in open areas) can vary from a linear decrease, to an exponential decrease or initial stimulation followed by a decrease, depending solely on the relative strengths of stimulatory and competitive effects of trees on grasses. Scanlan (2002) also observed that pasture production may be up to 50% higher in paddocks with high variability in the distribution of trees compared to areas where trees are uniformally distributed.

Tall woody vegetation such as trees can reduce velocities of wind, rainfall intensity, and stormwater runoff. In recent simulations conducted by Ryan (2007) particular configurations of tree belts in open grasslands led to: increased interception of stormwater runoff, a significant reduction in water velocity (up to 50%) which otherwise causes erosion, the filtering of sediments/nutrients from runoff and increased infiltration over broad areas of the landscape. Consequently, tree community design can greatly affect production and environmental outcomes at farm and/or catchment scales. In addition to direct benefits for the land manager, a significant advantage for catchment groups of linked design is a reduction in peak flow discharge which causes damage to riparian systems. This also serves to remove sediment from the waterways as well as preventing mass failure of creek banks, and increases the residence time of water which recharges aquifers and can lead to longer duration environmental flows (Ryan 2007).

# Objectives

Currently, little is known about the economic opportunities and risks associated with operating silvopastoral enterprises in central Queensland. This project evaluates the silvopastoralism potential of two widespread regrowth woodland communities (land types) in central Queensland: brigalow/blackbutt (brigalow) and poplar box with shrubby understorey (eucalypt). A key question is whether a silvopastoralism system can produce better financial and environmental outcomes compared with extensive grazing-only systems. This project was designed to assess silvopastoralism systems including direct tree plantings on previously cleared land and managed native forest regrowth in alleys or strips which allow for cattle grazing between and within the rows.

The key research tasks undertaken in this report include:

- a literature review of silvopastoralism systems suitable to central Queensland
- spatial analysis of land suitability for agroforestry in the Fitzroy Basin
- collation of relevant (local where possible) tree growth and yield data for target land systems
- a review and collation of regional marketing, costs and price data for forestry and livestock products relevant to central Queensland
- collation of modelled relationships between tree basal area, pasture production and carbon sequestration including the stimulatory and competitive impacts of woody vegetation strips in pastoral paddocks
- construction of bio-economic models to evaluate conventional grazing systems against preferred silvopastoralism systems for two central Queensland land systems (brigalow and eucalypt)
- discussion of model projections, assumptions used in the modelling and sensitivity of outcomes to changes in the assumptions.

# Methodology

The project evaluated the regional feasibility of silvopastoralism in the low rainfall (600–750 mm/yr) areas of central Queensland. The project reviewed what is known about key bio-physical factors influencing pasture growth, cattle grazing and forestry outcomes for selected woodland communities in central Queensland including the dynamics (and trade-offs) between tree and pasture growth and likely forest product yields (biomass and merchantable volumes) by land type. The review also sought to identify key research gaps and data limitations for the assessment of silvopastoralism in the region, and evaluate the application of the multiple land use model MIDAS (Pannell, 1996) to these livestock systems.

A review of the MIDAS bioeconomic model was conducted as part of the project to assess its feasibility for evaluating silvopastoral grazing options in central Queensland. The MIDAS model was developed to provide whole farm analysis of agricultural production decisions and inter-related functions across farm units (that is, paddocks) and time (Pannell, 1996). It has been applied to an extensive number of production and natural resource management issues, particularly in Western Australia and some other regions such as parts of New South Wales, but is presently limited to cropping and sheep grazing activities. Given the short time frame of the project, it was not possible to develop the MIDAS model to incorporate beef cattle activities and associated native pasture and animal production functions for central Queensland. A purpose built bioeconomic model calibrated for central Queensland was instead developed as part of an initial scoping exercise to evaluate the feasibility of tree alley systems. The MIDAS model is a potential future tool for evaluating beef cattle grazing and related silvopastoral systems in Queensland, but would require significant data input and development.

The economic feasibility of six agroforestry options for central Queensland was evaluated using discounted cash flow analysis and regional costs and prices for both livestock and forestry products. Uncertainty in key variables such as tree growth rates and product prices was incorporated using sensitivity analyses. A 1000 ha paddock on a regionally representative cattle property (e.g. property area, herd size) was used to assess the economic performance of the silvopastoralism options versus business-as-usual (i.e. maintain a largely treeless grazing paddock). The resultant measures of enterprise profitability (i.e. NPV) were used to compare the silvopastoralism options compared to extensive grazing (i.e. low tree basal area) management systems. The modelling assumed each scenario was managed in a manner that maintains or enhances land condition, utilising best management grazing practices and silvicultural practices.

Constructing the bioeconomic model and undertaking the economic comparisons reported here required the following seven steps (which are described in turn):

1. spatially analyse agroforestry land suitability in central Queensland
2. design two business-as-usual and four silvopastoralism scenarios to be modelled
3. derive tree regrowth models
4. calculate pasture production and livestock carrying capacities
5. calculate tree biomass and timber products
6. incorporate the data obtained in steps 1 to 5 into an agroforestry bioeconomic model relevant to central Queensland
7. undertake economic analysis.

Tree growth data investigated included the TRAPS woodland monitoring system, various plantation trials managed by the QPIF and private industry, spatial tree cover and productivity indices from the National Forest Inventory and physiological growth models such as 3-PG (Landsberg & Waring, 1997). These data were used to derive an indicative range of possible wood yields. Pasture yields for given tree basal areas were calculated or obtained from recent agroforestry scenarios using the GRASP/AussieGRASS pasture growth models either developed for central Queensland or observed from direct grazing trials.

## Spatial analysis of land suitability for agroforestry in the Fitzroy Catchment Area

Currently little is known about the amount of land suitable for agroforestry in central Queensland, its specific location within the catchment in relation to enabling regional infrastructure (roads, timber mills, ports) and its compatibility to existing or neighbouring land uses. Constraints mapping using ArcGIS 9.2 software and based on the following criteria was used to determine the area of private land suitable for agro-forestry development within the Fitzroy Basin:

- average annual rainfall greater than or equal to 600 mm
- land assessable as non-remnant vegetation under *Vegetation Management Act 1999*
- private land use classes that were primarily agricultural or otherwise suitable for forestry development based on the Australian Land Use Mapping classification (ALUM) (for example, excludes wetlands, built up areas and public land, and so on).

The ALUM classification layer (ALUM, Version 6, June 2006, Bureau of Rural Science (BRS)) used in this analysis required additional classification into public versus private land and is summarised in Table 1.

**Table 1 Land classification categories designated as public and private land**

| ALUM Simplified Categories of the Secondary Classification Attribute | |
|---|---|
| Public | Private |
| Managed resource protection | Cropping |
| Manufacturing and industrial | Grazing natural vegetation |
| Marsh/wetland | Intensive animal production |
| Lake | Intensive horticulture |
| Mining | Irrigated cropping |
| Nature conservation | Irrigated perennial horticulture |
| Other minimal use | Irrigated seasonal horticulture |
| Reservoir/dam | Residential |
| River | Perennial horticulture |
| Transport and communications | Plantation forestry |
| Services | Production forestry |
| Utilities | |
| Waste treatment and disposal | |

The ALUM private classification attributes were categorised on their potential for silvopastoralism. An example of this is the intensive and irrigated horticulture or cropping, as in the majority of cases some of the land could be used for silvopastoralism.

The spatial analysis commenced with an overlay of the Fitzroy Basin showing private versus public land tenure.  Next land classified as non-remnant in the regional ecosystem 2003 layer (Survey and Mapping of 2003 Remnant Vegetation Communities and Regional Ecosystems of Queensland, Version 5.0 created December 2005, Queensland Herbarium, Environmental Protection Agency) was extracted to create a non-remnant vegetation layer. The non-remnant vegetation layer was then overlayed with the Fitzroy Basin land use layer to generate a map of privately owned land consisting of non-remnant ecosystems.

A mean annual rainfall layer of equal to or greater than 600 mm in the Fitzroy Basin was then created (Bureau of Rural Sciences, for the period 1980-99 created on January 2001, raster cell size of 5 $km^2$). The rainfall layer was overlayed with the non-remnant ecosystem layer only on private land and the overlapping zones extracted.  This final product represents the total suitable land within the Fitzroy catchment area identified as being suitable for agro-forestry purposes.

Finally a timber overlay was constructed by combining information sourced from the Central Queensland Forestry Association (CQFA) and Timber Queensland of current timber processing mills as at May 2008.  Buffers were then applied to the mills at a radius of 50, 100, 150 and 200 km to determine the amount of land suitable for agro-forestry within viable haulage distances to existing mills.

## Design of two business-as-usual and four agroforestry scenarios for central Queensland

The modelling seeks to compare a traditional grazing property conducting a breeding and finishing cattle enterprise on two different land types (brigalow and eucalypt) to four alternative agroforestry / silvopastoralism options comprising:

- grazing and complementary carbon sequestration (including and excluding livestock methane emissions) from regrowth strips on brigalow land types
- grazing and complementary carbon sequestration (including and excluding livestock methane emissions) from regrowth strips on eucalypt land types (i.e. poplar box)
- grazing and complementary spotted gum plantation for electrical transmission poles on brigalow land types
- grazing and complementary spotted gum plantation for woodchip on brigalow land types.

Each scenario is now defined.

### Scenario 1    Brigalow grazing – clear all regrowth (business-as-usual) scenario

The 1000 ha paddock in this scenario contains 10-year-old brigalow regrowth (*Acacia harpophylla* woodland regrowth) which had been pulled with a bulldozer and chain and raked 10 years previously (Figure 2).  The initial tree basal area was 5.5 $m^2$/ha.

**Figure 2 Two brigalow (*Acacia harpophylla*) communities. (a) Remnant brigalow forest and (b) brigalow regrowth.**

**(a)** **(b)**

The paddock has a mature stand of buffel pasture, two watering points and a carrying capacity of 1AE[3]:6 ha. The property operates a breeding and finishing business turning off 2 year old steers for the European Union (EU) market. Appendix 2 contains summaries of the herd structure, variable costs and herd gross margins used in the analysis.

In the second year of the analysis, all regrowth is blade-ploughed and the paddock spelled for 6 months (Figure 3). In Year 3 grazing is reintroduced and the carrying capacity for the property slowly declines over the following 23 years as brigalow regrowth competes with pasture for moisture, nutrients and sunlight. The stocking rate is adjusted to match the declining carrying capacity over the life of the analysis.

[3]An Adult Equivalent (AE) refers to a method of comparison between animals of different feed requirements with a recognised standard of a single adult animal feed ration. The international standard being a single non-pregnant, non lactating animal of 455 kilograms live weight.

**Figure 3 Blade ploughing of brigalow regrowth communities. (a) Recent blade ploughing of brigalow regrowth community, and (b) paddock showing the relatively small amount of regrowth following blade ploughing.**

## Scenario 2 Brigalow grazing – retain regrowth strips scenario

The retain-regrowth-strips scenario begins with the same 1,000 ha paddock and 10-year-old brigalow regrowth as Scenario 1 (Figure 2).

In year two of the analysis, the regrowth is blade-ploughed with regrowth strips 20 m wide left every 60 m (similar to Figure 4). The paddock is spelled for 6 months - that is, post wet season cattle are reintroduced and the carrying capacity for the property adjusted over the following 25 years as regrowth in the cleared and uncleared strips slowly increases and competes with the pasture for moisture, nutrients and sunlight.

