GOVERNMENT OF
WESTERN AUSTRALIA

Department of
Agriculture and Food

Carbon Capture Project
Final Report

An evaluation of the opportunity and risks of carbon offset based enterprises in the Kimberley-Pilbara region of Western Australia

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Industry Development - Rangelands,

Department of Agriculture and Food WA

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CARING FOR OUR COUNTRY

Rangelands NRM Western Australia

ChemCentre EXPERT SOLUTIONS

GOVERNMENT OF WESTERN AUSTRALIA

Department of Agriculture and Food

EXECUTIVE SUMMARY

Commercialisation of carbon in the Australian Rangelands could lead to the development of a multi-billion dollar industry, and Western Australia has the potential to capture a significant share of this revenue. A significant proportion of the WA Rangelands is degraded which is the legacy of the exploitative practices of historical pastoral development and the mining industry. Full environmental restoration of these areas is well beyond the fiscal capacity of land managers and the WA State Government. Carbon based enterprises have the potential to restore large tracts of degraded land in a cost-effective manner and can deliver a number of other socio-economic co-benefits to regional WA. The WA Rangelands have the potential to play an important role in mitigating the adverse impacts of climate change primarily through biosequestration and controlled savanna burning programs. There are a number of issues which need to be resolved in order for this potential to be realised. This study makes a contribution to the resolution of some of these issues.

This study was an initiative of the Department of Agriculture and Food WA, Rangelands NRM WA and the ChemCentre and was funded by the *Caring for our Country* Program of the Commonwealth Government. The study involved an in-depth assessment of the greenhouse gas (GHG) biosequestration potential of three case study business in the Kimberley-Pilbara region of WA. The study completed a natural resource inventory of the pastoral leases and financially benchmarked the existing pastoral businesses. A comprehensive carbon accounting survey of the three leases was then conducted in order to establish the baseline levels of carbon. The survey directly measured the main carbon pools (i.e. aboveground woody material, coarse woody debris, herbaceous standing and surface litter and soil carbon) and used allometric relationships to derive estimates of the others. Finally, carbon modelling of different management scenarios based on a range of grazing and savanna burning regimes was conducted for the three businesses in order to examine the potential for biosequestration.

We sought to develop a comprehensive understanding of the resources (financial, physical, environmental and social) currently available to each of the three case study businesses and identify innovative ways in which they could potentially capitalise on the emerging carbon industry in the WA Rangelands.

The principal findings from this study include:

1. GHG emissions produced by the three case study businesses ranged from 0.85 to 1.8 t CO_2-e ha^{-1} yr^{-1} or 25.4 to 54.4 t CO_2-e per cattle unit yr^{-1} (inclusive of emissions from enteric fermentation, diesel and petrol consumption and savanna burning).

2. Methane constituted a relatively minor proportion of the total GHG emissions that were produced by the case study pastoral businesses (< 6% of the total). Emissions from diesel and petrol consumption were the primary source of emissions followed by savanna burning (CH_4 and N_2O gases only included for savanna burning). Consequently, significant reductions in GHG emissions could be achieved if the businesses adopted and/or developed technology and management practices which reduce diesel and petrol consumption (e.g. telemetry, solar power, electric powered vehicles, redesign of paddock configuration and low stress stock handling).

3. The estimated baseline amount of total carbon of the 12 land-systems surveyed in this study ranged from 100 to 373.7 t CO_2-e ha^{-1} (inclusive of carbon stored in the woody vegetation, coarse woody debris, herbaceous standing and surface litter and the soil pools).

4. Carbon held in the coarse woody debris and the soil pools comprised the majority of the carbon that was stored on the lease in the Pilbara (74% of the total). Carbon in the woody vegetation on this lease only comprised 17% of the total. In contrast, carbon in the woody vegetation (inclusive of above and belowground material) comprised more than 60% of the total carbon stored on the two Kimberley pastoral leases.

5. The land-systems with the higher pastoral potentials (i.e. highest net primary production) had significantly more soil carbon ($P<0.001$) compared to the land-systems with low pastoral potentials. However, some land-systems with low pastoral potentials which had a high density of trees and shrubs had some of the highest baseline levels of total carbon.

6. The level of variability of the estimates of the 12 different land-systems was considerable; the relative standard errors (RSE) of the carbon estimates for the land-systems ranged from 3 to 69%. The RSEs at a whole lease scale for the three businesses were all relatively similar and ranged from 28 to 35%.

7. Stocking rate (calculated as the percentage difference of the actual livestock numbers to the potential carrying capacity) had a significant effect on total carbon levels at the survey sites, however we found no distinct trend or pattern and a number of the factors confounded any plausible explanation. Increasing stocking rates did appear to result in a reduction in soil carbon at the sites, however the result was not significant ($P>0.05$).

8. Fire frequency had no significant effect on the total amount of carbon stored at the sites (inclusive of the woody vegetation, coarse woody debris, herbaceous vegetation and soil carbon pools). However, the amount of carbon stored in the woody vegetation was higher at sites which had a moderate fire frequency.

9. Strong relationships (e.g. $R^2 = 0.63$) between ground cover and soil carbon was found for some of the land-systems on the Pilbara pastoral lease. However, the relationship became very weak to almost non-existent for land-systems in the Kimberley region (e.g. $R^2 = 0.11$). We suggest that this is principally related to the greater requirement of semiarid ecosystems to attract and retain water and nutrients and enhance heterogeneity at a local scale.

10. The model results suggest that full destocking and implementing a controlled savanna burning regime on the two Kimberley pastoral leases will biosequester the highest level of carbon compared to any of the other management options (i.e. set-stocking with a 15% or 30% utilisation rate; rest-based grazing). This is primarily because this management regime leads to a substantial increase in the amount of carbon biosequestered in the woody vegetation.

11. The model results suggest that management regimes which involved livestock grazing can biosequester carbon albeit not to the same extent as the full destock scenarios.

12. Based on the modelling output we found that depending on the type of grazing and savanna burning regime that is adopted, at a whole lease scale, the gross income derived from the sale of carbon offsets could range from -\$1.02 to \$27.10 ha^{-1} yr^{-1} (carbon price used was \$10 t CO_2-e). However, much higher returns could be achieved if offset projects were conducted at much smaller spatial scales (< 10,000 ha) and on areas that are highly degraded with very low baseline carbon levels. This is because the variation in carbon levels (degraded *cf* non-degraded areas) can be homogenized at larger scales and therefore the capacity to improve the existing baseline level may diminish accordingly.

13. The financial and economic analyses found that the scenarios which involved fully destocking, controlled savanna burning and/or rest-based grazing systems were more feasible compared to scenarios that involved set-stocking at 15% or 30% utilisation rates. This is primary due to the significant increase in the carbon biosequestered in the woody vegetation and the potential sale of this as an offset at a price of \$10 t CO_2-e. Real cattle prices and the price of carbon had a significant impact on the feasibility of the management scenarios.

14. The financial equity and borrowing capacity of two of the case study businesses in this study may expose them to unmanageable financial risk and this may limit their capacity to implement some of the management scenarios.

15. Managing landscapes principally for carbon offsets could potentially cause adverse distortions to the socio-economic and environmental integrity of the pastoral businesses and the broader Kimberley-Pilbara region. It is important that a balanced assessment is made of the suitability of the management scenarios or a 'hybrid' of the management scenarios. Accordingly, we developed a qualitative framework to assist land managers, service providers and policy makers to evaluate the different enterprise options.

In summary, this study found evidence to suggest that a change in management practices on the case study businesses in the Kimberley-Pilbara region may increase the baseline levels of soil and woody plant carbon. We demonstrated that biosequestering carbon and livestock grazing are not mutually exclusive and we suggest that pastoralists in the Kimberley-Pilbara region may have an opportunity to reduce GHG emissions and improve rangeland condition whilst continuing to produce high quality beef for both the export and domestic markets. However, we recognise that the potential financial returns that may arise from carbon offset based enterprises is at present heavily dependent on the voluntary carbon market and the policy settings of the Commonwealth and State Governments.

We have identified six major issues which are currently impeding the development of the WA Rangelands carbon industry:

1. **Research base –** limited carbon baseline data of most WA rangeland land-systems.

2. **Measurement and verification –** development of robust, transparent and cost-effective methodologies and standards applicable for the various carbon asset classes in the rangelands.

3. **Land tenure –** existing pastoral lease conditions in the WA rangelands and the required approval processes discourage diversification.

4. **Security and liability** – consideration of any ongoing liability for the State Government of potential changes in baseline carbon levels in the rangelands.

5. **Information exchange –** inadequate sharing and dissemination across State agencies, landholders, traditional owners, service providers and investors.

6. **Market uncertainty –** currently the emerging carbon industry is heavily reliant on the voluntary carbon market and the market is susceptible to change due to future State and Federal Government climate change policies.

To address these issues we recommend that the WA State Government in conjunction with other research organisations, commercial partners and non-government organisations (NGOs) undertake the following actions in the short to mid-term:

1. Conduct a desk-top feasibility study to identify areas that would be suitable for plantation based carbon projects (Kyoto Protocol Article 3.3) in the WA Rangelands (with consideration of: tenure arrangements, water supply, agronomic issues, local employment and skills capacity, environment and conservation, indigenous heritage, synergies with other industries).

2. Develop a controlled savanna burning project in the North Kimberley, initially on lands held by the Department of Environment and Conservation (DEC), and then develop similar projects in areas which involve more complex tenure arrangements and cross-jurisdictional borders (i.e. partnerships across Northern Australia). This could be integrated with the current activities undertaken by the North Australian Indigenous Land and Sea Management Alliance (NAILSMA) and the Kimberley Land Council (KLC). Controlled savanna burning projects aim to reduce fire frequency in order to reduce GHG emissions and increase the existing amount of woody vegetation.

3. Develop effective business plans for controlled savanna burning projects which are applicable for the Kimberley Region and mutually satisfy the diverse interests of project participants.

4. Develop the existing partnerships with resource companies which are investigating the opportunities for Biofuel 1st generation and Bioenergy 2nd generation with the view of having a commercial scale project in operation within five years.

5. Identify management practices and technologies that reduce livestock GHG emissions and are applicable to the WA pastoral industry. This may require a targeted project or could be embedded in existing DAFWA rangeland extension projects (e.g. the co-funded Meat and Livestock Australia and DAFWA *Northern Grazing Systems Project*).

6. Provide institutional and technical support for commercial operators who may seek to commercialise the emission reductions from the removal of non-domestic grazers (e.g. emission reductions from the humane culling of feral camels).

7. Undertake further carbon accounting field surveys in order to improve the accuracy of estimates of carbon pools in the WA Rangelands with a specific focus on areas which have the greatest capacity for change in the baseline level of carbon. These surveys should be undertaken in a way which will enhance the utility of remote sensing tools and other simulation modelling currently used for national carbon accounting purposes.

8. Develop carbon project methodologies for reforestation and afforestation asset classes in the most ‘deforested’ areas of the State (e.g. more than 30% of the Gascoyne-Murchison region is degraded and therefore it is likely to have a very low carbon baseline).

9. Develop and implement technologies and practices which improve the efficiency of petrol and diesel consumption on pastoral businesses in the WA Rangelands such as telemetry, solar power, electric powered vehicles, redesign of paddock configuration and low stress stock handling.

10. Clarify the legal requirements necessary to trade carbon that is biosequestered in the native vegetation and the soil on leasehold land in the WA Rangelands. Identify any relevant changes that could be made to the Land Administration Act as a part of the DRDL Land Tenure Review process. Provide technical and policy advice in order to assist the private sector to secure the necessary Carbon Rights over the land area where these projects will occur;

11. Assist the WA Valuer General in determining the appropriate value of carbon credits that may be created under different carbon project methodologies on leasehold land to facilitate the application process for Carbon Rights on WA leasehold land.