**Figure 4 Blade ploughed brigalow regrowth with retained regrowth strips.**

An additional benefit from retaining timber strips is carbon sequestration. It is assumed for the purposes of this model that any sequestered carbon will be valued at \$10/t $CO^2$e with a price sensitivity testing undertaken above and below this level. Sequestration rates will be based on changes in estimated annual tree basal area and above- and belowground allometrics (Burrows *et al.,* 2002; Scanlan, 1991; Zerihun *et al.,* 2006). The release of carbon from clearing regrowth in the inter-row zone was not included in the calculations to estimate net carbon sequestration.

## Scenario 3 Eucalypt grazing – clear all regrowth (business-as-usual) scenario

The 1000 ha paddock in this scenario contains 10-year-old eucalypt regrowth (e.g. poplar box, *E. populnea,* woodland regrowth) which had been pulled with a bulldozer and chain and raked 10 years previously (Figure 5). The initial regrowth basal area was 3.2 $m^2$/ha.

**Figure 5 Poplar box woodland a. remnant before clearing and b. regrowth a 5-10 years after clearing (pulling).**

**(a)** **(b)**

The paddock has native pasture, two watering points and is currently stocked at 1AE:10 ha and also operates a breeding and finishing business. In year two of the analysis, the regrowth is pulled, stick raked and spelled for 6 months (see Figure 6). In year 3 grazing is reintroduced. The carrying capacity for the property slowly declines over the following 23 years as the regrowth regrows and competes with pasture for moisture, nutrients and sunlight. The stocking rate is adjusted to match the declining carrying capacity over the life of the analysis.

**Figure 6 Pulled poplar box regrowth community. This paddock has not been stick raked.**

## Scenario 4 Eucalypt grazing – 'with' regrowth strips

The eucalypt-grazing retain-regrowth-strips scenario begins with the same 1,000 ha paddock and 10-year-old eucalypt regrowth as Scenario 3 (Figure 5).

In year two of the analysis, the regrowth is pulled (Figure 6) and stick raked with regrowth strips 20 m wide left every 60 m. The paddock is spelled for 6 months - that is, post wet season cattle are reintroduced and the carrying capacity for the property adjusted over the following 25 years as regrowth in the cleared and uncleared strips slowly increases and competes with the pasture for moisture, nutrients and sunlight. The stocking rate is adjusted to match the declining carrying capacity over the life of the analysis.

An additional benefit from retaining timber strips is carbon sequestration. It is assumed for the purposes of this model that any sequestered carbon will be valued at \$10/t $CO_2$-e with a price sensitivity testing undertaken above and below this level. Sequestration rates will be based on changes in estimated annual tree basal area and above- and below-ground allometrics (Burrows *et al.*, 2002; Scanlan, 1991; Zerihun *et al.*, 2006). The release of carbon from clearing regrowth in the inter-row zone was not included in the calculations to estimate net carbon sequestration.

## Scenario 5 Plantation for pole production on the brigalow land type

The pole production scenario model begins the same as the 'brigalow grazing' scenarios (Scenarios 1 and 2) (Figure 2) consisting of a 1,000 ha paddock of 10 year old brigalow regrowth with a tree basal area of 5.5 $m^2$/ha. The paddock has a mature stand of buffel pasture, two watering points and is currently stocked at 1AE:6 ha. The property operates a breeding and finishing business. In year two of the analysis, the regrowth is blade-ploughed (Figure 4). The paddock is spelled for 6 months. Plantation strips are planted in 50m wide sections separated by 150m strips of buffel pasture (Figure 7).

In year 4 cattle are reintroduced at an initial stocking rate of 1AE:4.5 ha across the whole paddock. The carrying capacity for the property slowly declines over the following 22 years as regrowth and plantation growth competes with the pasture for moisture, nutrients and sunlight. The stocking rate is adjusted to match the declining carrying capacity over the life of the analysis.

The key assumptions used in the development of the timber pole model are summarised in Table 2.

**Figure 7 Eucalypt plantation on grazing land (Photo from DPI&F 2005)**

## Scenario 6 Plantation for 'chip' production on the brigalow land type

The 'chip' production scenario model begins the same as the 'brigalow grazing' scenarios (Scenarios 1 and 2) (Figure 2) consisting of a 1,000 ha paddock of 10 year old brigalow regrowth with a tree basal area of 5.5 $m^2$/ha. The paddock has a mature stand of buffel pasture, two watering points and is currently stocked at 1AE:6 ha. The property operates a breeding and finishing business. In year two of the analysis, the regrowth is blade-ploughed (Figure 4). The paddock is spelled for 6 months. Plantation strips are planted in 50 m wide sections separated by 150 m strips of buffel pasture (Figure 7). The wood chip rotation is 10 years.

In year 4 cattle are reintroduced at an initial stocking rate of 1AE:4.5 ha across the whole paddock. The carrying capacity for the property slowly declines over the following 22 years as regrowth and plantation growth competes with the pasture for moisture, nutrients and sunlight. The stocking rate is adjusted to match the declining carrying capacity over the life of the analysis.

The key assumptions used in the development of the timber pole and pulp models are summarised in Table 2.

**Table 2 Key parameters for Scenario 5: Plantation for pole production on the brigalow land type and Scenario 6: Plantation for chip production on the brigalow land type.**

| System Name and Number | Scenario 5 Brigalow Pole with Grazing | Scenario 6 Brigalow Chip with Grazing |
|---|---|---|
| Species Modelled | Spotted gum, lemon-scented gum (*C. citriodora* subsp. *citriodora* only), spotted irongum | Spotted gum, lemon-scented gum (*C. citriodora* subsp. *citriodora* only), spotted irongum |
| Initial planting (stems/ha) | 833 | 1 000 |
| First thin (year, stems/ha left) | 5 300 | n/a |
| Second thin (year, stems/ha left) | 8 150 | n/a |
| Ground prune (year) | 5 | n/a |
| Carry-up pruning (year) | 8 | n/a |
| Final harvest (year) | 25 | 12 |
| Harvest product split | 67% Electrical pole | 100% Pulp |
| | 17% Sawlog grade A | |
| | 16% Sawlog grade B | |
| Costs and prices | | |
| Establish cost ($/ha) | $1 490 | $1 548 |
| 1st Non-commercial thinning ($/ha) | $300 | n/a |
| 2nd Non-commercial thinning ($/ha) | $250 | n/a |
| Carry-up pruning cost ($/ha) | $350 | n/a |
| Harvest/Snig costs ($/ha) | $2 700 | $4 500 |
| Distance to market (km) | 200 | 200 |
| Log haulage cost ($/km) | $0.13 | $0.13 |
| Total timber harvest ($m^3$/ha) | 270 | 150 |
| Harvested timber poles ($m^3$/ha) | 180 | n/a |
| Harvested timber saw log A ($m^3$/ha) | 45 | n/a |
| Harvested timber saw log B ($m^3$/ha) | 45 | n/a |
| Harvested price ($/$m^3$) | $120 | $95 |
| Saw log A price ($/$m^3$) | $100 | n/a |
| Saw log B price ($/$m^3$) | $50 | n/a |

## Derivation of tree regrowth models

Relationships between time since clearing and stand basal area and regrowth height were generated for the brigalow and eucalypt land types from local data in central and southern Queensland (Table 3; Figure 8; Figure 10 and Figure 11presents the eucalypt regrowth relationships between time since clearing and stand basal area and regrowth height used in the bioeconomic modelling.

Figure 10 and Figure 12). The available data for regrowth rates was quite variable, as shown for example with the basal area increase following clearing for the brigalow land type (Figure 8). The high variability is related to clearing history, efficacy of clearing (i.e. number of live stumps remaining), site productivity and post clearing history (e.g. stick raking, fire). The relationship for the eucalypt regrowth height was poor, however the relationship appeared reasonable based on the experience of the authors.

A research gap identified during the development of tree regrowth models was the relatively poor understanding of regrowth and plantation growth rates in the region, particularly as clearing success (in terms of woody plant death and number of surviving stems per hectare) is highly variable. Table 3 Data source of regrowth and plantation basal area and height growth rates used in the analysis provides a summary of data used in generating tree regrowth and plantation basal areas and height growth rates used in the analysis.

**Table 3 Data source of regrowth and plantation basal area and height growth rates used in the analysis**

| Relationship | Data source | Comments |
|---|---|---|
| Brigalow stand basal area and time since clearing (tree strip – All data) (Figure 8) | McKeon *et al.*, (2008)<br>Chandler *et al.*, (2007)<br>Scanlan (1991)<br>Bradley (2007) and associated unpublished data. | Data from southern and central Queensland |
| Brigalow stand basal area and time since clearing (blade-ploughed strip – Bradley <25yr) (Figure 8) | Bradley (2007) and associated unpublished data. Using data points less than <25 years since clearing. | Data from southern Queensland |
| Brigalow stand height and time since clearing (Figure 9) | McKeon *et al.*, (2008)<br>Scanlan (1991)<br>Bradley (2007) and associated unpublished data. | Data from southern and central Queensland |
| Eucalypt stand basal area and time since clearing (Figure 10 and Figure 11presents the eucalypt regrowth relationships between time since clearing and stand basal area and regrowth height used in the bioeconomic modelling.<br>Figure 10a) | McKeon *et al.*, (2008)<br>TRAPS woodland monitoring site data. Back *et al.*, (2009) and Burrows *et al.*, (2002) and associated unpublished data. | Data predominately from poplar box (*Eucalyptus populnea)* woodland in central and southern Queensland. Two sites were ironbark (*E. melanophloia* and *E. crebra*) woodland. |
| Eucalypt stand height and time since clearing (Figure 10 and Figure 11presents the eucalypt regrowth relationships between time since clearing and stand basal area and regrowth height used in the bioeconomic modelling.<br>Figure 10b) | McKeon *et al.*, (2008)<br>TRAPS woodland monitoring site data. Back *et al.*, (2009) and Burrows *et al.*, (2002) and associated unpublished data. | Data predominately from poplar box (*Eucalyptus populnea)* woodland in central and southern Queensland.<br>Relationship poor. |
| Plantation stand basal area since planting (Figure 12a) | Huth (2007) | Data from Central Queensland plantation species trials. Data calculated from individual stem basal area (average of the five best taxa at each site) multiplied by the number of stems at planting and following the two thinning operations in year 5 and 8 (Table 2). |
| Plantation stand height since planting (Figure 12b) | Huth (2007) | Data from Central Queensland plantation species trials. Data is an average of the five best taxa at each site. |

Figures 8 and Figure 9 presents the brigalow regrowth relationships between time since clearing and stand basal area and regrowth height used in the bioeconomic modelling. The *All data* relationship was used for the retained regrowth strips and the *Bradley <25yr* relationship was used for the blade ploughed strips.

**Figure 8 Brigalow regrowth relationship between time since clearing and stand basal area at 30cm height.**

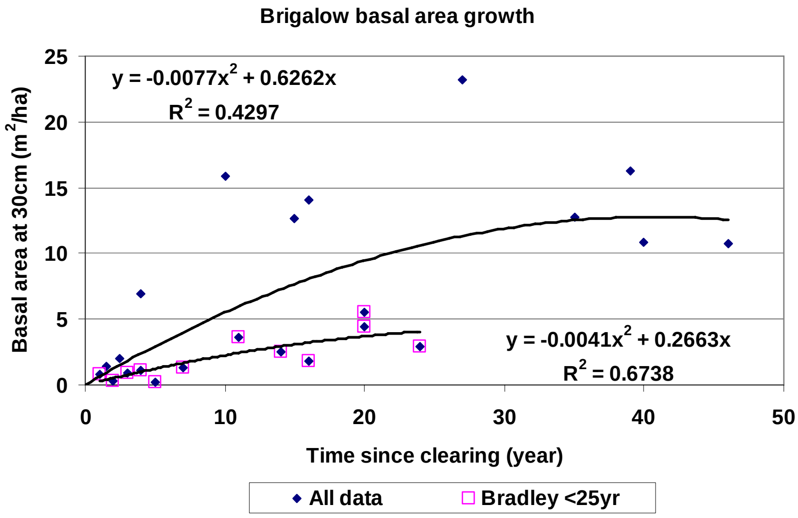



**Figure 9 Brigalow regrowth relationship between time since clearing and regrowth height.**

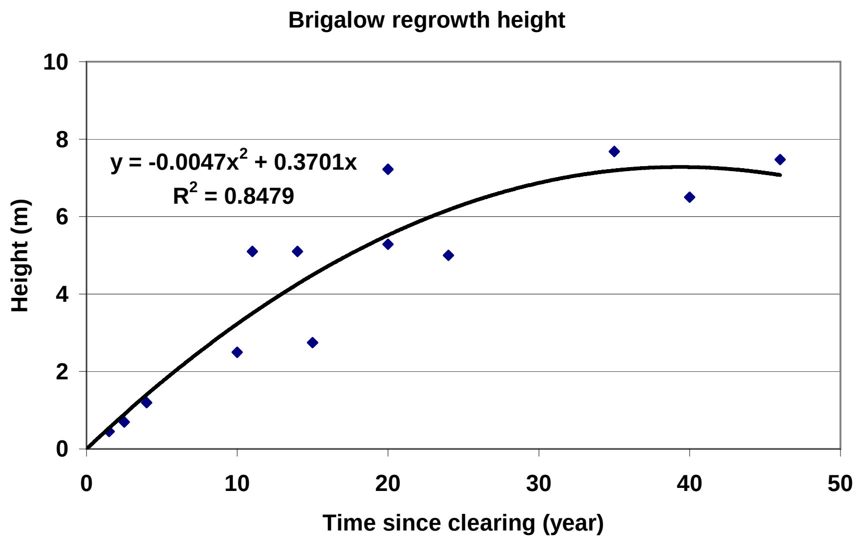



Figure 10 and Figure 11presents the eucalypt regrowth relationships between time since clearing and stand basal area and regrowth height used in the bioeconomic modelling.

**Figure 10 Eucalypt regrowth land type relationship between time since clearing and stand basal area at 30cm height.**

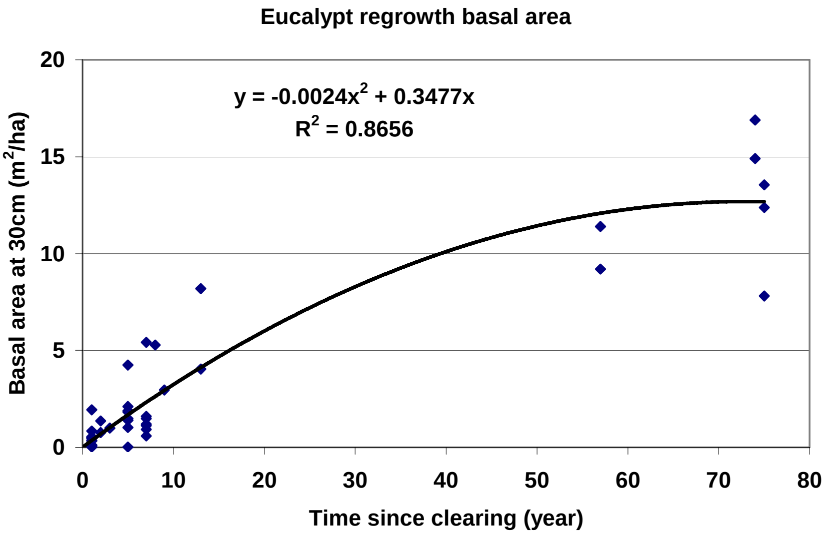



**Figure 11 Eucalypt regrowth land type relationship between time since clearing and regrowth height.**

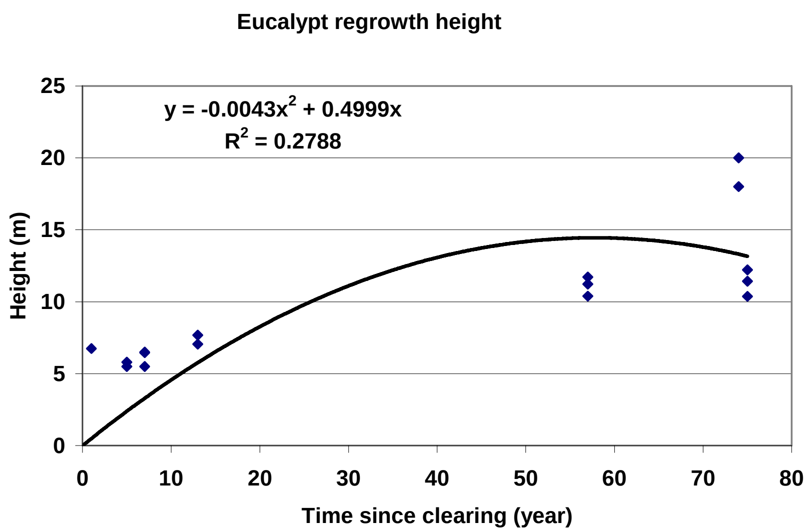



Figure 12 and Figure 13 presents the eucalypt plantation relationships between time since planting and Huth basal area and regrowth height used in the bioeconomic modelling.

**Figure 12 Eucalypt plantation relationship between time since planting and stand basal area at 30cm height.**

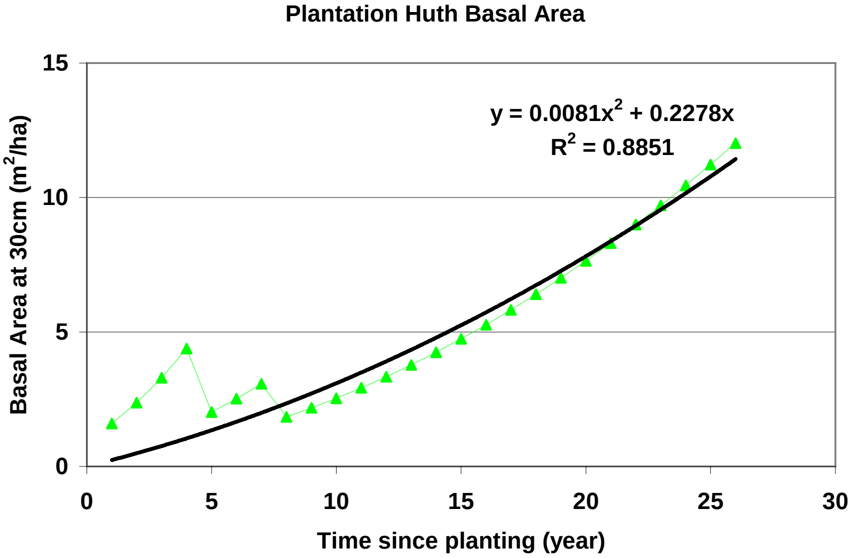
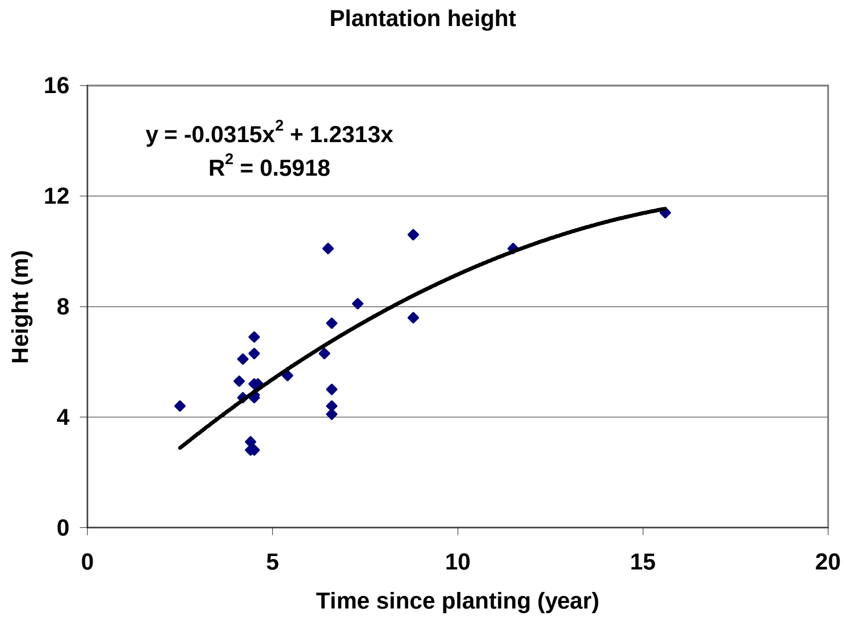


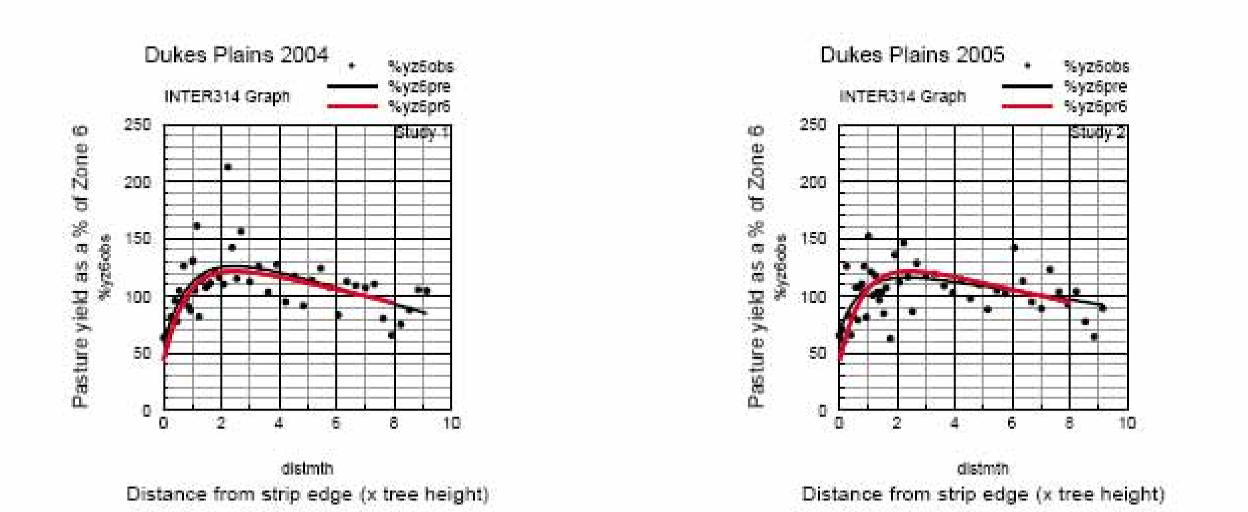

**Figure 13 Eucalypt plantation relationship between time since planting and regrowth height.**




## Pasture production and livestock carrying capacities

McKeon *et al.* (2008) reported zones of constrained and stimulated pasture growth associated with tree strips which were not accounted for by the tree basal area in that zone. They modelled relationships between relative pasture growth expressed as a percentage of pasture yield with no tree impact and distance from the edge of the tree strip measured in tree heights (e.g. Figure 14). These relationships were used to derive the constrained and stimulated pasture production factors used in the bioeconomic modelling.

**Figure 14 Relationship between pasture yield expressed as a percentage of pasture yield with no tree impact and distance from edge of tree strip expressed in multiples of tree height. Source: McKeon *et al.* (2008).**




Using these principles the paddock was split into five zones (Figure 15) which were modelled separately to estimate pasture production and livestock carrying capacity for the paddock. The zones were dynamic with zonal width changing as the height of the trees in the strips grew each year. The prevailing winds blow from the left of the diagram to the right. Table 4 defines the width of each zone and the corresponding discount or stimulation factor applied to pasture production.