The Office of Climate Change (OCC) currently has a coordinating role within the WA Government to ensure all Departments are making a positive contribution to the government’s response to climate change. Therefore, the OCC may be the appropriate WA body to catalyse the necessary resources and partners in order to achieve the proposed actions. However, given the complex nature of the issues associated with the rangelands carbon industry it may be necessary for government to appoint a specialised task force either within the OCC or DRDL in order to progress the issues. Alternatively, there is an opportunity for the DAFWA to take a lead role in the commercialisation of the opportunities by establishing a Rangelands Carbon Program which could be a part of the portfolio of programs within the *Growing the North* Program. There are a number of reviews currently underway within the WA government which are examining alternative tenure arrangements and conditions of pastoral leases in WA. There is an opportunity for the information from this report to assist the relevant committees in determining how rangelands carbon should be managed within the State’s natural estate.

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ABBREVIATIONS

AEU	Australian Emission Units
CP	Cheela Plains pastoral lease
CU	Cattle Unit
DAFWA	Department of Agriculture and Food Western Australia
DCF	Discounted cashflow
DRDL	Department of Regional Development and Lands
EBIT	Earnings Before Interest and Tax
EMU	Ecosystem Management Unit
ERU	Emissions Reduction Unit
ETS	Emissions Trading Scheme
FTE	Full-time equivalent (is equal to 48 weeks labour)
GHG	Greenhouse gas
GIS	Geographical information system
GWP	Greenhouse warming potential
IPCC	Intergovernmental Panel Climate Change
IRR	Internal Rate of Return
KPI	Key performance indicator
LAA	Land Administration Act 1997
LCCA	Land cover change analysis
LSD	Least significant difference
LSU	Large Stock Unit
LULUCF	Land use, land use change and forestry
MB	Mount Barnett pastoral lease
NCOS	National Carbon Offset Standard
NGERS	National Greenhouse and Energy Reporting System
NPV	Net present value
NOAA	National Oceanic and Atmospheric Administration
ORIA	Ord River Irrigation Area
PCC	Potential carrying capacity
PLB	Pastoral Lands Board
RP	Roebuck Plains pastoral lease
RSE	Relative standard error
VCS	Voluntary Carbon Standard
VER	Verified Emission Reduction
WALFA	Western Arnhem Land Fire Abatement Project

CHAPTER I – THE KIMBERLEY-PILBARA REGION OF WESTERN AUSTRALIA

> "It is merely a district with fertile plains which will, I believe and hope, be suitable for pastoral purposes, and, in its more northern portion, in the future for tropical culture; but those who venture in its development will have to incur a large expenditure in getting their stock to the country, and much trouble and difficulty and years of toil under a tropical sun, before they make their fortunes, and they require the easiest terms and conditions". John Forrest, Report on the Kimberley District, 1883.

1.1 The national context

On the 3rd December 2007 the Commonwealth Government ratified the Kyoto Protocol and therefore it is now obligated to meet a national emissions reduction target. This signified a fundamental shift in climate change policy in Australia. Consequently, climate change has become a major item on the policy agenda for all three levels of government in Australia. Climate change has also rapidly gained political currency and has become an important issue in mainstream Australian society. The current Federal Government has committed to introducing policies which can mitigate the impacts of climate change and this may involve an emissions trading scheme (ETS) sometime into the future.

An ETS is likely to provide facility for the trading of carbon offsets. This is based on the fact that Australia has the opportunity to offset a significant proportion of its GHG emissions by storing carbon in the vegetation and the soil and changing the emissions profile of the agricultural sector (CSIRO, 2009). CSIRO conservatively estimates that rehabilitation and reforestation of Australia's overgrazed rangelands and implementation of controlled savanna burning could biosequester and mitigate a total of 113 Mt CO_2-e yr^{-1} (CSIRO, 2009). This is equivalent to approximately 19% of Australia's total GHG emissions (Department of Climate Change, 2009).

Therefore, there is scope for rangelands to make a significant contribution to the fulfilment of an Australian emissions reduction target. However, there are both risks and opportunities in managing rangeland landscapes in order to create carbon offsets for trading purposes. Recently, there have been a number of reports examining the impact of an ETS and the emerging carbon economy on Australian agriculture (CSIRO, 2009; Garnaut, 2008; Keogh, 2007; Bray and Willcocks, 2009; Gowen, 2009; Ford *et al*. 2009; Dean *et al.* 2009). However, to date there has not been any detailed investigations into the specific opportunities and risks associated with generating carbon offsets in the Kimberley-Pilbara region of WA.

1.2 The Western Australian agricultural sector context

The WA State Government has set an official priority "to make decisions that lead to progressive and profitable agriculture and food sectors driving value for the WA economy" (WA Government, 2009). Five key strategies with related tactics are being implemented by the Department of Agriculture and Food WA (DAFWA) in order to achieve this government priority. This project specifically contributed to the implementation of Tactic Three of Strategy Two which is focussed on "emissions mitigation, climate adaptation and leading carbon management options in agriculture" (DAFWA, 2009). The project also makes a contribution to fulfilling the objectives of the DAFWA's '*Climate Change Response Strategy*' (Bennett, 2010).

The genesis of this project arose from the recognition of the opportunity of carbon-based enterprises in the WA rangelands. There was limited data which quantified the magnitude of the opportunity and therefore the DAFWA, Rangelands NRM and the ChemCentre considered it was important that this data was available in order to guide astute business investment in the region and policy decisions at a State and Federal level. The project had a total investment of $692,809 provided by the Commonwealth Government through the *Caring for Our Country* Program and the DAFWA's Rangelands Industry Development Program.

1.3 Project focus

To assist the industry in the development of property-scale strategies that are profitable, sustainable and adaptive to climate change, this study sought to gather detailed data of pastoral businesses in the Kimberley-Pilbara region. Specifically, there were three key questions which this study sought to address:

1. What is the estimated annual net GHG emission profile of a pastoral business in the Kimberley-Pilbara region of WA?

2. Can GHG emissions from a pastoral business be offset by biosequestration through improved grazing management and controlled savanna burning?

3. Is it financially feasible for a pastoral business to trade carbon offsets in the voluntary market?

The findings from this study are presented in six chapters:

Chapter I: provides a profile of the Kimberley-Pilbara region and a brief overview of the fundamental principles of carbon offsets and the climate change policies that presently underpin carbon markets in Australia.

Chapter II: provides an overview of the environmental and financial profiles of the three case study businesses.

Chapter III: details the methodology used to complete the carbon accounting survey on the case study businesses.

Chapter IV: reports the results from the carbon accounting field surveys and evaluates whether grazing or fire management has had an impact on the amount of carbon stored on the case study businesses.

Chapter V: examines the potential scope for grazing management and controlled savanna burning to increase biosequestration in different land-types on the case study businesses. It includes an evaluation of the financial, environmental, social and cultural implications of potential options.

Chapter VI: identifies the potential pathway for the development of the WA Rangelands carbon industry

1.4 A profile of the Kimberley-Pilbara region of Western Australia

To fully evaluate the potential scope for WA pastoralists in the Kimberley-Pilbara region to participate in the nascent voluntary offsets market, it is important to have a comprehensive understanding of the existing socio-economic and environmental profile of the region. The following section provides a brief overview of the region's location, climate, soils and vegetation communities, rangeland condition, land-use and land tenure arrangements. It also provides a history of pastoral development in the region in order to assess the scope for improvement of management practices and carbon storage in the future.

Figure 1: the Kimberley-Pilbara region of Western Australia

1.4.1 Geographic location and size

The Kimberley-Pilbara region extends from Kununurra (15°46'S, 128°44'E) in the northeast to Newman (-23°1'S. 119°14'E) in the south and canvasses seven Shires: Wyndham-East Kimberley, Halls Creek, Derby-West Kimberley, Broome, Roebourne, Ashburton and East Pilbara. The Kimberley-Pilbara region encompasses 919,562 km^2 of land (Figure 1). This area comprises 36% of Western Australia (WA) and is more than three and a half times the size of England.

1.4.2 Climate and seasonal conditions

The Kimberley region has an arid to semi-arid monsoonal climate, characteristically hot and wet in the summer (wet season) and warm and dry in the winter (dry season) (Petheram and Kok, 2003).The dry season (April to October) is relatively mild with daily temperatures ranging between 32°C and 16°C respectively. For the remainder of the year, maximum temperatures can exceed 35°C (Petheram and Kok, 2003). Annual rainfall in the Kimberley ranges from over 1000 mm in the north-west coastal areas to less than 250 mm towards the south (Figure 2). In contrast, the Pilbara is drier and its rainfall is generally more variable.

Rainfall in the Pilbara generally occurs during the summer period, although winter rainfall is not uncommon. Annual mean rainfall in the Pilbara ranges from 266 mm in the south-eastern desert district to 364 mm towards the northern end of the region. A high frequency of rain-bearing cyclones can substantially increase the annual rainfall. Mean summer temperatures in the Pilbara are similar to the Kimberley and typically exceed 30°C, although the humidity is not as high. It is considerably cooler during the winter months in the Pilbara; temperatures can reach as low as -2.2°C, but usually remain in the daily range of 28°C max to 13°C min (Van Vreeswyk *et al*. 2004a).

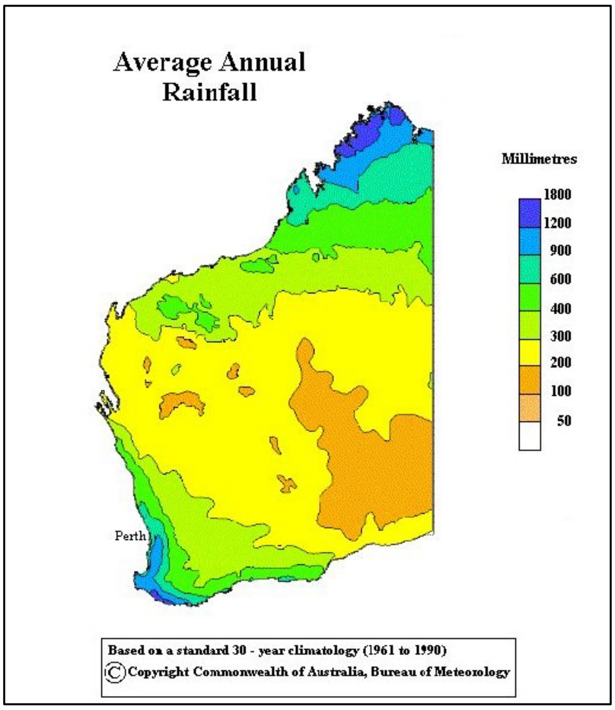


Figure 2: mean annual rainfall of Western Australia

1.4.3 Soils and vegetation communities

The Kimberly-Pilbara region is a highly heterogeneous landscape comprised of land-types ranging from fertile floodplains to stony, skeletal spinifex (*Triodia* spp.) ridges and red sandy deserts. There are 20 broad land-types involving 102 land-systems[1] in the Pilbara region. The Kimberley includes 107 land-systems (Van Vyresswyk, *pers comm*. 2010).

Kimberley landscapes are dominated by open-canopied woodland with a prominent perennial grass layer. This savanna is punctuated by strips of riparian forest, small patches of rainforest and coastal ecosystems such as mangroves. Rivers are usually lined with dense groves of paperbarks (*Melaleuca* spp.) and dispersed pockets of pandanus. There are 30 major rivers in the Kimberley which flow north or west, incising sandstone gorges in their descent to the coast. In draining the inland margins of the region, other rivers have formed extensive alluvial plains to the south and east (DEC, 2009). A large proportion of the Kimberley region is very rugged sandstone country which, although it is well watered and has a relatively high rainfall, it is generally inaccessible and considered unsuitable for commercial pastoral production.