**Figure 15 Schematic diagram of the different zones modelled and the relationship to relative discount or stimulation of forage production in the cleared strips (Compiled by C. Horn).**

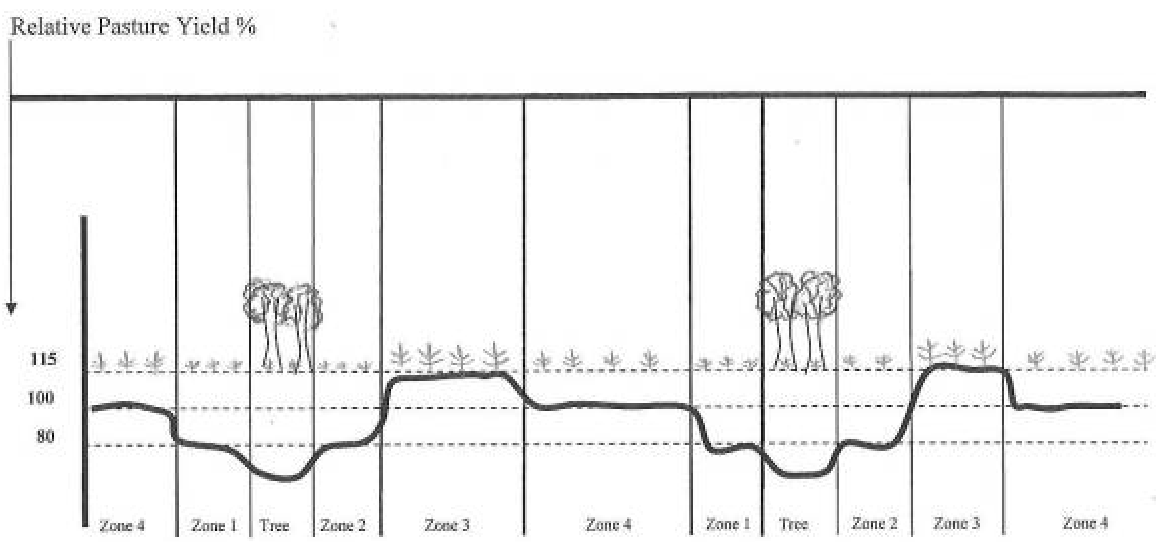
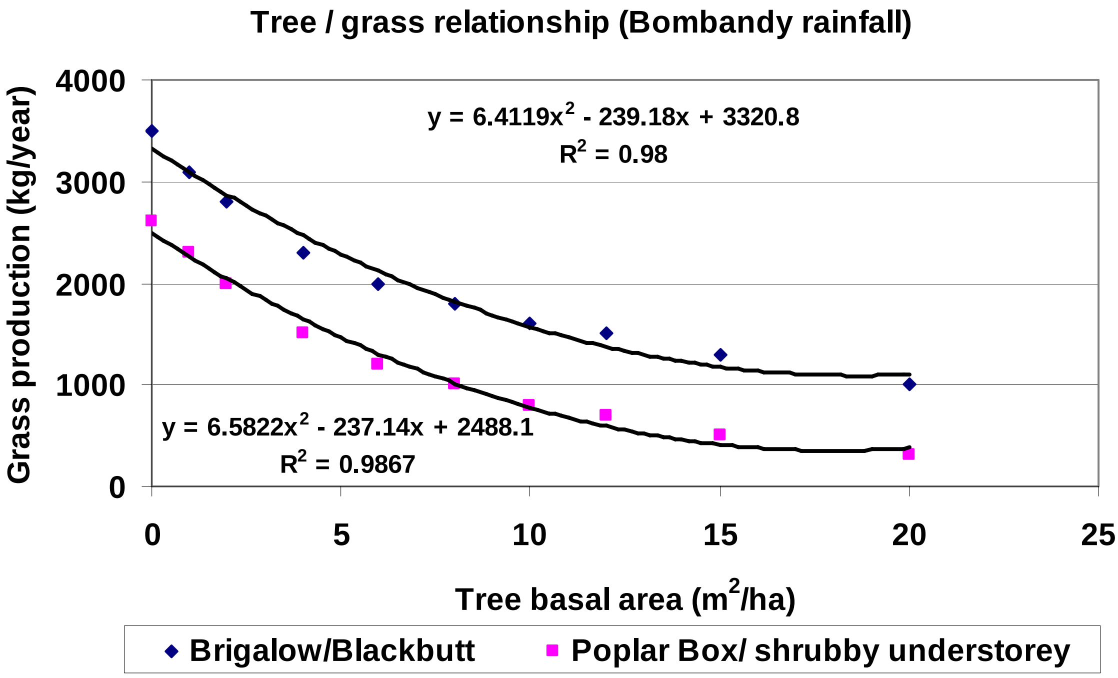


**Table 4 Width, constraint and stimulation factors for different zones where strips of regrowth have been cleared and strips of regrowth retained (see Figure 15).**

| Zone | Width | Relative pasture yield |
|---|---|---|
| Tree | Retain regrowth strip width | Based on tree strip basal area |
| Zone 1 | 1 times tree height | Discounted by 0.8 of cleared strip basal area |
| Zone 2 | 1 times tree height | Discounted by 0.8 of cleared strip basal area |
| Zone 3 | 4 times tree height | Stimulated by 1.15 of cleared strip basal area |
| Zone 4 | Remaining with of cleared strip | Based on cleared strip basal area |

Pasture production was estimated using tree basal area and pasture production relationships derived from GRASP pasture modelling and extracted from the StockTake database (DPI 2004) (Figure 16). The brigalow/blackbutt and poplar box with shrubby understorey land types were modelled in GRASP using climate data drawn from a data drill for Bombandy station (located north of the Middlemount township in central Queensland).

**Figure 16 Relationship between tree basal area and grass production for the brigalow/blackbutt and poplar box with shrubby understorey land type**




For each paddock zone, pasture production per hectare was estimated annually based on the tree basal area in the zone and applying the associated stimulation or discount factor for the zone. Assuming a 25% utilisation rate and 10 kg dry matter per day intake the livestock carrying capacity was calculated. The total number of livestock carried for that year was the sum of the carrying capacity for each zone by the area of that zone in the paddock. This analysis assumed an even utilisation rate and a matching of livestock numbers to forage production so that land condition was maintained or improved. The modelling also assumed no seasonal variation in rainfall and pasture production.

## Tree biomass and timber products

Stand biomass in the tree zone was the sum of above- and below-ground woody biomass. The above-ground stand biomass calculations were based on the tree basal area and the stand allometrics of Burrows *et al.* (2002) for eucalypts and Scanlan (1991) for brigalow. The root biomass was estimated to be 0.4 of above-ground stand biomass (Zerihun *et al.* 2006). The carbon content of the biomass was assumed to be 50%.

Key assumptions used in the calculation of timber products are contained in Table 2.

## Construction of an agroforestry bioeconomic model relevant to central Queensland

QPIF's agroforestry bioeconomic model is a purpose built spreadsheet that incorporates the derived tree regrowth relationships, pasture production and livestock carrying capacity relationships and tree biomass and timber production functions described above. Using this data the model conducts a discounted cash flow analysis and calculates the NPV for each of the 6 agroforestry scenarios analysed. The model integrates the 5 pastoral zones associated with regrowth/plantation strips and takes into account the growth of woody vegetation and its associated impact on grass production and livestock carrying capacity. The model also allows sensitivity testing of a range of input values including regrowth and plantation growth rates, input costs (for example, clearing costs and plantation establishment) and output returns (for example, cattle prices, carbon prices and chip prices).

## Economic analysis

For this study a standard discounted cash flow (DCF) investment analysis was used to evaluate the proposed farming practice changes where capital investment is required. The DCF analysis estimates the net present value (NPV) or lump sum present value equivalent of the incremental net cash flow stream over an investment period (for example, 25 years). It arises directly as a result of estimating the difference in the annual cash flow pattern for the farm, with and without any proposed changes. The net present value is calculated as:

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

Where $n$ = number of periods in the investment

$r$ = the discount rate

$t$ = the time of the cash flow

$C_t$ = cash flow at time $t$

The economic analysis reported here compares the net present value of conventional grazing systems to a range of alternative scenarios described as scenarios 2-6. The analysis takes into account timber clearing costs, changes in pasture production and carrying capacities as a result of changes to tree basal area, herd gross margins, thinning and harvest volumes, forest establishment and maintenance costs, timber/pulp harvest and transport costs and delivered prices of harvested products to estimate the expected cash flows and economic returns from each production system. In each of the silvopastoralism models sequestered carbon sales (net of livestock methane emissions) were included in the analysis for the retained tree strips.

To determine the relative profitability of the conventional grazing system to each of the alternative systems analysed, the NPVs of scenarios 2, 4, 5 and 6 were compared with the returns of the conventional grazing systems (scenarios 1 and 3) based on profit at full equity.

Risk analysis of the base case scenarios of each of the management category levels was undertaken using the Pieman program. Risk analysis methodology captures and describes the possible, but unpredictable, variation that exists in yields and prices due to seasonal conditions and market fluctuations. This is achieved by incorporating the expected range of possible outcomes for each of the variables used in the analysis and applying probabilities of likely occurrence in the form of a cumulative distribution and the probabilities of likely occurrence. Pieman uses random sampling techniques to define the distribution of the required output (farm business profit) in terms of the cumulative distributions and the probability allocated for each variable throughout the model. The result is a distribution curve of farm business profit for each grazing system and the probability of likely outcomes.

## Costs and prices

All forestry costs are based on industry[4] estimated contractor rates for establishment, silviculture, harvesting, transport, and annual management. Therefore, costs do not include direct land owner investments in capital such as machinery for site preparation, harvesting or transport. In each analysis it was assumed that the land was already owned and used for extensive grazing – that is, the sale and purchase of the land was not included in any of the comparative partial budgets. Costs for all forestry systems – establishment, post-establishment treatments, pruning, thinning, harvesting and transport are summarised in Table 2.

Grazing gross margins used in the analysis were drawn from Best (2007) and are presented in Appendix 1. Gross margins per adult equivalent including interest on livestock capital were used in the analysis to reflect annual changes in the value of herd capital as carrying capacities changed.

It was assumed for Scenarios 2 and 4 that any sequestered carbon would be valued at \$10/t $CO^2e$. Only the carbon sequestered in the retained tree strips was sold. Carbon released from the clearing of regrowth in the inter-row zones was not included as a cost in the economic analysis. Instead it was assumed that any regrowth in the inter-row zone would be in a perpetual cycle of being cleared, regrowing and cleared again. Transaction costs associated with the sale of sequestered carbon and the ongoing monitoring and reporting of carbon stocks were not included in the analysis. Sequestration rates were based on changes in estimated annual tree basal area and above and belowground allometrics (Burrows et al. 2002; Scanlan 1991; Zerihun et al. 2006). Livestock methane emissions were estimated to be 1.5t CO2-*e*/yr per adult equivalent (E Charmley 2009, pers.comm., 20th May). Sequestered carbon and livestock emissions were not included in either the plantation pole or pulp models (Scenarios 5 and 6).

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[4] Forestry Plantations Queensland, Integrated Tree Cropping (ITC), Queensland primary Industries and Fisheries and the Central Queensland Forestry Association were consulted during the estimation of costs and returns used in developing the forestry models.

# Results

92 per cent or 14.3 Mha of the Fitzroy Basin was mapped as privately owned land. Figure 17 presents the area classified as private land use in the Fitzroy Basin.

**Figure 17 Private land use in the Fitzroy Basin.**


56 percent of the basin (8.8 Mha) was mapped as non-remnant vegetation (Figure 18).