Similarly, more than 50% of the Pilbara region is dominated by spinifex hills and sandplains which is of limited value for pastoral production, and only 10% of the area is the preferred alluvial and river plains with tussock grasses (Van Vreeswyk *et al*. 2004a). The spinifex hills have shallow, skeletal soils and shed large amounts of water and nutrients to the alluvial and river plain areas which are favoured by livestock. The river plains which support groves of *Eucalypt* and *Acacia* trees periodically flood during intense, cyclonic activity, but usually provide limited surface water. The alluvial plains and *Acacia* woodlands can support a wide diversity of palatable saltbush and bluebush shrub (*Atriplex* and *Maireana spp*. respectively) and grass species. The semiarid, erratic climate of the Pilbara means endemic plant species are well adapted to acute moisture and nutrient constraints.

[1] A land-system is an area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation. These recurring patterns can be seen using aerial photography or other remotely sensed images. Land-systems are grouped into land-types according to a combination of landforms, soils, vegetation and drainage patterns (Payne *et al*. 1998).

The geology, soils and vegetation of the Kimberley-Pilbara region have been surveyed by a number of detailed studies, these include: Ashburton River Catchment Survey (Payne *et al*. 1988), Pilbara Survey (Van Vreeswyk *et al*. 2004a), Broome Shire Survey (Cotching, 2005), North Kimberley Survey (Speck *et al.* 1960) and the Ord-Victoria area Survey (Stewart *et al.* 1970) (see Appendix 1 for a WA State map showing the areas which have had the natural resources surveyed). For a concise overview of the soil and vegetation associations in the Kimberley-Pilbara region refer to Petheram and Kok (2003, pp. 5-6) and Van Vreeswyk *et al*. (2004a, p. 17-33) respectively.

The flora of the Pilbara is diverse with over 1100 plant species occurring in the Pilbara (Van Vreeswyk *et al*. 2004a). The Kimberley has over 2000 plant species with 230 endemic to the region (Sinclair, T. *pers comm*. 2010). The most common genera in the Pilbara are *Acacia*, *Aristida*, *Ptilotus*, *Senna* and *Triodia*. In comparison, the common genera in the Kimberley include *Eucalyptus*, *Chrysopogon*, *Sehima*, *Plectrachne* and *Sorghum*. The majority of these species have adaptations to regular frequency of fire.

As one of the few remaining true wilderness areas in the world with such rich flora diversity, there is growing pressure for the conservation of the Kimberley-Pilbara region by a range of stakeholders.

1.4.4 Rangeland condition

Figure 3: Mount Barnett valley

Rangeland condition is a collective term used to describe the relative distribution, density and diversity of perennial vegetation and soil surface condition (Pringle *et al*. 1994). The most recent survey of the Pilbara region assessed the region as 77% good condition, 11% fair condition and 12% poor condition (Van Vreeswyk *et al*. 2004a). However, aggregated values can be somewhat misleading, because a much higher proportion of the land-systems with high pastoral potential (i.e. highly suited to livestock production) are degraded. Accelerated soil erosion is not considered to be widespread in the Pilbara region, but it is a serious problem in localised areas on a few susceptible vegetation and soil types. The rangeland condition of the Kimberley region has been assessed as 80% good condition, 10% fair condition and 10% poor condition (PLB, 2006). The north-west of WA is in much better condition compared to the WA Southern Rangelands (Figure 4). Therefore, there is a strong impetus for government and the land managers of the region to maintain it in its present condition.

The Pilbara landscape has several inherent features that assist in mitigating degradation caused by inappropriate land use practices (Van Vreeswyk *et al*. 2004a). These include widespread stony mantles on pediments, extensive nearly level plains subject to episodic sheet flow with tall shrub strata largely unaffected by grazing and extensive sandy plains with moderately dense spinifex grasslands. The local areas in which the landscape is most susceptible to inappropriate land use practices are floodplains and alluvial plains (Van Vreeswyk *et al*. 2004a). These have been disproportionately grazed and provided they have not been driven past critical biophysical thresholds, they should respond to improved management.

In the Kimberly, recent assessments of a regional network of rangeland monitoring sites[2] found no significant change in perennial grass density between 2004 and 2006. The consistent improvement seen at previous reassessments (1999 and 2002) appears to have stabilised, with no significant change recorded. This suggests that stocking rates are generally being aligned with the seasonal carrying capacity (PLB, 2006). In the Pilbara, there was evidence of a decline between 2003 and 2006. This was particularly observed on Roebourne Plains grass sites and amongst sites assessed in the western part of the region. Seasonal conditions were consistently dry from 2001 (in some cases 2002) to 2005 and this would have played a large part in the observed decrease in perennial grass frequency.

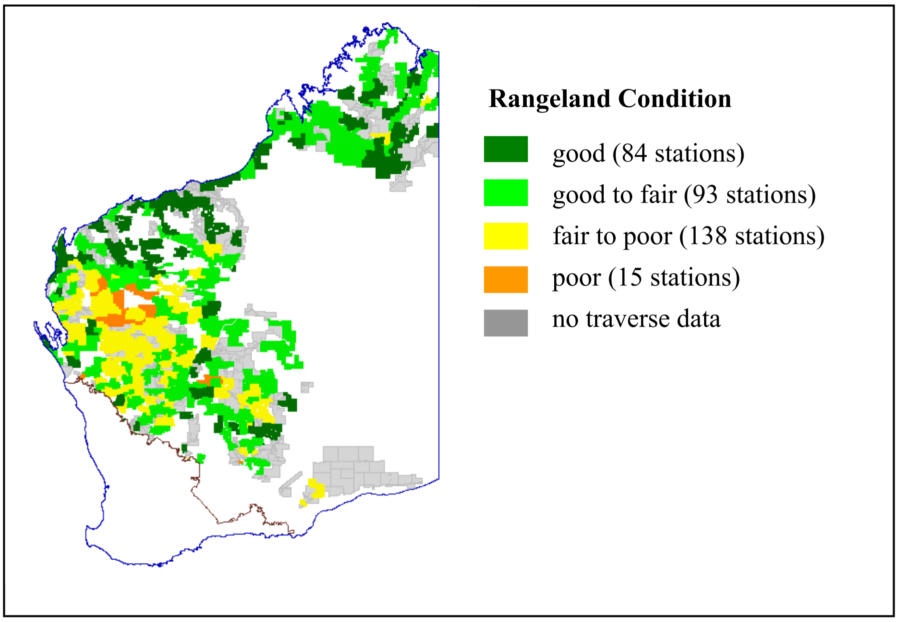


Figure 4: Condition of the WA rangelands as assessed by the Department of Agriculture and Food WA (Van Vreeswyk and Thomas, 2008)
(Note: data is derived from inspection of leases between 1999 and 2006)

1.5 Land-use and drivers of economic wealth

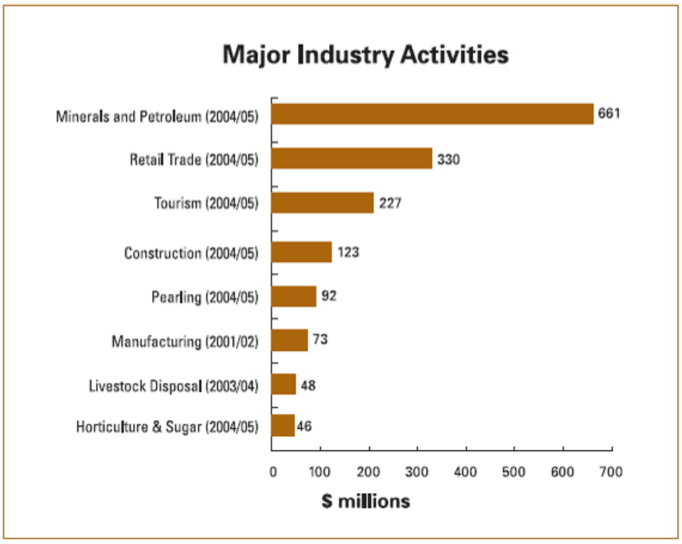
The Kimberley-Pilbara region has a number of inherent socio-economic and environmental assets that are of significant value to multiple groups of stakeholders. The Gross Regional Product (GRP) of the Kimberley in 2006/07 was estimated to be $1.7 billion and $7.6 billion in the Pilbara. This GRP represented 6.6% of WA's Gross State Product which is notable considering the region has only 3.8% of the WA state population. The Kimberley GRP increased by 51% between 2001/02 and 2006/07 and there are forecasts for strong growth in the mid to long-term (Kimberley Development Commission, 2009).

[2] Western Australia Rangeland Monitoring System (WARMS) sites

Specifically the key land-uses of the region include:

- mining for bulk commodities and energy resources;
- tourism;
- pastoralism (primarily export beef cattle);
- conservation;
- Indigenous culture and heritage; and
- irrigated agricultural and horticultural production.

1.5.1 Mining and resource sector



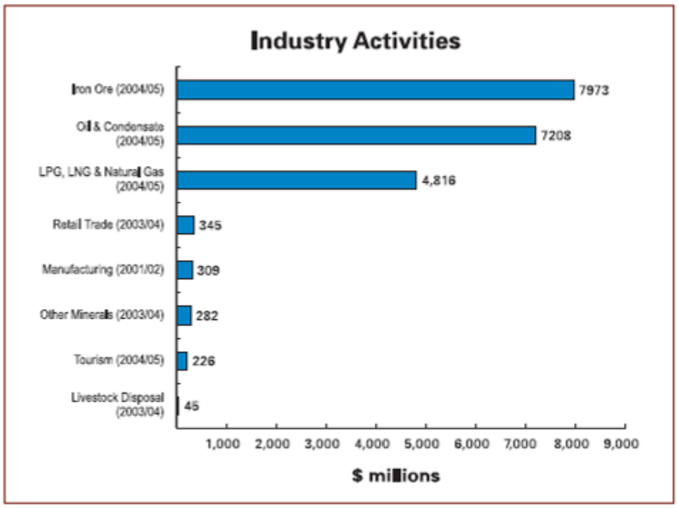


Figure 5: Major industry activities in the Kimberley (top) and Pilbara (bottom) regions
Note: Industry activities are based on the value of production, turnover and expenditure.

(Source: Department of Local Government and Regional Development WA)

The mining and resource sector is the largest single contributor to the GRP in the Kimberley-Pilbara region (Figure 5). In 2006/07 the sector generated $33.5 billion and directly employed more than 10,000 people. The Pilbara's economy is dominated by the mineral and petroleum industries and in 2006/07 the region contributed over 60% of the value of WA's mineral and petroleum production.

Mining in the Pilbara is largely confined to ironstone ranges and greenstone belts as these are rich in iron ore deposits. Other minerals extracted from the Pilbara region include salt, silver, gold, manganese and base metals.

In comparison, the Kimberley region only contributed 1.9% of the value of WA mining in 2006/07 (GRP: $990 million). However, a number of planned major resource projects, including the Browse Basin and Gorgon liquefied natural gas (LNG) hubs, will significantly enhance the existing GRP of mining in the Kimberley. Presently, diamonds are the predominate mineral produced in the Kimberley, followed by nickel, iron ore, crude oil and rock.