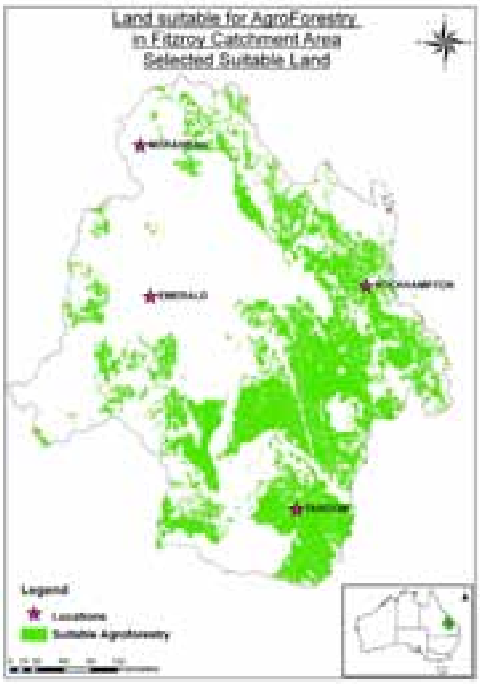
**Figure 18 Non-remnant (historically cleared) vegetation in the Fitzroy Basin.**

A mean annual rainfall layer of equal to or greater than 600 mm in the Fitzroy basin was created (Bureau of Rural Sciences) for the period 1980-99 created on January 2001, raster cell size of $5km^2$(Figure 19).

**Figure 19 Mean annual rainfall equal to or greater than 600mm in the Fitzroy Basin**


The rainfall layer was overlayed with the non-remnant ecosystem layer only on private land and the overlapping zones extracted. This final product represents the total suitable land within the Fitzroy Basin identified as being suitable for agro-forestry purposes (Figure 20). 31% (4.9 Mha) of the Fitzroy Basin was identified as being suitable for agro-forestry purposes.

**Figure 20 Land suitable for agro-forestry within the Fitzroy Basin.**



Of the land identified as suitable for agroforestry purposes, 3.3 Mha were within a 50 km radius of existing timber mills, 4.5 Mha within 100 km, , 4.8 Mha within 150 km and 4.9 Mha within 200km, respectively (Figure 21).

**Figure 21 Area of agroforestry suitable land within a. 50 km and b. 100km of current mills in the Fitzroy Basin.**

**(a)** **(b)**

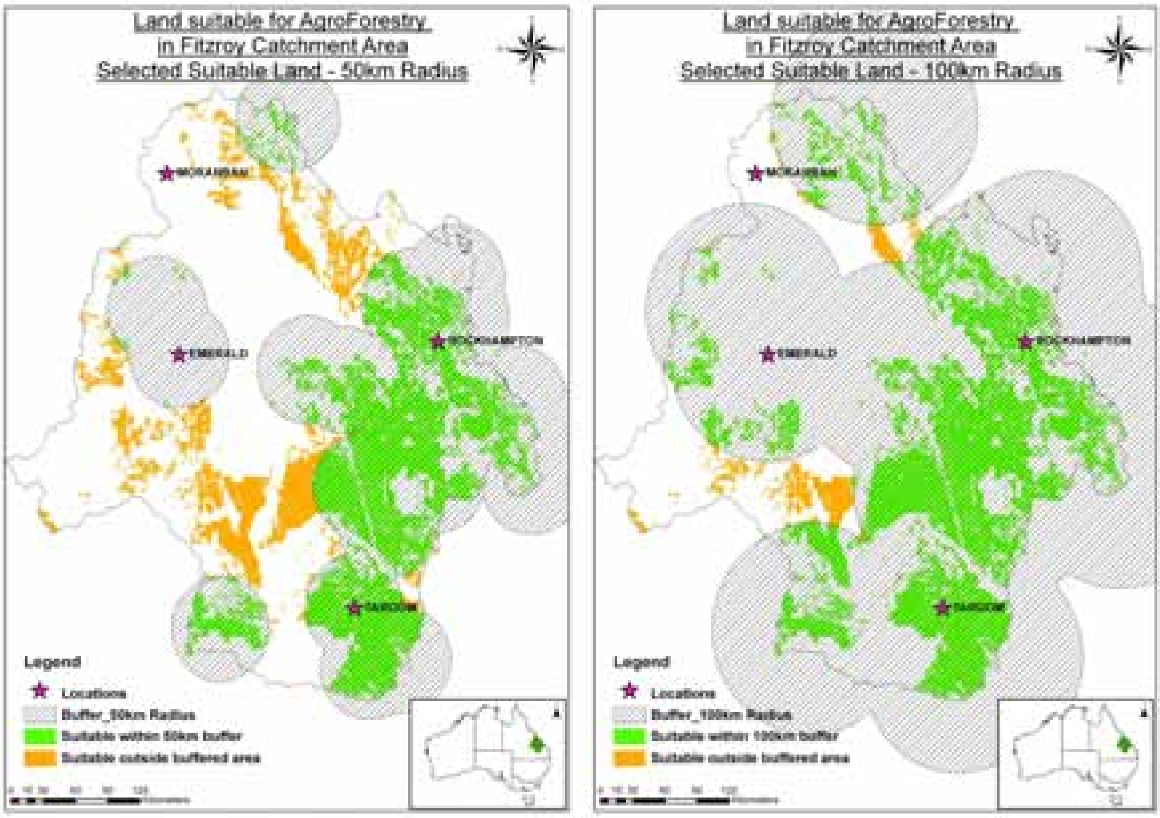



Table 5 provides a summary of the spatial analysis of land suitable for agroforestry in central Queensland.

**Table 5 Summary of area of each data layer in the Fitzroy Basin**

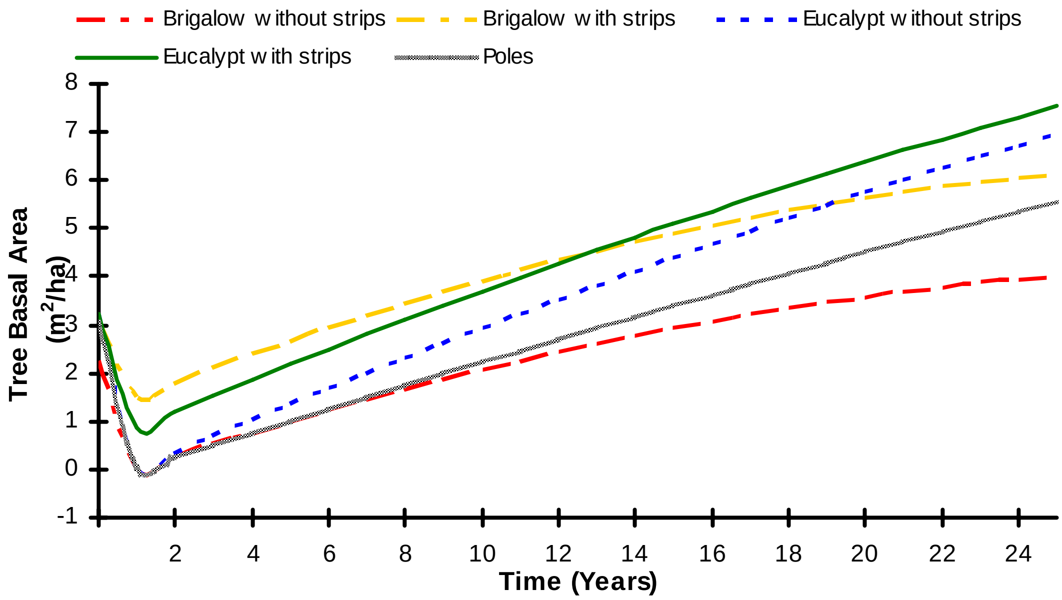
| Data layer | Area (Mha) |
|---|---|
| Fitzroy Basin | 15.6 |
| Private land use | 14.3 |
| Non remnant vegetation | 8.8 |
| Equal to or greater than 600mm rainfall | 9.7 |
| Total area suitable for agroforestry | 4.9 |
| Area within 50km of mill | 7.6 |
| Area within 100km of mill | 13.2 |
| Suitable land within 50km of mill | 3.4 |
| Suitable land within 100km of mill | 4.5 |
| Suitable land within 150km of mill | 4.8 |
| Suitable land within 200km of mill | 4.9 |

Note: areas rounded to 1 decimal

## Tree basal area

Figure 22 presents changes to tree basal area over time for each of the scenarios modelled.

**Figure 22 Modelled tree basal area change**




## Carrying capacity

Figure 23 and Figure 24 illustrate changes in carrying capacity for each of the 6 modelled agroforestry scenarios. After the initial clearing of regrowth in year 1 cattle are excluded from the paddock for six months in the case of scenarios 1 and 3 and up to two years for scenarios 2, 4, 5 and 6. As the stimulatory and competitive impacts of the woody vegetation strips become established, tradeoffs in pasture production reduce the total number of cattle carried over time in each treatment. The only exception to this rule is the timber pulp model where cattle are removed after the first harvest (year 12) and reintroduced in year 15.

**Figure 23 Total adult equivalents over time**

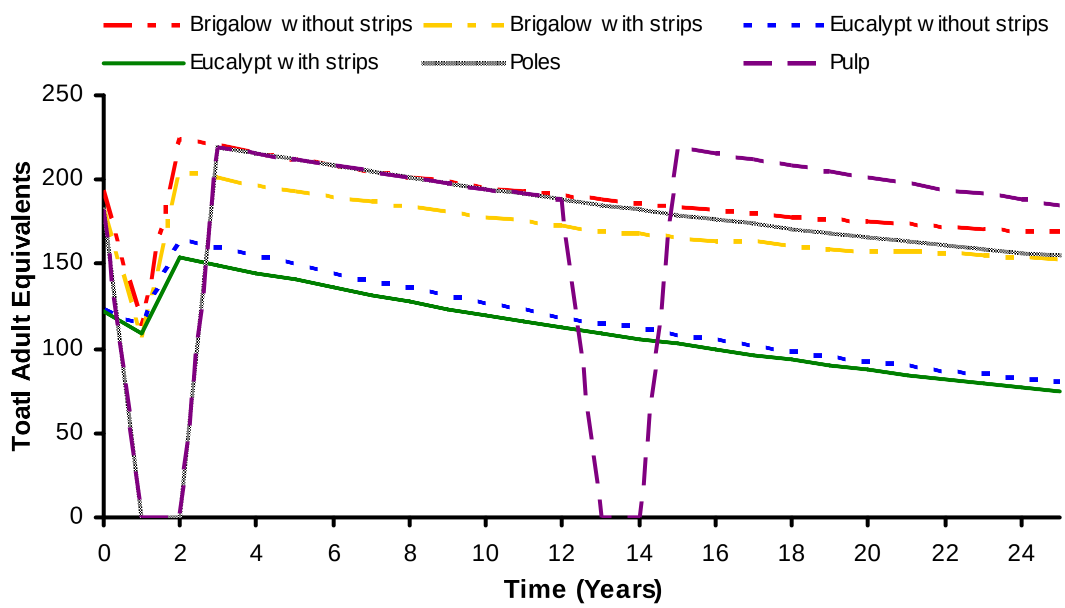
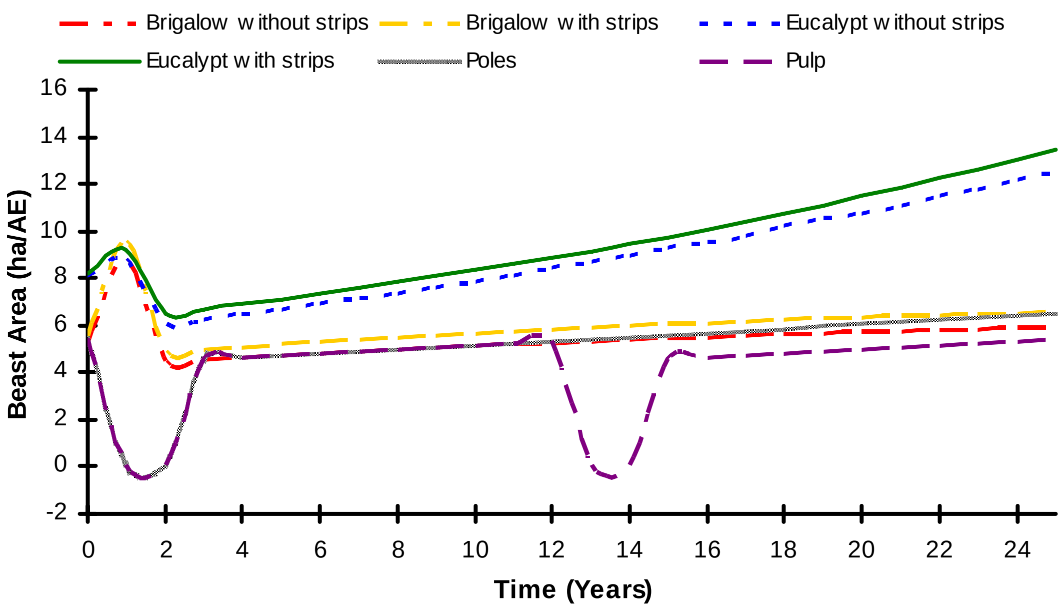



**Figure 24 Beast area equivalents over time**




## Brigalow with and without tree strips

Table 6 presents the NPV of the with- and without-tree strip scenarios for the brigalow and eucalypt land types (scenarios 1, 2, 3 and 4).