1.5.2 Tourism

Figure 6: Lake Argyle, East Kimberley

The rugged beauty of the landscape and favourable seasonal conditions during the dry winter months supports a buoyant tourism sector in the Kimberley-Pilbara region. Major population centres and natural attractions such as the Buccaneer Archipelago, Cable Beach, Cape Leveque, Geikie Gorge National Park, Lake Argyle, Manning Gorge, Mitchell Falls, Purnululu (Bungle Bungles) National Park, Windjana Gorge National Park and Wolfe Creek meteor crater, continue to provide a wide range of tourism options in the Kimberley (Tourism Council, 2010). In the Pilbara, tourism is much smaller but remains a valuable contributor to the Pilbara's economy. The growing appeal of cultural tourism and ecotourism augurs well for the future of the tourism industry in the region.

The Pilbara also has a variety of attractions from the gorges and waterfalls of the Karijini National Park to the sweeping scenery of Millstream-Chichester National Park and fishing and boating pursuits around the Dampier Archipelago. The GRP of tourism in the Kimberley in 2006/07 was $257 million compared to $167 million in the Pilbara. This revenue was generated by holiday activities of over 220,800 international and domestic visitors (DLGRD, 2009)

1.5.3 Pastoralism

The Kimberley-Pilbara region is the most productive area of the WA rangelands. The large scale of pastoral operations coupled with a low cost of production provides profitable business opportunities. There are 100 pastoral leases in the Kimberley and 135 in the Pilbara (PLB, 2006). Pastoral leases range in size from 50,000 to over 500,000 hectares. The value of cattle disposals from the Kimberley and Pilbara in 2006/07 were $76.4 million and $50.5 million respectively (or 11% of the WA state total). In 2005/06 the Kimberley herd was estimated to be 600,000, representing around 30% of the total State herd. In comparison, the Pilbara herd was much smaller with an estimated 245,000 head in 2005/06. Most cattle turnoff from the Kimberley is exported live to Indonesia, Malaysia and the Middle East. In 2003/04, approximately 128,000 Kimberley cattle were exported live from the region. A further 36,000 were sold as store cattle (transferred from one station to another) and 10,000 to abattoirs. The live cattle trade is expected to increase into the future following the signing of recent agreements with Eritrea, Saudi Arabia and Jordan (DLGRD, 2009). The majority of cattle from the Pilbara are exported, although a proportion of the cattle are sold as stores into the domestic market in the southwest agricultural region of WA.

1.5.4 Conservation

The unique landscape of the Kimberley-Pilbara region attracts significant public and private investment for conservation purposes. The Kimberley is recognised as one of Australia's 15 National Biodiversity Hotspots and its marine environment is internationally renowned as one of the world's most pristine and ecologically diverse. Similarly, the Pilbara region has a high conservation value and has been the focus of growing interest as mining development continues to expand across the region. Overgrazing for extended periods combined with intense fire regimes has caused damage to habitat and this has resulted in a number of extinctions among medium-sized mammals and reduced the densities of granivorous small mammal and bird populations (Gill *et al*. 1998; DEC, 2009).

Increased development due to mining and tourism combined with exotic pests and diseases have also had an impact on habitat and the natural integrity of the ecosystem. Public and private conservation bodies have principally responded to this degradation by acquiring land and managing it for conservation purposes. In addition, government has sought to impose more stringent environmental guidelines and endeavoured to broker partnerships with the incumbent land manager/owner to protect the ecosystem. Vast tracts of the Kimberley are currently being assessed in order to be considered for National Heritage Listing (Australian Heritage Council, 2010). Key environmental assets in the Kimberley include the Prince Regent Nature Reserve, areas in the vicinity of the Mitchell Plateau, marine areas such as Camden Sound, Lacepede Islands, Montgomery Reef/Islands, Walcott Inlet/Secure Bay and elements of Roebuck Bay.

1.5.5 Indigenous culture and heritage

Many Kimberley and Pilbara Indigenous people have an unbroken history of managing their traditional lands. There are over 8,500 cultural heritage sites listed within the Kimberley-Pilbara region[3] which highlights its high level of cultural significance. Presently, there are over 150 remote indigenous communities in the Kimberley-Pilbara and they are in various states of self-governance, economic self-sufficiency and quality of life. A much higher proportion of the resident population in the Kimberley is indigenous (50%) compared to the Pilbara (18.4%). In 2006/07 there were 17,957 indigenous people (inclusive of Torres Strait Islanders) in the Kimberley-Pilbara which is the highest proportion of any other region in WA (Figure 7).

[3] Information sourced from the Department of Indigenous and Affairs website (www.dia.wa.gov.au).

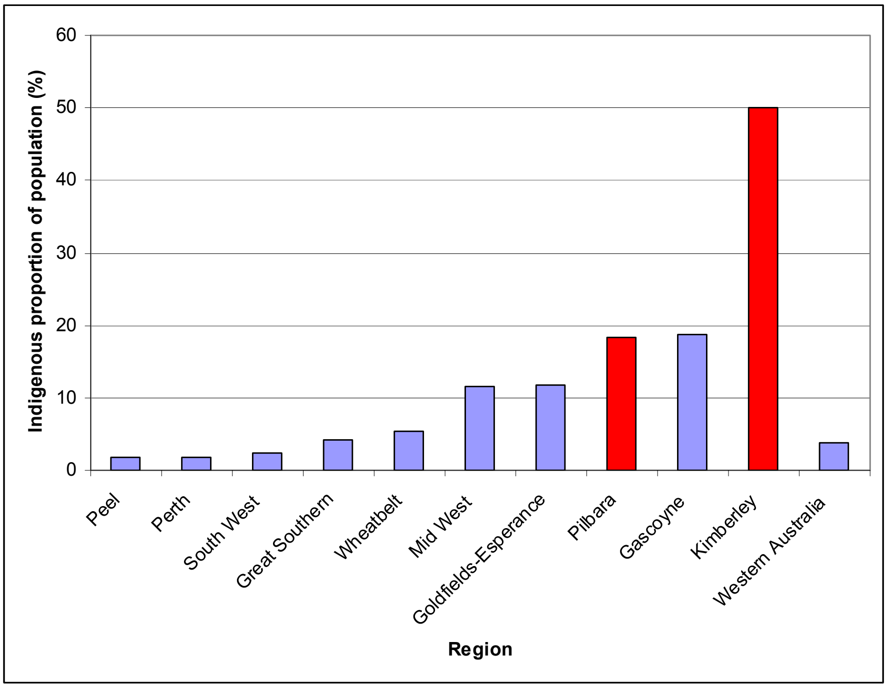


Figure 7: Indigenous population distribution in the regions of Western Australia (Source: Department of Local Government and Regional Development)

One of the major challenges that indigenous communities in the region face is the growing exodus of the young people from their traditional lands due to the limited employment options and the attraction of modern living and entertainment in large centres. This trend is familiar to remote and regional communities throughout Australia, however the impact is deemed to be of a higher consequence for indigenous people because it can lead to an irretrievable breakdown of traditional culture. The increasing expectation by society for indigenous communities to no longer be welfare-dependent and assimilate into the mainstream economy places even greater pressure on the community particularly when there are presently limited enterprise options. In this context, the opportunity for communities to become suppliers of carbon offsets for commercial trade has considerable merit and has been investigated (Heckbert *et al*. 2008).

1.5.6 Intensive agricultural and horticultural production

Irrigated agricultural and horticultural production in the Kimberly-Pilbara is dominated by the region's largest irrigated agricultural project, the Ord River Irrigation Area (ORIA), located near Kununurra. The ORIA includes approximately 14,000 hectares of developed land and has access to considerable water resources from Lake Argyle on the Ord River. The ORIA has seen a major shift away from crops of chickpeas, sorghum seed, melons, pumpkins, mangoes, bananas, citrus and irrigated pastures to a significant expansion of sandalwood plantations. In 2008/09 the Indian sandalwood plantations comprise approximately 30% of the developed land of the ORIA. In 2007/08 the total value of irrigated agriculture from the ORIA was $95.9 million (DAFWA, 2009).

The Ord East Kimberley Development Project which involves a total investment of $415 million between 2009 and 2012 will expand the existing developed land in the ORIA to 28,000 ha and is expected to significantly increase the value of production from the area (Landcorp, 2009). There is a relatively small horticulture industry operating near Broome and Derby in the West Kimberley currently producing mangoes, melons, bananas and irrigated pasture seeds. The economic value of irrigated agriculture in the Kimberley exceeds that of the region's cattle industry.

In contrast to the Kimberley, the Pilbara only has a number of very small agricultural and horticultural precincts. In 2004/05 the value of crop production was only $400,000. However, there is growing interest from resource companies in the region who own pastoral leases to explore the scope for irrigated agriculture using water sourced from mine pits, underground mining activities and waste water from worker's villages (Pracilio, 2009). The focus of this would be on establishing biofuel plantations that could supplement the fuel consumption of mining operations and potentially act as a source of carbon offsets. There is also investigation of the opportunity to produce irrigated hay and grains for a feedlot that could be vertically integrated into a small-scale abattoir that could provide locally grown meat for the mining camps, communities and regional centres.

Figure 8: Forage sorghum at Kilto Station, West Kimberley

1.6 Land tenure and Carbon Rights in WA

The Land Administration Act (LAA) 1997 is the primary piece of legislation which outlines the policy and guidelines related to pastoral leases throughout WA. Part 7 of the Act details the terms and conditions related to the possession of a pastoral lease, including reference to diversification, development and infrastructure improvements, stocking rates, soil conservation, land clearing and the introduction of non-indigenous plant species (WA Government, 2010). The Pastoral Lands Board[4] also expects pastoralists to abide by 'Best Practice Management Guidelines' prepared by the DAFWA. The LAA stipulates that a pastoral lessee requires a permit if they wish to diversify their business from a livestock production based enterprise.

Another piece of important legislation which relates specifically to the ownership and trade of carbon offsets on pastoral leasehold land in WA is the Carbon Rights Act (CRA) 2003. The CRA establishes a statutory basis for the ownership and protection of carbon rights in order to facilitate trading (Eckert and McKellar, 2008). It enables a carbon right to be registered on the land title as a separate interest in the land. The CRA also provides the basis for the owner of the carbon right (if they are different to the lessee) to enter into an agreement (or covenant) in order to protect the carbon in the land over which the carbon right is registered. As a carbon right is a separate interest in land it can be dealt with in ways similar to other interests in land

[4] The Pastoral Lands Board is a statutory authority established under section 94 of the LAA 1997, charged with administering WA pastoral leases in accordance with Part 7 of this Act.

(Landgate, 2010). It can be transferred, surrendered, extended or mortgaged. It can also be given away by will. However it cannot be varied once registered. No stamp duty is payable on the creation of a carbon right, but any subsequent transfers or other dealing will be subject to stamp duty in the normal way (Landgate, 2010).

To date there have been no carbon rights administered on any pastoral leasehold land in WA (Eckert, *pers comm*. 2010). Therefore, the rights to the carbon currently remain with the WA State Government. This has important implications for pastoral businesses who may seek to create and trade carbon offsets on their pastoral leases.

No precedent has been set and securing the rights may be a challenge. However, the Department of Regional Development and Lands (DRDL), which is the State agency responsible for administering the rights, has indicated that it is willing to support applications which demonstrate clear benefits for the environment, the economy and indigenous heritage.

The lack of forthcoming applications for the carbon rights on pastoral leasehold land largely results from a limited understanding of the carbon offset opportunities by pastoralists, uncertainty regarding future climate change policy and the generalised estimations of present and potential volumes of carbon offsets. Of importance, is the fact that the creation of a carbon right is a future act under the Native Title Act 1993 and hence may require the appropriate "future act process" to be satisfied before it could be completed (Eckert, *pers comm*. 2010). This may require an Indigenous Land Use Agreement between the lessee or other applicant and the traditional owners of the region so that native title is not extinguished. This may require the lessee or applicant to provide some form of compensation or profit-sharing arrangement in the carbon-based enterprise with the Traditional Owners.

1.7 A brief early history of pastoralism in the Kimberley-Pilbara region

The foundation of the Kimberley cattle industry began in 1885 when pastoralists settled in a region of "reliable rainfall" and a "sea of grass" as described by Alexander Forrest (Bolton, 1953). The first pastoral lease in the Pilbara had been taken up 20 years earlier by Walter Padbury. There were many significant early challenges that faced the pioneering pastoralists in both regions including distance from markets, market fluctuations, no permanent infrastructure, shortages of capable labour, livestock pests and diseases, flood damage and the slaughter of livestock by settlers and Indigenous people. However, the determination of the pastoralists and their families combined with the favourable seasonal conditions and the resilience of the landscape enabled livestock numbers to increase, resulting in many fortunes to be made by pastoralists. Some local groups of Indigenous people also provided significant local knowledge and assisted pioneering pastoralists.

In the Kimberley, despite significant spikes in activity associated with gold mining, the pastoral industry was the mainstay of the regional economy until the early 1980s when major resource projects like the Argyle Diamond Mine and development of the Ord River Irrigation Area went into full-scale production. Likewise the Pilbara pastoral industry supported the economic growth of the Pilbara until mining activity accelerated and eventually dwarfed the value of pastoral production in the mid-1970s.

The development of the emerging WA colony was the primary focus of the government at the time and therefore there was a strong emphasis on increasing stocking rates on the pastoral leasehold land throughout the Kimberley-Pilbara region. Stocking clauses in the Pilbara stipulated that twenty sheep or two head of large stock had to be introduced onto every 1000 acres held. At one stage there was a penalty of double the rent or total forfeiture of a lease for non-compliance. The impetus for development of the pastoral industry is demonstrated by the stocking rates on Ord River Station; between 1885 and 1902 the herd on the lease increased in size from 4000 to 47,000 (a compounding increase of 15.6% over the 17 year period). With increasing livestock came economic prosperity. Upper Liveringa pastoral lease was an example of such prosperity; in 1903 it employed a total of 100 people (European and Indigenous) and had 103,200 sheep and 5,600 cattle across 1 million acres.

Permanent infrastructure such as homesteads and paddocks were not developed in the Kimberley until the late 1880s when it became clear that there was a strong future for the industry. The West Kimberley was generally settled by sheep graziers from southwest WA and therefore they had tendency to construct paddocks. In contrast, in the East Kimberley pastoralists were usually from Queensland and Victoria who were more accustomed with open range grazing.

Figure 9: Development of permanent watering points extended the grazing area in the Kimberley

In the early 1890s there was a major fall in the price of wool. The banks responded to the market crash by calling in old cash advances, and declining to make new loans. In addition, the financial institutions were not prepared to release the owners from their obligations (Bolton, 1953). Consequently, station properties, at that time were regarded as almost unsaleable. This dire situation improved in the early 1900s when the population of WA increased from 49,782 in 1891 to 184,124 in 1901 due to gold rush in the Goldfields. This resulted in a significant upswing in demand for red meat and the government had trade-related legislation in place which ensured that WA meat would be the chief source of supply. The industry continued on its positive trajectory throughout the early 1900s as average to above-average seasonal conditions continued and the marketing of livestock from the region became more sophisticated.

In the Pilbara, optimism prevailed concerning the prospects of the industry and at that time there did not appear to be sound recognition of an upper limit of the carrying capacity and the consequences of exceeding it for an extended period, particularly during below-average seasons.

By 1905 the Kimberley was Australia's major beef-producing area outside of Queensland with a total herd of 380,994 head of cattle. Improvement in living conditions encouraged more absentee owners to permanently relocate to the Kimberley region. The momentum of the industry in the East Kimberley was momentarily dulled with the inadvertent introduction of the *Ixodes bovis* parasite (cattle tick). Fear of ticks by cattle producers from around WA closed the transport of cattle from the East Kimberley and this encouraged exporters to explore markets into Southeast Asia. This malady of events proved to be beneficial as the export of cattle from the Kimberley became vital for its long-term viability.

The Kimberley pastoral industry was of significant importance to the WA economy, however during the 1910s the interest of the State Government was centred on the development of agriculture in the South-West. This shift in political focus occurred at a difficult time as the insidious symptoms of landscape degradation were beginning to become readily apparent throughout the region. Up until 1905, Kimberley pastoralists were not generally concerned about the cumulative effect of overgrazing of alluvial floodplains, riparian zones and other sensitive areas of the landscape.

The extended below-average rainfall beginning in 1905 brought a sudden realisation to the industry that the productive capacity of the Kimberley was not unlimited. The manager of Liveringa Station at the time recognised that the "frontage country gradually became eaten out with continued heavy stocking" and considered that "thousands of kangaroos assisted in the deterioration" (Bolton, 1953, p. 168). The Pilbara pastoral industry also endured the early 1900s dry period and also had a major setback as a result of the 1930s dry period. These dry conditions coincided with the peak in livestock numbers, which resulted in major stock losses (Figure 10). The direct financial impact of this was compounded by the 1929 Great Depression which resulted in a major dumping of agricultural commodities and a commensurate collapse in market prices.

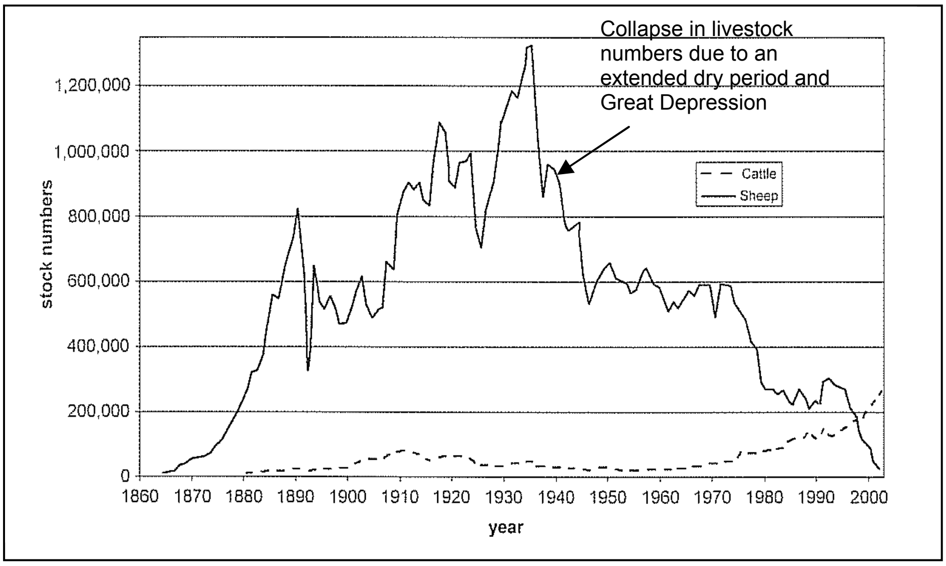


Figure 10: Sheep and cattle numbers in the Pilbara from 1864 to 2002 (Van Vreeswyk, 2004a)

Since the 1930s the Kimberley-Pilbara region has undergone the regular cycle of fluctuating seasons and commodity prices. Rising input costs and the substantial increase in the standard of living in Australia in the more recent decades has reduced pastoral business profit margins and made it difficult to source adequately trained staff. Today, a large proportion of leases are owned by private and public companies. Indigenous corporations and communities own one third of the pastoral leases in the Kimberley; these leases have a wide range in livestock production capacities.

1.8 Contemporary Kimberley-Pilbara pastoral management

The two distinct seasons, 'the wet' (November to March) and 'the dry' (April to October), largely dictate the husbandry operations on the Kimberley pastoral leases (Petheram and Kok, 2003). There is limited access to paddocks during the wet season, consequently cattle are mustered and handled during the dry season. Despite rapid advancements and uptake in cattle husbandry practices and technologies by pastoralists in other areas throughout Australia, the majority of pastoralists in the Kimberley are yet to integrate these into their businesses. For example weaning, herd segregation, controlled breeding, supplementation and pasture management occur only on a limited number of pastoral leases. Instead, management generally entails one full muster each year where cattle are accumulated, branded, tagged, dehorned, administered with animal health treatments and speyed and then any saleable animals are drafted off for transportation for either the export or domestic markets. Similarly, cattle operations in the Pilbara remain relatively low input with minimal management activities beyond basic husbandry requirements.

Figure 11: Roebuck Plains Station

Shorthorn cattle were the primary breed of cattle introduced in the 1880s. However, since the Brucellosis-Tuberculosis Eradication Campaign (BTEC), which was a major effort to completely eradicate the viruses from the Australian herd between 1970 and 1990, there has been a gradual infusion of Bos Indicus genetics. Herd sizes on individual leases fluctuate due to seasonal conditions and market opportunities, but across the region livestock numbers have generally decreased since their peak in the 1916/17.

Some leases have managed to increase their herd sizes with improved pastures (viz *Stylosanthes* spp., *Cenchrus ciliaris, C. setiger*), grazing management and controlled savanna burning strategies, however they are presently the exception rather than the rule in the Kimberley. In most recent decades, pastoral businesses in the Kimberley-Pilbara region are managing a higher proportion of breeders and are turning off cattle at a younger age which has enabled them to maintain profitability.

Further unrealised potential to grow beef production in the Kimberley-Pilbara region has been discussed and anticipated for some years (Niethe and Quirk, 2008). However, a comparison of property cattle numbers reported to the PLB with the carrying capacity estimates from the DAFWA suggests that, at best, the Kimberley is already stocked at its potential carrying capacity while the Pilbara may already be stocked beyond its capacity. The only exception for both regions was indigenous properties where there appears to be potential to increase overall cattle numbers by up to 100% and 35% in the Kimberley and Pilbara respectively (Niethe and Quirk, 2008).

The short to mid-term future of the Kimberley-Pilbara cattle industry is largely underpinned by the Southeast Asian live export market. Presently, direct sale to live export is generally the most profitable market for cattle. The region's processing works are closed, and it is unlikely that they would be reinstated unless they were heavily subsidised by the government or a major upswing in market demand and prices. The Pilbara is better placed than the Kimberley to service both live export, through northern and southern WA ports, and processing markets. The future of the industry is also dependent on its capacity to sustainably utilise the pasture resource and improve present rangeland condition.

The iconic nature of the Kimberley-Pilbara region requires the industry to exhibit best practice management in order to satisfy the growing environmental expectations of the community. There is evidence that suggests the broader community is willing to pay for a range of environmental services including carbon offsets (Bayon *et al*. 2009). This may provide an opportunity for pastoral businesses in the Kimberley-Pilbara region to strengthen their financial profitability by adopting practices which achieve co-benefits for the environment and their cattle enterprise and thereby secure their long-term financial future.

1.9 Climate change policies that underpin the carbon offset markets

The emergence of carbon offsets as a commodity which can be traded has created a new platform of technical and institutional infrastructure in Australia. Understanding the pathway by which offsets can be created, verified, accredited, traded and retired can be overwhelming for pastoralists, service providers, investors and government agencies. This section provides a brief summary of the fundamental principles of carbon offsets and the climate change policies that underpin carbon markets in Australia.

1.9.1 A narrative of climate change policy and the trading of carbon offsets

To appreciate the context and drivers of carbon offset markets in Australia it is important to have a basic understanding of the global institutional pressures related to climate change policy. Figure 12 provides a narrative of recent events related to the development of emissions trading in Australia.