**Table 6 NPV of grazing with and without tree strip on 1000 ha for 25 years**

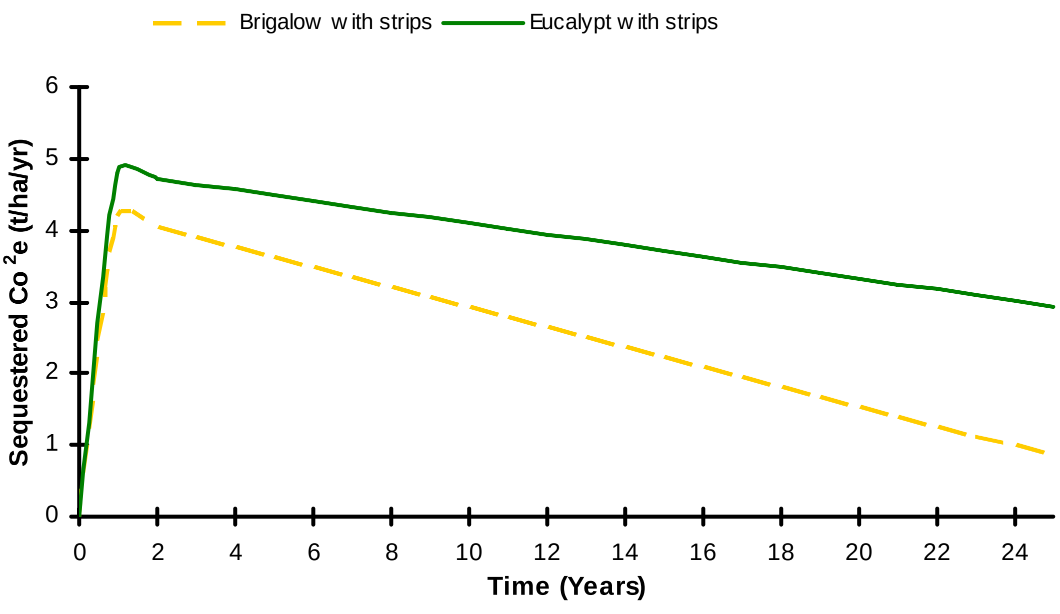
| | NPV of grazing without tree strips | NPV of grazing with tree strips | NPV of change |
|---|---|---|---|
| Brigalow land type | $268,392 | $253,660 | -$14,732 |
| Eucalypt land type | $126,024 | $124,323 | -$1,701 |

The decision to clear regrowth and retain timber strips 20 m wide every 60 m for 20 years would have left the grazier marginally out of pocket (-$1,701) on the eucalypt land (scenario 4) and -$14,732 worse off on brigalow land (scenario 2).

## Sequestered carbon

Avoided deforestation may provide graziers with an additional opportunity to benefit from carbon sales via the CPRS. Scenarios 2 and 4 were reanalysed with the inclusion of a carbon sequestration budget. It was assumed that the grazier would be paid (or would need to pay) for sequestered carbon (or release of carbon in the case of inter-row clearing) resulting from the retained tree strips. Figure 25 provides a summary of the modelled sequestered carbon for scenarios 2 and 4.

**Figure 25 Annual sequestered $C0_2$-e**




The inclusion of net carbon sales alters the economic outcome of retaining regrowth strips. Table 7 presents the NPVs of retaining tree strips with the inclusion of sequestered carbon sales from tree growth. The model was analysed using a carbon price of $10/t $CO_2$-e**.**

**Table 7 NPV of grazing with tree strips including carbon sales**

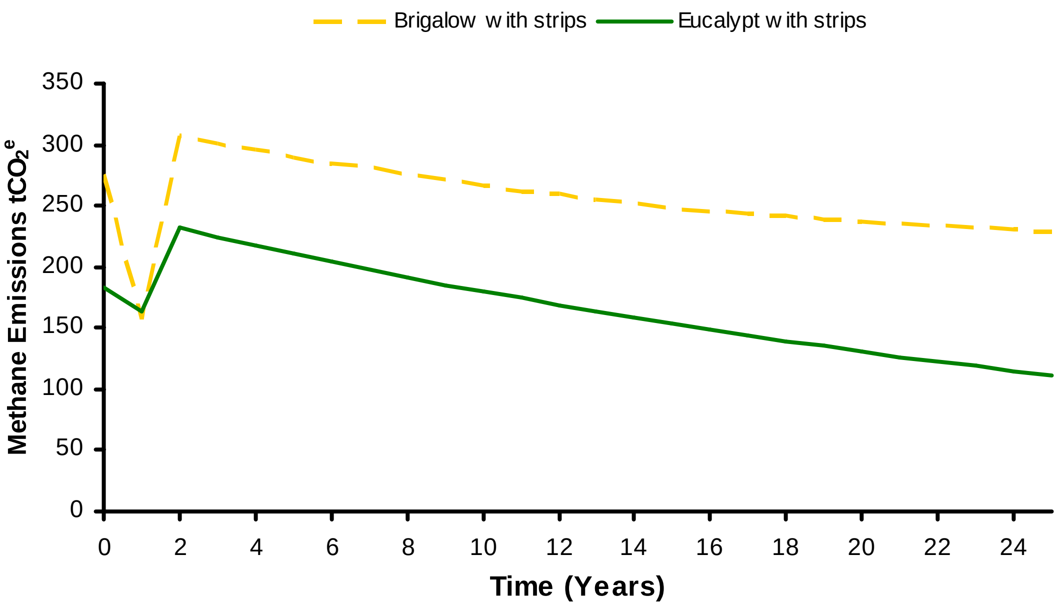
| | NPV of grazing without tree strips | NPV of grazing with tree strips and carbon sales ($10/t $CO_2$-e) | NPV of change |
|---|---|---|---|
| Brigalow land type | $268 392 | $352 499 | $84 107 |
| Eucalypt land type | $126 024 | $263 014 | $136 989 |

The inclusion of carbon sales dramatically alters the economic outcome of retaining regrowth strips. At $10/t $CO_2$e the grazier would be $84,107 better off over 25years retaining tree strips, continuing to graze and selling any sequestered carbon from brigalow land (scenario 2). In the case of eucalypts, higher rates of sequestration (refer to figure 4) and lower opportunity costs from foregone grazing potential translate into higher NPVs. At $10/t $CO_2$-e the grazier is $136,989 better off retaining tree strips. At $30/t $CO_2$-e this benefit grows to $414,370.

## Methane emissions

Methane emissions from livestock represent a significant contribution to Australia's greenhouse gas emissions. For this reason, scenarios 2 & 4 were reanalysed with the inclusion of a carbon sequestration budget net of methane emissions[5]. It was assumed the grazier would be paid (or would need to pay) for sequestered carbon (or release of carbon) resulting from the retained tree strips net of any methane emissions. Figure 26 provides a summary of the modelled methane emissions for scenarios 2 and 4.

**Figure 26 Estimated annual methane emissions**




[5] Livestock methane emissions were estimated to be 1.5 t $CO_2$-e per annum per adult equivalent (Charmley E pers comm. 2009).

The inclusion of carbon sales net of methane emissions in scenarios 2 and 4 alters the economic outcome of retaining regrowth strips. Table 8 presents the NPVs of retaining tree strips with the inclusion of sequestered carbon sales net of any methane emissions. The model was analysed using three prices of $10, 20 and 30per tonne $CO_2$-e.

**Table 8 NPV of retaining tree strip and selling sequestered carbon net of methane emissions**

| | NPV of grazing without tree strips | NPV of grazing with tree strips and carbon sales net of methane | NPV of change ($10/t $CO_2$-e) |
|---|---|---|---|
| Brigalow land type | $268,392 | $317,212 | $48,820 |
| Eucalypt land type | $126,024 | $238,901 | $112,876 |

At $10/t $CO_2$-e the grazier with brigalow land would be $48,820 better off over 20 years if he chose to retain regrowth strips, continued to graze and sold any sequestered carbon net of methane emissions. In the case of eucalypts, higher rates of sequestration per hectare (Figure 25), lower carrying capacities and less methane emissions per hectare (Figure 26) translate into a higher NPV for scenario 4. At $10/t $CO_2$-e the grazier with eucalypt land would be $112,876 better off retaining tree strips and selling sequestered carbon net of methane emissions.

## Brigalow with and without complementary spotted gum strips for electrical transmission poles

Table 9 presents the NPVs of grazing with and without plantation strips for electrical pole or pulp production (scenarios 5 and 6).

**Table 9 NPV of grazing with complementary plantation timber strips**

| | NPV of grazing without tree strips | NPV of grazing with plantation strips | NPV of change |
|---|---|---|---|
| Brigalow land type (electrical poles) | $268,392 | $477,479 | $209,087 |
| Brigalow land type (pulp) | $268,392 | $365,547 | $99,155 |

The decision to clear brigalow regrowth and plant spotted gum strips 50 m wide every 150 m for the purposes of harvesting electrical transmission lines, whilst continuing to graze (scenario 5) would have left the grazier $209,087 better off than clearing all the regrowth and continuing to graze only (scenario 1). If the grazier had instead opted to plant spotted gum for pulp production whilst continuing to graze, the NPV would have been only $99,155.

## Sensitivity analysis

A sensitivity analysis was undertaken to test the sensitivity of the results to changes in a number of the key assumptions underpinning the analysis. The assumptions tested included the percentage of the paddock under strips/trees, grazing gross margins, pasture utilisation rates, the price of carbon dioxide equivalents, the price of electrical transmission poles, sawn timber and pulp and the quantity of timber/pulp harvested from the two plantation models (scenarios 5 and 6).

### *Altering the percentage of paddock under trees*

Altering the percentage of the paddock either planted to trees or retained as regrowth marginally alters the NPV of retaining tree strips and grazing compared to clearing all trees and grazing. As the area of the paddock retained as regrowth strips was increased from 15% to 35% the NPV of the change for brigalow land fell slightly compared to the eucalypt case study where the NPV improved slightly (Table 10).