In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted as the basis for a global response to the issue of climate change. The UNFCCC has near-universal membership and has an ultimate objective of stabilising GHG concentrations in the atmosphere at a level which will prevent dangerous human interference with the climate system (UNFCCC, 2010). The Australian Government is a member of the UNFCCC and under this agreement it agreed with other member countries to non-binding emission reduction targets. Therefore, Australia compiles and submits national accounts of its total annual emissions to the UNFCCC in accordance with the Intergovernmental Panel Climate Change (IPCC) inventory-accounting guidelines.

The Kyoto Protocol (KP) is linked to the UNFCCC and is a five year (2008 to 2012) international agreement which goes a step further by committing signatory countries to binding targets which amount to an average 5% reduction of 1990 emissions levels. Australia ratified the KP in December 2007 and committed itself to maintaining its emissions at 108% of 1990 emission levels between 2008 and 2012. Currently, Australia is likely to achieve this target. The detailed rules for the implementation of the KP were adopted in 2001, and are called the Marrakech Accords.

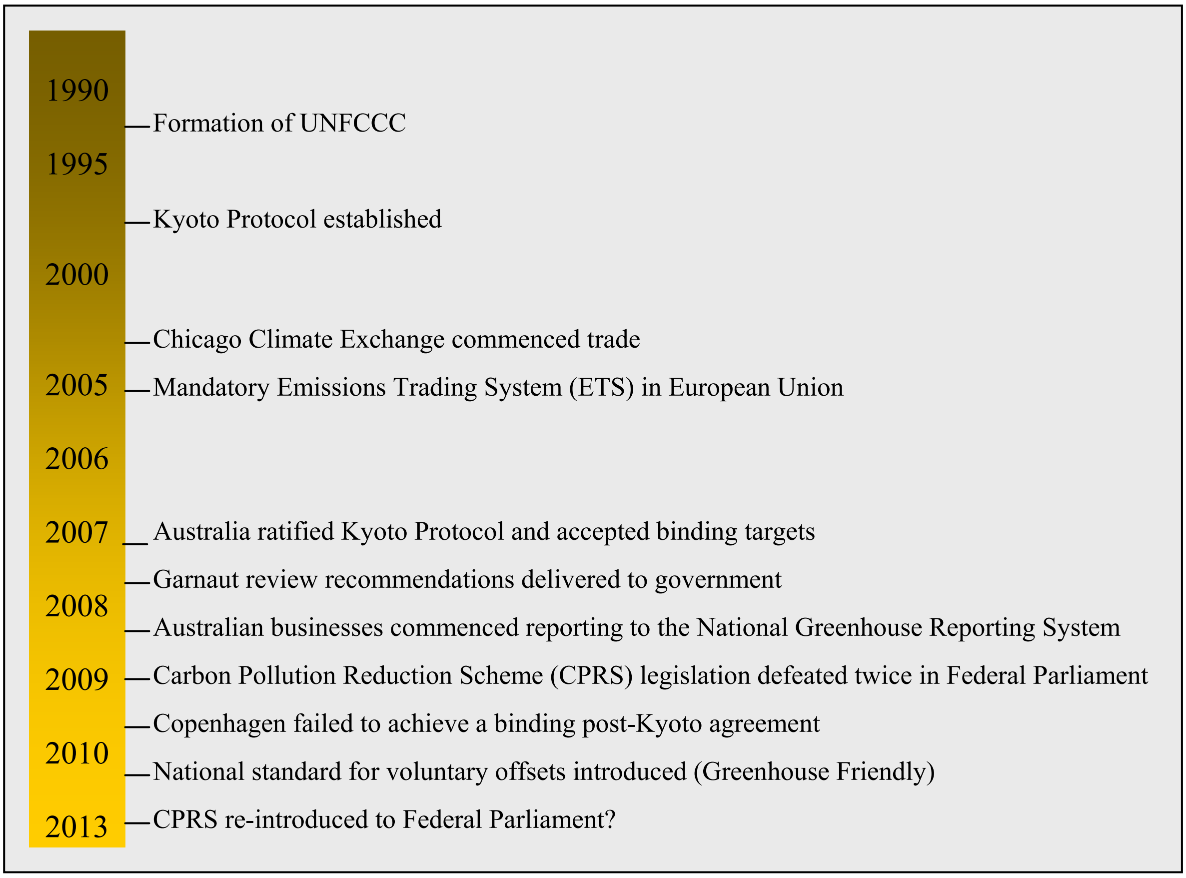


Figure 12: Timeline of international climate policy

Key features of the KP reporting requirements include Articles 3.3 and 3.4. Article 3.3 consists of three reported activities: *Afforestation, Reforestation* and *Deforestation*[5]. Each of these activities, which are considered to be a deliberate human action, must take place on areas of land which were cleared before 1990 in order to qualify. The accounting process calculates the land area that has become afforested, reforested or deforested and the associated emissions and removals of all greenhouse gases (e.g. CO_2, CH_4, N_2O) and carbon pools (above and belowground) over the commitment period (2008 to 2012).

Article 3.4 (Additional Activities) include Forest Management, Cropland Management, Grazing Land Management and Revegetation. Signatory countries are also required to account for the changes that occur due to activities associated with Article 3.4. However, the level of detail at which they do this, is largely at the discretion of each individual country (Tier 1 to 3 datasets). Presently, the Federal Government does not include GHG emissions from activities associated with Article 3.4 in its national GHG accounts because it considers there is a lack of verifiable data. Australia is also required to submit a second set of national GHG accounts to the UN Secretariat as a part of the KP which are similar to the UNFCCC accounts although there are some differences in the accounting methods.

[5] *Deforestation* is the conversion of forest (defined as >20% canopy cover, 2 m in height and 0.2 ha in area) to a non-forest condition sometime after 1 January 1990. *Reforestation* is the conversion of previously forested land which has been cleared in the 50 years prior to 1990 back to a forested condition (i.e. meeting the forest definition). *Afforestation* is the same as *Reforestation*, but for lands that were cleared more than 50 years prior to 1990, or were never in a forested condition.

In April 2007, despite not having ratified the KP, the Howard Government commissioned Prof. Ross Garnaut to undertake a landmark review on climate change adaptation in Australia (Garnaut, 2010). Prof. Garnaut delivered the final report to the subsequent Rudd Government in September 2008 and it included four overarching recommendations:

1. Australia's emission reduction commitments must have a global context.
2. Australia should adopt an emissions trading scheme.
3. Research and application of new knowledge should continue to advance sustainable, cost-effective and low emission based options.
4. The burden of emissions mitigation should be shared across all industry sectors and society.

The Rudd Government accepted in principle the Garnaut Review recommendations and used it as the basis for the introduction of an emissions trading scheme (ETS) to Federal Parliament in 2009. The ETS, known as the Carbon Pollution Reduction Scheme (CPRS), was defeated after being introduced to Parliament on two occasions in 2009. If the CPRS is passed it will either complement or replace existing schemes[6] which currently aim to reduce Australia's GHG emissions. The Rudd Government has indicated it is unlikely to re-introduce the CPRS to Federal Parliament until 2013.

There are two distinct elements of the proposed CPRS: a cap on GHG emissions and the ability to trade. The cap aims to achieve the environmental outcome of reducing Australia's GHG emissions (six Kyoto gases will be included[7]). The ability to trade ensures GHG emissions are reduced at the lowest possible cost. The Commonwealth Government would set a cap on the total amount of GHG emissions allowed to be produced by the Australian economy by covered sectors (long-term reduction target of 60% of 2000 emission levels by 2050).

As a part of the CPRS, the Commonwealth Government would set the reduction targets and establish an independent carbon bank which would be responsible for issuing permits for emissions (known as Australian Emission Units or AEUs) up to the annual cap each year. Annual caps would be set for five years and re-evaluated based on progress over time. Businesses that generate GHG emissions would need to acquire a permit for every tonne of GHG that they emit from an open auction system. The quantity of GHG emissions produced by each firm would be monitored and verified by the National Greenhouse and Energy Reporting System (NGERS). At the end of each year, each liable business would need to surrender a permit for every tonne of carbon pollution the firm produced in that year.

If the CPRS was introduced it is unclear how GHG emissions produced by the agricultural sector would be covered by the scheme. The major issue with full coverage of agriculture in the CPRS would be the cost-effective measurement and monitoring of emissions abatement in the sector (Ford *et al*. 2009). In the most recent draft of the CPRS the Rudd government indicated that it would offer the agricultural sector an opportunity to sell verified offsets into the scheme despite it not being directly covered. This is aimed at encouraging a shift in

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[6]Schemes include the Mandatory Renewable Energy Target Scheme, the NSW Greenhouse Gas Reduction Scheme and the ACT Greenhouse Gas Reduction Scheme.

[7]Kyoto gases include: carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, hydrofluorocarbons and perfluorocarbons.

Australian agriculture to technology and management practices that have a lower GHG profile.

In summary, there is international pressure for Australia and other developed countries to take appropriate action on climate change. To date Australia has taken a measured response and it may introduce a compliance carbon market (i.e. an ETS) in an effort to reduce GHG emissions sometime in the future. The specific impacts and opportunities available for individual pastoral businesses in the Kimberley-Pilbara region of WA will largely depend on the coverage of the agriculture sector in the scheme.

1.9.2 Voluntary carbon offsets markets

Voluntary carbon offset markets in Australia are currently unregulated, with the general exception of trade laws about false or misleading advertising, such as the Australian Trade Practices Act (Riedy and Atherton, 2008). There are over 85 carbon offset providers in Australia who deliver a diverse range of products and services and offer prices of up to $50 t CO_2e- for offsets (Carbon Offset Guide, 2010). Figure 13 provides a summary of the common offset project types.

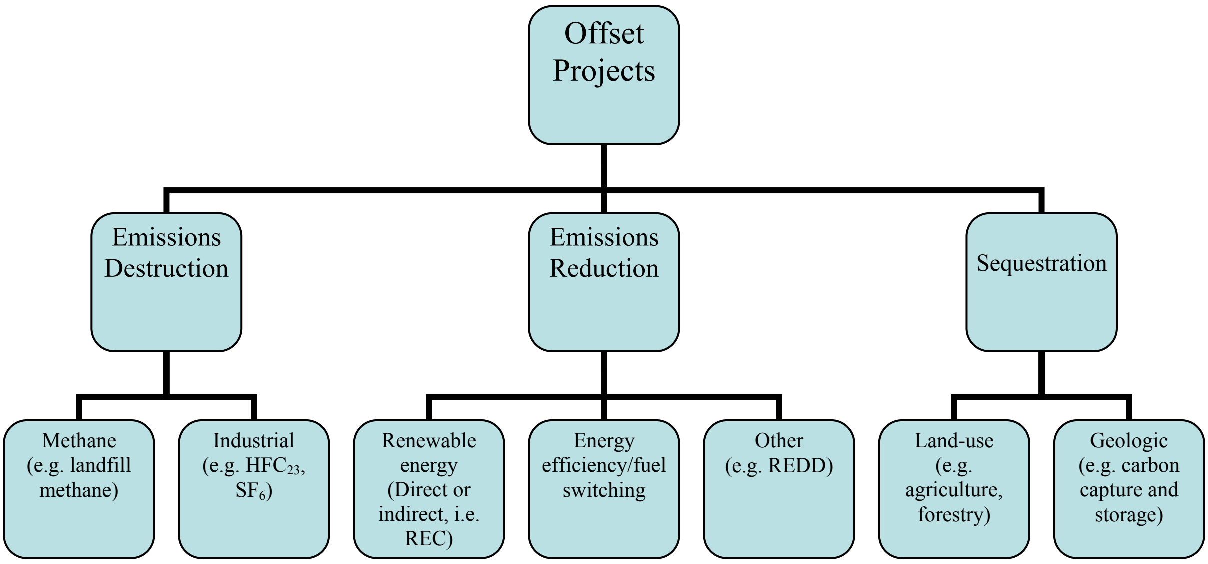


Figure 13: Common emission reduction and biosequestration project categories

Presently, there is no regulation of the voluntary market, but there are numerous voluntary carbon offset standards which service providers use to accredit the offsets they offer to the market (Riedy and Atherton, 2008). In fact, a study of the voluntary offsets market in Australia found that the majority of offset providers sold voluntary carbon credits generated under voluntary standards or mandatory schemes (Riedy and Atherton, 2008). The most common schemes and standards in Australia include:

- **Clean Development Mechanism (CDM)**. CDM is a carbon offset program administered by the UNFCCC and allows accredited projects to generate Certified Emission Reduction (CER) credits that can be sold either to entities which have regulatory requirements under the Kyoto Protocol or into the voluntary market. In 2008, the average CER price was

23.49 AUD. There were a total of over 4000 projects in the CDM pipeline in July 2009 and the UNFCCC expects to have over 2.9 billion CER units registered by 2012.

- **NSW Greenhouse Gas Abatement Scheme (GGAS).** GGAS is mandatory scheme started in NSW and the ACT which allows electricity retailers to reduce their emissions by buying NSW Greenhouse Gas Abatement Certificates (NGACs) generated by abatement projects. NGACs generated under the GGAS can alternatively be sold in the voluntary market. The maximum price for NGACs on the open market is effectively constrained by the cost of non-compliance (i.e. the penalty set by the scheme administrator) set at 12 AUD per t CO_2-e. In 2008, NGACs traded on average for 7 AUD. In 2009 a total of 224 offset projects were accredited under the NSW GGAS; the offset credits generated have amounted to over 90 Mt CO_2-e.

- **The Gold Standard.** The Gold Standard Foundation is a non-profit organization under Swiss law that operates a certification scheme for 'premium quality' carbon credits. It was developed by the World Wildlife Fund (WWF) in conjunction with non-government organisations (NGOs), governments and industry participants. The Gold Standard Foundation registers projects that reduce GHG gas emissions in ways that contribute to sustainable development and certifies their carbon credits for sale on both CDM and voluntary offset markets. The standard emphasises the sustainable development benefits of carbon offset projects, beyond simply the reduction of GHG emissions. The standard currently only applies to renewable energy projects in developing countries. Each Gold Standard Verified Emission Reduction unit (GSVER) is equal to one metric tonne of CO_2-e emissions abated. In 2008, the average price for a GSVER credit was 23.49 AUD per t CO_2e-.

- **Greenhouse Friendly** is an Australian Government scheme which certifies carbon neutral products and services and approves abatement credits for sale on the voluntary market, including to Greenhouse Friendly™ certified product and service providers. It has been attractive to corporate buyers due to the perceived independent judgment of government. The scheme may be replaced in the future by the government's new National Carbon Offset Standard (NCOS). Greenhouse Friendly™ product and service providers are likely to be able to continue development of carbon neutral products and services under the future NCOS by meeting the requirements of the new standard.

- **Voluntary Carbon Standard (VCS)** is an international GHG offset standard. It was founded by the Climate Group, the International Emissions Trading Association (IETA) and the World Business Council for Sustainable Development (WBCSD) in 2007. It is administered by VCS administrative bodies. Credits certified under the VCS are traded in the voluntary market as Voluntary Carbon Units (VCUs) and in 2009 they traded on average for 5.03 AUD per t CO_2e-.

- **VER+** was launched in 2007 and is a carbon offset standard that generally complies with guidelines for offsets accredited under the CDM program. Similar to VCS, it focuses on GHG reductions and does not require projects to deliver co-benefits in order to qualify for the standard. It was developed and is administered by TUV SUD, a Designated Operational Entity, which is an independent entity, accredited under CDM to independently verify CDM projects and emission reductions. Credits certified under VER+ are traded in the voluntary market. VER+ offsets traded on average at 5.03 AUD per t CO_2e- in 2009. In 2009, there were 87 projects registered under the VCS, and over 5.4 million VCUs issued.

- **Mandatory Renewable Energy Target** and **Renewable Energy (Electricity) Act 2000**. In 2001, the Australian Government introduced a Mandatory Renewable Energy Target (MRET) scheme that aims to increase the uptake of renewable energy in Australia's electricity supply. In 2007, the Rudd Government set a target of 20% of Australia's electricity supply to come from renewable energy sources by 2020. MRET requires all electricity retailers and wholesale buyers to contribute towards the generation of additional renewable energy. They can meet their obligations by acquiring Renewable Energy Certificates (RECs).

- **Australian Soil Carbon Accreditation Scheme (ASCAS).** ASCAS was the first scheme in Australia to pay land-holders for soil carbon they biosequestered. The scheme does not trade in offsets *per se*, as the administrator simply pays for the verified carbon and does not seek to on-sell the credits to emitters. The scheme is financially underwritten by the private sector and farmers are paid Soil Carbon Incentive Payments (SCIPs) for validated soil carbon increases above initial baseline levels. SCIP are currently paid at a price of 25 AUD t CO_2-e.

(Riedy and Atherton, 2008; UNFCCC, 2010; Stockholm Research Institute, 2010; CDM Gold Standard, 2010; Department of Climate Change, 2010; Voluntary Carbon Standard, 2010; Jones, 2007; Bayon *et al*. 2009; Keogh, 2007).

This brief summary provides an insight into the existing range of different standards and schemes within Australia and abroad. It is not surprising that some groups within the corporate sector are easily confused by the complexity of the market and unsure which product and scheme satisfies their existing legal obligations and beyond-compliance aspirations. Similarly, pastoral businesses who are seeking to participate in the carbon offset market may also be unsure of how to progress offset project development. The existing lack of uncertainty in the voluntary market is likely to be clarified if Australia adopts an ETS in the future.

Some market analysts suggest that the introduction of an ETS in Australia would have a significant affect on the future size, shape, offerings and longevity of the voluntary offsets market (Hogarth, 2008). This is largely due to the fact that offsets originated in Australia and currently sold in the voluntary market are not 'additional' because they will be counted within the Kyoto-cap on Australia's emissions. This means that the types of offsets which are compliant with the Kyoto protocol could be involved in an ETS in Australia.

Voluntary offsets that fail to meet the ETS criteria may be purchased by companies who have beyond legal-compliance motivations, including personal accountability, corporate social responsibility, staff or community engagement and motivation, competitive differentiation, perceived customer demand and supply chain commercial requirements (Hogarth, 2008; Bayon *et al*. 2009). Genuine and proven carbon reduction is paramount, but a rich offset 'story' that adds other social, environmental and/or economic 'co-benefits' is also seen to be important for many buyers participating in the voluntary offset market (Hogarth, 2008; Bayon *et al*. 2009). It is likely that WA Rangeland carbon offsets could operate in this area of the market in the short to mid-term.

If an ETS was introduced in Australia it is likely that it would result in a reduction in the volume of voluntary offsets currently traded under the Federal Government's own Greenhouse Friendly™ voluntary standard which may be replaced by the National Carbon Offset Standard (NCOS). The major carbon price collapse in 2007 of Greenhouse Abatement Certificates under the NSW Greenhouse Gas Abatement Scheme (NGAS) caused by the speculation of a future regulated national carbon market is evidence of market volatility and the impact of policy uncertainty (Hogarth, 2008). It should be noted that the relatively small size of the NGAS made it susceptible to high market volatility. One of the issues of the voluntary carbon market is that it currently lacks cohesion as a sector and risks being sidelined or simply overlooked while government and industry is focused on the higher stakes associated with a future ETS (Hogarth, 2008). The Mandatory Renewable Energy Targets and greater attention on energy efficiency are the next highest priorities, with the future of the niche voluntary market lagging well behind (Hogarth, 2008).

Notwithstanding the policy issues, there is a view that the potential of Australian agriculture to biosequester and mitigate an estimated 164 Mt CO_2-e yr^{-1} cannot be overlooked and the sector can play an important role in addressing the impact of climate change (CSIRO, 2009). However, this potential may only begin to be explored once the domestic carbon markets in Australia (both mandatory and voluntary) reach a level of maturity and the easily attainable sources of offsets have largely been developed. Undoubtedly, as the price of carbon increases in response to future government emissions caps, then investment in rangeland based carbon offsets are also likely to become increasingly more attractive to offset project developers. This study provides information which will assist offset project developers to capitalise on the potential for biosequestration in the WA rangelands.

1.10 Previous carbon accounting and inventory studies in the WA Rangelands

At present there are limited empirical data relating to the amount of carbon that is present in the soil and vegetation pools throughout the WA rangelands. In most areas there are no data at all, and most estimates that are currently used for accounting purposes rely heavily on extrapolated output. There is little empirical knowledge of the variation in carbon levels between and within different land-systems in the region, and the extent to which management (*viz* improved grazing management and controlled savanna burning) can influence the amount of carbon stored and released. In some cases this has led to overly optimistic and unsubstantiated claims concerning its potential for carbon storage. Therefore, research is required to investigate the key ecological processes and mechanisms that determine the principal drivers affecting carbon cycling (Derner and Schuman, 2007).

At the time of writing there have been two comprehensive carbon inventory field studies which have been completed in the WA Rangelands. The first study was completed in the Pilbara region by the University of Western Australia (UWA) Ecosystem Research Group on a number of pastoral leases owned by Hamersley Iron, BHP and Robe (Adams *et al.* 2001). The study investigated the above-ground biomass and its carbon content in shrubland and woodland communities. Soil carbon measurements were not taken in this study.

The second comprehensive carbon inventory study was conducted in the semiarid shrublands of the North-East Goldfields of WA (Yamada *et al.* 1999). A research consortium led by the Japanese Science and Technology (JST) Group selected shrub and tree species in four plant communities and destructively sampled them to measure their contributions to the total carbon pool (samples were partitioned into leaves, branches, stems and roots). Yamada *et al.*

(1999) found that in this region, trees contributed 12% of plant numbers, but 88% of the biomass, indicating that measurement of this pool is critical for accurate total C estimates. The estimated amount of baseline carbon per hectare in the aboveground biomass (trees, shrubs, surface litter, coarse woody debris, grasses) ranged from 0.286 t ha^{-1} to 39.11 t ha^{-1}.

1.11 Conclusion

Over 120 years have passed since the WA explorer John Forrest made a promising report to the State Government on his vision for a successful pastoral industry in the North-West of WA. With initial support from government the pastoral industry in the Kimberley-Pilbara region became an economic engine room for the emerging WA colony. Despite, the environmental degradation caused by the early exploitative pastoral practices, the industry contributed to the development of essential physical and social infrastructure in the region which enabled other more profitable sectors such as mining to expand.

Today, there is scope for a new industry to develop in the region which is based on the production and sale of carbon offsets. This new industry may deliver a suite of co-benefits similar to the early phase of pastoral development in the region.

The immediate future of the carbon offset industry is largely dependent on the policy and guidelines governing the eligibility of offsets produced in the rangelands. The level of support from the community for emission reduction targets in Australia and the potential adoption of an ETS will determine the magnitude of the opportunity in the region.

There are a number of genuine constraints to commercialising carbon offsets in the Kimberley-Pilbara region, these include:

- **Large spatial size and remote geographical location.** One of the greatest challenges is the cost-effective measurement and accounting of biosequestered carbon over extensive areas and in remote locations. Offset project developers and regulators are also tentative about the capacity for landholders to effectively manage carbon over such large areas.

- **Variable climate and comparatively low rainfall.** This may result in areas becoming both sinks and sources of carbon at different timescales which can be difficult to account for particularly in legally binding contracts between vendors and customers.