However, once the sale of sequestered carbon (including or excluding methane emissions) was considered, the effect of altering the area retained as regrowth dramatically changed the NPV of retaining regrowth strips. Increasing the area of retained vegetation within the paddock to 35% whilst selling sequestered carbon at $10/t $CO_2$-e increased the NPV of retaining regrowth strips to $121,195 in the case of brigalow and $192,872 for eucalypt land. By including methane emissions the NPVs are reduced slightly to $87,590 and $169,556 respectively (Table 10).

**Table 10 NPV of retaining a range of regrowth strips with and without carbon sequestration**

| Percentage of paddock retained | NPV of retaining regrowth strips | NPV of retaining regrowth strips and selling sequestered carbon ($10/t $CO_2$-e) | NPV of retaining regrowth strips and selling sequestered carbon net of methane emissions ($10/t $CO_2$-e) |
|---|---|---|---|
| Brigalow | | | |
| 15% | -$12,308 | $46,995 | $10,029 |
| 20% | -$13,558 | $65,513 | $29,390 |
| 25% | -$14,732 | $84,107 | $48,820 |
| 30% | -$15,947 | $102,660 | $68,213 |
| 35% | -$17,179 | $121,195 | $87,590 |
| | | | |
| Eucalypt | | | |
| 15% | -$2,108 | $81,107 | $56,197 |
| 20% | -$1,904 | $109,048 | $84,536 |
| 25% | -$1,701 | $136,989 | $112,876 |
| 30% | -$1,498 | $164,931 | $141,216 |
| 35% | -$1,294 | $192,872 | $169,556 |

Note: Shaded cells indicate the base case scenario.

### *Grazing gross margin sensitivities*

The gross margins per AE reported in Appendix 1 are critical in estimating the economic consequence of transitioning from a conventional grazing system to each of the alternatives presented in this report (scenarios 2, 4, 5 and 6). To test the sensitivity of the results to changes in grazing gross margins, the analysis was repeated using a 10% and 20% increase and decrease in gross margin/AE. The results of this test are presented in Table 11.

**Table 11 Gross margin sensitivities**

| Percentage change in gross margin per AE | NPV of retaining regrowth strips | NPV of retaining regrowth strips and selling sequestered carbon ($10/t $CO_2$-e) | NPV of retaining regrowth strips and selling sequestered carbon net of methane emissions ($10/t $CO_2$-e) |
|---|---:|---:|---:|
| Brigalow | | | |
| -20% | -$5,984 | $92,855 | $57,568 |
| -10% | -$10,358 | $88,481 | $53,194 |
| Base scenario | -$14,732 | $84,107 | $48,820 |
| 10 | -$19,106 | $79,733 | $44,446 |
| 20% | -$23,480 | $75,359 | $40,072 |
| | | | |
| Eucalypt | | | |
| -20% | $960 | $139,650 | $115,537 |
| -10% | -$371 | $138,320 | $114,207 |
| Base scenario | -$1,701 | $136,989 | $112,876 |
| 10% | -$3,031 | $135,659 | $111,546 |
| 20% | -$4,362 | $134,328 | $110,215 |

Note: Shaded cells indicate the base case scenario.

Altering the gross margin/AE had little effect on the NPV of retaining regrowth strips when compared to clearing all the regrowth and continuing to graze.

## Sequestered carbon equivalent sale price sensitivities

To test the sensitivity of the results to changes in carbon prices the analysis was repeated using two additional carbon prices of $20/t $CO_2$-e and $30/t $CO_2$-e (Table 12 NPV of changing to a silvopastoralism system utilising tree strips and carbon sales).

**Table 12 NPV of changing to a silvopastoralism system utilising tree strips and carbon sales**

| | NPV of change ($10/t $CO_2$-e) | NPV of change ($20/t $CO_2$-e) | NPV of change ($30/t $CO_2$-e) |
|---|---|---|---|
| Brigalow land type | $84,107 | $182,946 | $281,785 |
| Eucalypt land type | $136,989 | $275,680 | $414,370 |

At $20/t $CO_2$-e the grazier would be $182,946 better off over 20 years retaining tree strips, continuing to graze and selling any sequestered carbon from brigalow land (scenario 2). At $30/t $CO_2$-e this benefit is increased to $281,785. In the case of eucalypts, higher rates of sequestration (refer to Figure 4) and lower opportunity costs from foregone grazing potential translate into higher NPVs. At $20/t $CO_2$-e the grazier is $275 680 better off retaining tree strips. At $30/t $CO_2$-e this benefit grows to $414,370.

Table 13 presents the NPVs of retaining tree strips with the inclusion of sequestered carbon sales net of methane emissions. The model was again reanalysed using the base price of $10/t $CO_2$-e and two additional carbon prices of $20/t $CO_2$-e and $30/t $CO_2$-e.

**Table 13 NPV of retaining tree strip and selling sequestered carbon net of methane emissions**

| | NPV of change ($10/t $CO_2$-e) | NPV of change ($20/t $CO_2$-e ) | NPV of change ($30/t $CO_2$-e) |
|---|---|---|---|
| Brigalow land type | $48,820 | $112,372 | $175,925 |
| Eucalypt land type | $112,876 | $227,453 | $342,031 |

At $20/t $CO_2$-e the grazier with brigalow land would be $112,372 better off over 20 years if he chose to retain regrowth strips, continued to graze and sold any sequestered carbon net of methane emissions. At $30/t $CO_2$-e this gain would have increased to $175,925. In the case of eucalypts, higher rates of sequestration per hectare (Figure 25), lower carrying capacities and less methane emissions per hectare (Figure 26) translate into a higher NPV for scenario 4. At $20/t $CO_2$-e the grazier with eucalypt land would be $227,453 better off retaining tree strips and at $30/t $CO_2$-e this benefit would have increased to $342,031.

### *Pasture utilisation rate sensitivity*

Each of the scenarios analysed assumed that 25% of new growth would be grazed in any one year. Changing this assumption directly alters carrying capacity and herd gross margins. To test the sensitivity of the results to changes in pasture utilisation rates the analysis was repeated using 15%, 20%, 30% and 35% pasture utilisation rates. The results of this test are presented in Table 14.

**Table 14 Pasture utilisation sensitivity tests**

| Pasture utilisation rates | NPV of retaining regrowth strips | NPV of retaining regrowth strips and selling sequestered carbon ($10/t $CO_2$-e) | NPV of retaining regrowth strips and selling sequestered carbon net of methane emissions ($10/t $CO_2$-e) |
|---|---|---|---|
| Brigalow | | | |
| 15% | $2 669 | $101 508 | $80 314 |
| 20% | -$6 187 | $92 652 | $64 403 |
| 25% | -$14 732 | $84 107 | $48 820 |
| 30% | -$23 670 | $75 169 | $32 863 |
| 35% | -$32 041 | $66 798 | $17 427 |
| Eucalypt | | | |
| 15% | $3 464 | $142 154 | $127 686 |
| 20% | $839 | $139 529 | $120 238 |
| 25% | -$1 701 | $136 989 | $112 876 |
| 30% | -$4 398 | $134 292 | $105 356 |
| 35% | -$6 836 | $131 854 | $98 096 |

Note: Shaded cells indicate the base case scenario.

As the pasture utilisation rate increases, the NPV of retaining regrowth strips decreases reflecting increasing opportunity costs resulting from not clearing all the regrowth and benefiting from increasing carrying capacities. A similar trend is observed when sequestered carbon sales are incorporated into the NPV calculations. As carrying capacities are reduced (as a result of decreasing pasture utilisation rates) the economic benefit of retaining regrowth strips increases.

This result suggests that the economic attractiveness of retaining regrowth strips alters with the capacity of the land to grow pasture and hence carry cattle. A CPRS paying graziers for sequestered carbon obtained via retained regrowth strips may provide the financial incentive needed to reduce stock numbers and allow land condition to be restored on degraded[6] brigalow and eucalypt land types in central Queensland. Additional analysis is required to test this further.

### *Plantation hardwood price sensitivity*

To test the sensitivity of the results to changes in timber prices, the analysis was repeated using a 10% and 20% increase and decrease in sawn timber and pulp prices. The results of this analysis are presented in Table 15.

**Table 15 Timber price sensitivity analysis**

| Changes to timber/pulp prices | NPV of changing to agroforestry model (electrical poles) | NPV of changing to an agroforestry model (pulp) |
|---|---|---|
| Brigalow | | |
| -20% | -$121,188 | -$42, 947 |
| -10% | $43,950 | -$160,896 |
| Base scenario | $209,087 | $99,155 |
| 10% | $374,225 | $359,206 |
| 20% | $539,363 | $619,257 |

Note: Shaded cells indicate the base case scenario.

The data in Table 15 indicates high price sensitivity for both models. A 20% change in the price of timber and pulp alters the economic outcome by 158% and 523% respectively.

### *Plantation hardwood yield sensitivity*

To test the sensitivity of the results to changes in timber yields, the analysis was repeated using a 10% and 20% increase and decrease in timber/pulp yields. The results of this analysis are presented in Table 16.

[6] The Fitzroy Basin Association has identified significant areas of brigalow and eucalypt land types in central Queensland that have been classified as being in “D” or “C” condition using Queensland Primary Industry and Fisheries Stocktake grazing land condition scoring framework.

**Table 16 Timber yield sensitivity analysis**

| Changes to timber/pulp yield | NPV of changing to agroforestry model (electrical poles) | NPV of changing to an agroforestry model (pulp) |
|---|---|---|
| Brigalow | | |
| -20% | -$39,406 | -$256,704 |
| -10% | $84,841 | -$78,774 |
| Base scenario | $209,087 | $99,155 |
| 10% | $333,334 | $277,085 |
| 20% | $457,580 | $455,015 |

Note: Shaded cells indicate the base case scenario.

The data in Table 16 indicates high yield sensitivity for both models. A 20% change in the yield of timber and pulp alters the economic outcome by 119% and 359% respectively.

## Results summary

Table 17 provides a summary of the economic consequences of choosing to retain regrowth strips and continue grazing (with and without carbon sales) or to plant hardwood strips and continue grazing versus clearing all regrowth and continuing to graze the 1 000ha paddock.

**Table 17 Results Summary**

| | NPV of retaining regrowth strips | NPV of retaining regrowth strips and selling sequestered carbon ($10/t $C0_2$-e) | NPV of retaining regrowth strips and selling sequestered carbon net of methane emissions ($10/t $C0_2$-e) | NPV of changing to agroforestry model (electrical poles) | NPV of changing to an agroforestry model (pulp) ($) |
|---|---|---|---|---|---|
| Brigalow land type | -$14,732 | $84,107 | $48,820 | $209,087 | $99,155 |
| Eucalypt land type | -$1,701 | $136,989 | $112,876 | n/a | n/a |

The decision to clear all the timber and plant eucalypt strips for electrical poles (scenario 5) versus conventional grazing (scenario1) yielded the highest NPV ($209,087) for the brigalow land. Clearing and retaining regrowth strips for grazing purposes only (scenario 2) actually left the grazier $14,732 worse off in the case of brigalow and $1,701 worse off in the case of eucalypt lands.

The inclusion of potential carbon sales dramatically alters the economic consequences of retaining regrowth strips. Excluding methane emissions, the grazier would be $84,107 or $136,989 better off in the case of brigalow and eucalypt lands respectively by retaining regrowth strips and selling sequestered carbon. Even when methane emissions were included in the analysis, the decision to retain regrowth strips, continue to graze and sell sequestered carbon net of methane emissions left the grazier $48,820 better off in the case of brigalow and $112,876 better for eucalypt land.

Whilst the timber pulp model (scenario 6) provided a reasonable return to the grazier (NPV of $99,155) the sensitivity of the results to price and yield changes significantly altered the outcomes and provided significant levels of down side risk. In light of this variability it would seem unlikely that a grazier would choose to move from a low risk conventional grazing system to a relatively high risk pulp system given the assumptions used in this analysis.

# Discussion of Results

Silvopastoralism and strategic tree management are likely to become a more important component of whole farm enterprises in central Queensland. Stephens and Stunzner (2008) and Stunzner and Stephens (2008) identified a list of key issues likely to accelerate investment in agroforestry ventures in central Queensland in the future. They include:

- land use history and land degradation as a result of previous tree clearing;
- emerging carbon markets,
- reductions in public native wood availability and rising prices for timber relative to cattle;
- limited alternative use of grazing lands; and
- multifunctional benefits for livestock (e.g. reduced heat stress, better calving)

One critical gap in agroforestry knowledge constraining investment has been a lack of detailed economic assessment of agroforestry systems relevant to central Australia. This report helps fill this gap.

The analysis undertaken in this project suggests incorporating alley belt silvopastoralism systems in central Queensland comes at only a marginal cost to the grazier. Whilst the beneficial effects of retaining timber strips offset some of the forgone production, it is not sufficient to totally offset the estimated reduction in carrying capacity and resulting NPV. However, the inclusion of potential carbon sales dramatically improves the economic benefits accruing to the grazier from incorporating alley strips into existing grazing operations. Even when methane emissions were included in the analysis, the decision to retain regrowth strips on 1000 ha, continue to graze and sell sequestered carbon net of methane emissions left the grazier $48,820 better off in the case of brigalow and $112,876 better off for eucalypt land over 25 years. The results suggest that the inclusion of avoided deforestation as a source of biosequestration under the CPRS has the potential to provide graziers with an additional business enterprise whilst offsetting livestock methane emissions. However if graziers were required to account for the carbon released from clearing timber regrowth in addition to livestock methane emissions the results would alter dramatically. In this analysis it was assumed landholders were not required to offset any carbon released from the clearing of regrowth in the inter-row zones. If this was not the case, and landholders were required to offset carbon released from the clearing of regrowth, the costs are predicted to be so large that most rational graziers would elect to not clear regrowth in the first place.

The most profitable agroforestry system assessed in the analysis was to clear all the timber and plant eucalypt strips for electrical poles. Whilst complimentary grazing from year 3 onwards provides a source of ongoing income, the business would still need to support a substantial capital investment (peaking at $600,000) for 24 years before the crop is harvested and accumulated debts repaid. For many graziers this extended payback period would cause cash flow challenges significant enough to limit industry participation.

Most rangeland grazing research has previously focused on the direct impacts of animal stocking rate and tree basal area (clearing) on pasture biomass and livestock production, with an emphasis on the competitive effects of tree density on pasture growth. Such approaches essentially regard woody vegetation (i.e. trees) as an impediment to grazing profitability, although some work has focused on the ecological implications of the loss of perennial native grass species. The promising results presented here for alley belt systems capture the holistic value of multiple-use grazing systems compared to grazing only systems. For these scenarios, encouraging natural regrowth and/or planted trees is a potentially valuable activity that includes not only the direct commercial benefits available from planted or natural regrowth, but also the combined NRM benefits associated with increased trees in the landscape including soil and water/nutrient function, carbon sequestration and biodiversity habitat.

All modelling undertaken in this project assumed the land was in reasonable (A or B) condition. Assuming the land was in D or C condition the results of the analysis are likely to reflect much closer outcomes. Land in D or C condition will have lower initial carrying capacities, lower opportunity costs in transitioning to alley belts and is more likely to result in a positive NPV from the change. Further analysis is needed to remodel the scenarios presented here for land with a D or C start condition.

A significant constraint to the analysis was the availability of relevant data and statistically significant relationships for regrowth, plantation basal area and tree heights. Given the lack of available regrowth and tree growth data relevant to northern Australia and the relatively weak statistical relationships used to undertake some of this analysis (for example eucalypt regrowth height data) caution should be used in extrapolating these results beyond central Queensland.

The sensitivity testing undertaken suggests the grazing assumptions used in the bioeconomic modelling were sufficiently robust. However, small changes in both timber price and timber yield significantly altered the economic outcomes for both the timber pulp and electrical pole models. Whilst the timber price and yield estimates used in the analysis were obtained through industry consultation, it needs to be recognised that central Queensland hardwood plantations have not reached commercial harvesting for either timber pulp or electrical transmission poles. Any observed differences between expected and realised harvest yields are likely to significantly alter (positively or negatively) the economic outcomes presented in this report for plantation hardwoods.

Whilst the land suitability analysis identified land suitable for agroforestry development in the Fitzroy Basin, it did not include a number of additional constraints that could prevent a portion of the land identified as being suitable for agroforestry development from being developed. These additional overlays include nature conservation, forestry and vegetation reserves, state infrastructure corridors, salinity hazard mapping, key resource areas (mining, petroleum and quarry), mining, petroleum and liquefied natural gas exploration permits and licenses, topography mapping, riparian zones and overland flow (flooding). Further mapping incorporating these additional constraints needs to be undertaken in order to estimate the quantity of unconstrained land suitable for agroforestry within the Fitzroy Basin.

# Implications

This project contributes directly to the goals of the JVAP through a better understanding of the bio-economic potential for agroforestry development in the low rainfall areas of central Queensland (e.g. 500-750 mm/yr). In particular, the project addresses a number of key long term strategies identified in the JVAP R&D Plan for 2004-2009, including:

- on a regional basis assess existing and potential volume and continuity of product supply from agroforestry and farm forestry, including planning and marketing needs; and

- address landholder and investor decision making needs in developing cost-effective multi-purpose agroforestry systems to meet commercial and environmental objectives, including whole-farm economics, farm forestry design options, and decision making tools.

These aspects are particularly relevant in a north Queensland context since there is a perception amongst landowners that trees compete strongly with pasture and livestock production and are considered an economic liability rather than as a potential asset. Preliminary findings from MLA and JVAP jointly funded research suggest that certain designs of retained tree strips may lead to no net loss in total pasture production for a given area (NBP 316). This project builds on this research by evaluating the economics of these tree-grass dynamics on a whole farm enterprise basis. The project accounts for the timber value and woody biomass growth rates not accounted for in NBP316 and subsequent production estimates. The results of this research will help promote greater awareness of the economic value of trees in extensively grazed landscapes in northern Australia and should assist future investment decisions by landowners (for example design options for retained trees, tree yields by species).

This research does provide a "proof of concept" on the economic and environmental merits of silvopastoralism in northern Australia and in particular the potential contribution silvopastoralism may be able to make in meeting Australia's carbon emission reduction targets via the CPRS. The capacity of avoided deforestation (via silvopastoralism grazing systems) to provide a means to offset methane emissions from Australia's extensive grazing industry is very significant. RIRDC research publication No 09/064 (Jiang *et al.*, 2009) predicts a reduction in farm cash income of over 60 per cent for an average beef farm under the proposed CPRS with a carbon price of \$25/t $CO_2$-e and by 125 per cent if the price is \$50/t $CO_2$-e. The research presented in this report suggests these losses would become almost negligible for a central Queensland grazing business that retained tree strips to offset livestock emissions and released carbon from inter row clearing assuming avoided deforestation was recognised as a legitimate form of biosequestration under the CPRS.

The results of the research also suggest there is potential for silvopastoralism grazing systems to be used as a low cost land restoration tool in central Queensland. Replacing traditional grazing systems with a silvopastoralism systems incorporating retained tree strips may provide a low cost land restoration strategy for brigalow and eucalypt lands in D or C condition that has the added benefit of additional biodiversity and water quality outcomes.

# Recommendations

- Given the positive economic viability of selected tree alley options under a range of cost and price scenarios, and the potential to apply these practices across large land areas in central Queensland, more detailed bioeconomic analysis is strongly warranted. This research should focus on key land types, tree species and market outlooks for carbon sequestration and forest products, including electricity poles, sawlogs, pulpwood and other emerging markets such as bioenergy. This should include carbon accounting frameworks that take account of carbon stored in both trees and harvested wood products, given the potential for harvested products to increase the longer term pool of stored carbon and possible future commercial benefits.

- Additional research is also needed into other technical and social contraints to larger scale adoption of silvopastoralism in central Queensland, such as availability of suitable tree stock, knowledge and awareness of silvopastoral systems, capital availability and regulatory requirements under proposed carbon trading schemes such as the CPRS (e.g. third party verification and accreditation of biosequestration, 100 year plus permanence requirements for reforestation projects). This is because the modelling approach assumes there are no regulatory, social or other impediments to the achievement of forecast returns.

- As this project represents an initial “proof of concept” and first step in the adoption process of innovative silvopastoral systems such as alley belts, it is important that this information is disseminated through existing NRM and primary producer networks, as well as through the production of an industry brochure outlining general principles and outcomes from this project.

- A targeted workshop or series of seminars is needed with rural landowners and NRM agencies to encourage and promote the findings of the research and adoption of silvopastoralism in the region. This could also be incorporated with a major conference or event to maximise participation and cross-linkages with other work in central Queensland and other relevant regions.

- CSIRO should maintain its website outlining the project outcomes for at least two years as part of an extension strategy.

# Appendix 1

**Table 18 Eucalypt breeder store steer gross margin.**

| | Value ($) | $/Herd | $/Beast | $/AE |
|---|---|---|---|---|
| Net Cattle Sales | | 171,731 | 190 | 215 |
| Surplus Weaner Heifers | 30,669 | | | |
| Breeders | 36,578 | | | |
| Steer sales | 103,761 | | | |
| Husbandry costs | | 20,856 | 23 | 26 |
| Consisting of: | | | | |
| Surplus weaner costs | 325 | | | |
| Weaner costs | 6,552 | | | |
| Heifer costs | 1,886 | | | |
| Breeder costs | 11,973 | | | |
| Steer/bull costs | 114 | | | |
| Bull replacement | | 12,997 | 14 | 16 |
| Gross margin | | 137,879 | 152 | 172 |
| Gross margin less interest | | 84,265 | 93 | 105 |

**Table 19 Brigalow breeder EU production model**

| | Value ($) | $/Herd | $/Beast | $/A.E. |
|---|---|---|---|---|
| Net Cattle Sales | | 204,168 | 219 | 255 |
| Surplus Weaner Heifers | 31,110 | | | |
| Breeders | 32,566 | | | |
| EU steers | 140,492 | | | |
| Husbandry costs | | 15,260 | 16 | 19 |
| | | | | |
| Consisting of: | | | | |
| Surplus weaner costs | 366 | | | |
| Weaner costs | 4,624 | | | |
| Heifer costs | 1,205 | | | |
| Breeder costs | 7,853 | | | |
| Steer/bull costs | 1,212 | | | |
| Bull replacement | | 8,530 | 9 | 10 |
| | | | | |
| Gross margin | | 180,378 | 194 | 225 |
| | | | | |
| Gross margin less interest | | 124,518 | 134 | 156 |

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# The Bioeconomic Potential for Agroforestry in Northern Cattle Grazing Systems

*— An evaluation of tree alley scenarios in southern and central Queensland —*

RIRDC Publication No. 09/140

There is a growing understanding of the bio-economic interactions driving plantation hardwoods and an increasing demand for hardwood timber products. However there is currently little known about the opportunity to establish complementary agroforestry and pastoral systems (silvopastoralism) in northern Australia.

This report provides detailed information on the key bio-physical factors influencing pasture and woodland growth and forestry outcomes for two widespread woodland communities (land types) in central Queensland. The analysis incorporates tradeoffs between tree and pasture growth, likely forest product yields, carbon sequestration and livestock methane emissions, to construct a bio-economic model of four potential silvopastoralism systems for comparison with conventional grazing systems.

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