- **Heterogeneous landscapes.** The inherent variability in vegetation and soil types can cause significant geospatial statistical issues, making it difficult to provide a reliable estimate of the amount of carbon in an area.

- **Land-use and dominant drivers of economic wealth.** At present the WA economy is primarily driven by income generated by the mining and resource sector. Consequently, there is a high priority by the State Government to promote and support the ongoing development of this sector. This has the potential to create a shortage of intellectual capacity at political and bureaucratic levels to drive initiatives which support the nascent carbon offset industry in the WA rangelands.

- **Land tenure and Carbon Rights.** The vast majority of the Kimberley-Pilbara region is leasehold and the legislation may restrict the diversification of the business into enterprises such as the creation of carbon offsets. The potential constraints of leasehold title are compounded by the lack of precedence of ownership of the carbon rights by a private business in WA.

- **Inertia of industry to adopt new practices.** Adoption of management practices which can biosequester carbon in the rangelands will require a fundamental shift in management. History has shown that change of this magnitude by landholders can take a long time and this may be exacerbated due to the remoteness and isolation of businesses in the Kimberley-Pilbara region.

- **Market uncertainty** – The majority of corporate buyers are seeking assurances that any offsets that are purchased are fungible with a future compliance market. Clear policy and legislative direction is required in order satisfy these concerns.

These constraints elucidate why the opportunity for carbon offsets in the WA Rangelands has received limited attention to date. However, there is growing number of studies investigating the scope for offsets in the rangelands which is intensifying the focus on the issue by the political system and State and Federal bureaucracies. In this context, this study seeks to make a contribution to the scientific knowledge and understanding of the opportunity in order to inform key stakeholders in the Kimberley-Pilbara region and government. It also sought to develop practical processes and tools which could overcome the existing issues associated with the robust verification of biosequestration in the rangelands.

CHAPTER II: NATURAL RESOURCE INVENTORIES AND FINANCIAL PROFILES OF CASE STUDY BUSINESSES

> "We, perhaps, are the first generation of future eaters who have looked over our shoulder at the past, but we have done so quite late in the process of environmental destruction. If we can change our ways before we have consumed all of the future that we are capable of, then we will have achieved something very precious" (Flannery, 1994).

2.1 A case study approach

This project used a case study approach in order to investigate the potential for biosequestration in the Kimberley-Pilbara region.

The case studies were completed in three distinct phases:

Phase One: Completed a natural resource inventory and benchmarked the existing pastoral enterprise

Phase Two: Conducted a soil and vegetation carbon accounting survey.

Phase Three: Modelled enterprise and management scenarios and evaluated the results in terms of the financial, environmental, social and greenhouse gas emission impacts.

To make a balanced judgement about the benefits and risks of biosequestration we considered it was important to make a comprehensive evaluation of the financial, environmental and production components of the existing pastoral businesses.

Three commercial businesses from the Kimberley-Pilbara region were selected as case studies and this chapter provides a summary of the findings from Phase One. Specifically, this chapter provides a summary of:

- the investigative process undertaken to develop the natural resource inventory;
- the geographical location and spatial size of the three pastoral leases;
- the local climatic conditions and predicted impact of climate change on rainfall and temperature;
- the pastoral lease potential and infrastructure development;
- the fire frequency of the pastoral leases;
- the areas susceptible to flood and erosion on the pastoral leases;
- the biodiversity hotspots on the pastoral leases;
- external influences that may limit the scope for biosequestration on the leases;
- a history of grazing management regimes and stocking rates;
- the method used to analysis the present financial profiles of the three businesses; and
- the present financial profiles of the businesses.

2.2 Methodology of the natural resource inventory

The purpose of completing the natural resource inventory was to provide a context within which potential changes to existing management practices and enterprises could be evaluated. In November 2008, Mark Alchin and Dr. Ken Tinley (Landscape Ecologist) conducted an individual two-day workshop with each of the three partnering pastoral businesses.

The workshops were based on the Ecosystem Management Unit (EMU) model (Pringle and Tinley, 2001). This involved a process whereby pastoralists related their indigenous knowledge of their landscape and information of their infrastructure, management and production system. This information was drawn onto a series of transparent overlays which lay on top of a land-system map of the property. The map overlays provided spatial documentation of the following features at a property scale:

- Overlay 1: pastoral potential and infrastructure development;
- Overlay 2: site susceptibility to fire, water inundation and erosion;
- Overlay 3: biodiversity hotspots;
- Overlay 4: external influences; and
- Overlay 5: grazing management regime.

Information from these map overlays was then digitised into a GIS and used in later analyses in association with data from the carbon accounting surveys. The information was also used to develop alternative management scenarios for modelling as a part of Phase Three (refer to Chapter V).

The workshops also involved the pastoralist ground-truthing a land cover change analysis (LCCA) image[8] of their property by drawing on their long-term memory, government survey reports, photo-monitoring site records and paddock stocking history records. Reconnaissance field surveys of key environmental assets and areas of interest on the pastoral leases were then conducted.

2.3 Summary description of case study businesses

The three case study businesses were selected on the basis that they provided a representative cross-section of different land-systems, management systems and scale of enterprise within the Kimberley-Pilbara region (refer to Table 1 and Figure 14). The three businesses examined in the study were:

1. Cheela Plains (-23°00’S, 116°59’E), northwest of Newman;
2. Roebuck Plains (-17°55’S, 122°28’E), east of Broome; and
3. Mount Barnett (-16°39’S, 125°57’E), east of Derby.

[8] The LCCA image was compiled using Landsat images from 1989 to 2006 and was uploaded into Vegmachine™ by Jeremy Wallace (CSIRO Mathematical and Information Sciences, Leewin Centre, Floreat Park, Perth).

Table 1: Summary description of case study businesses

Business	Total lease area (ha)	Mean rainfall (mm)	Potential carrying capacity (CU)	Perennial vegetation condition (%)		
				Good	Fair	Poor
Cheela Plains	188,165	289 ± 136	3,430	46	43	11
Roebuck Plains	283,322	617 ± 284	21,080	43	47	10
Mount Barnett	125,303	774 ± 224	2,946	66	30	4

2.4 Ownership

Cheela Plains has been owned and managed by Evan and Robin Pensini since 2001. The Pensini Family Trust owned and managed the adjacent Wyloo Station between 1976 and 2001. When Wyloo Station was sold in 2001, Cheela Plains was excised and made an individual pastoral lease. The Traditional Owners of Cheela Plains are the Bunjima people. Roebuck Plains was a strategic acquisition by the ILC in 1999 with the express intention to develop and implement an employment and training strategy and to maximise employment opportunities for Indigenous people. Mount Barnett is owned and managed by the Kupangarri Corporation. The Traditional Owners of Mount Barnett are the Wilinggin people.

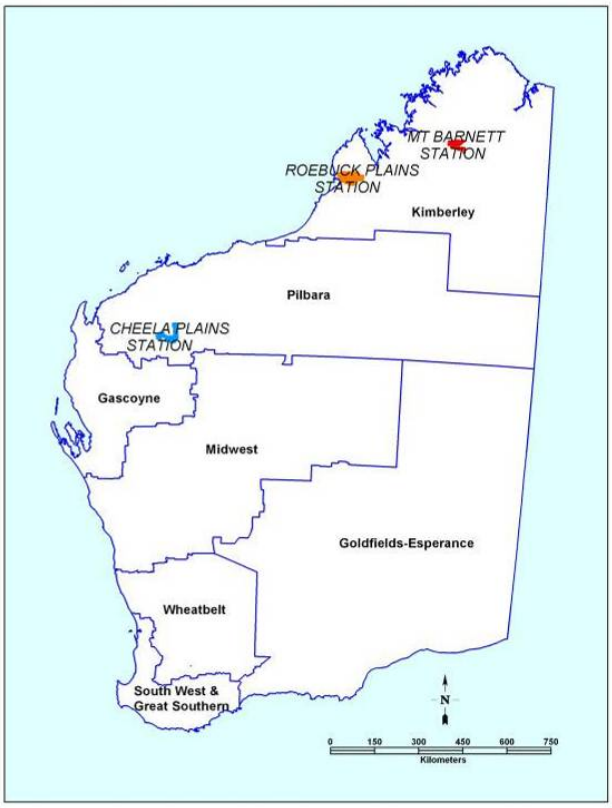


Figure 14: Geographical location of three case study businesses

2.5 Climatic conditions

Cheela Plains (CP) receives substantially less rainfall compared to Roebuck Plains (RP) and Mt Barnett (MB). The summer growing season at CP is not as pronounced as the subtropical climate of RP and MB (Figure 15). RP and CP have similar rainfall coefficients of variation (COV)[9], 45% and 47% respectively. In contrast, MB had a COV of 29% which indicates that the rainfall is more reliable.

An analysis using Rainman™ found that there is only approximately a 45% chance that CP will get 50 mm in 3 days by the end of its main growing season. This is compared to approximately an 85% chance at both RP and MB (Clewett *et al*. 2003). The unpredictable nature of cyclonic activity means that the annual rainfall and subsequent pasture growth can be highly variable at CP.

[9] COV is a measure of the variability of the annual rainfall; it is calculated as the standard deviation divided by the mean x 100.

The rainfall period also varies substantially between CP, RP and MB. MB has an annual mean number of 63 rain days compared to 34 rain days at RP and only 24 rain days at CP (Clewett *et al*. 2003). All of the properties have had extended periods (5+ years) where the annual rainfall was well-above and well-below average. CP had an exceptional period of above-average seasons between 1996 and 2001. RP has had almost a decade of above-average seasons (1998 to 2008), which is in contrast to the nearly 18 years of below average seasons which occurred between 1944 and 1961. MB also had a very dry period spanning more than 19 years between 1922 and 1941.

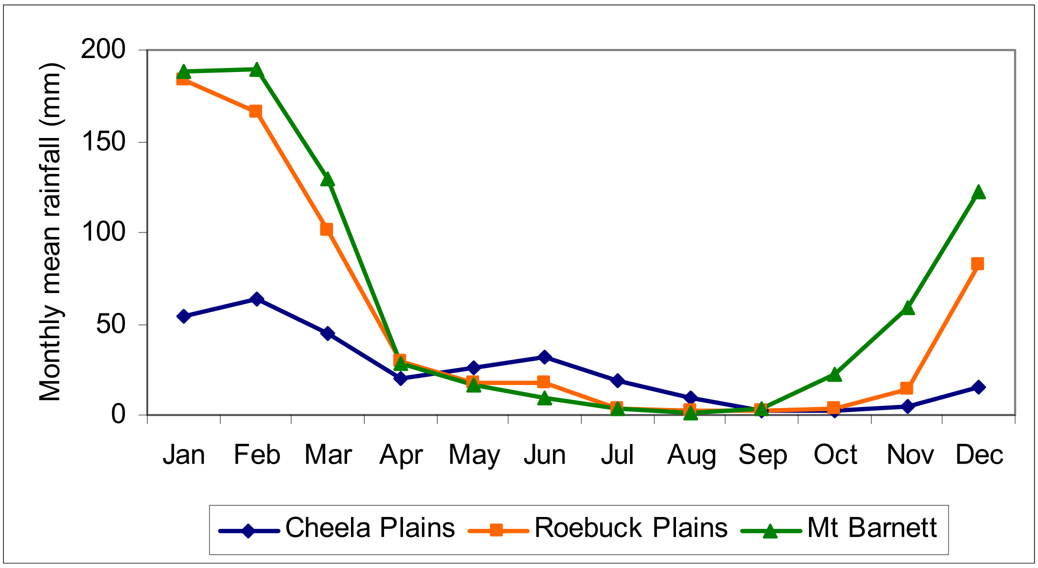


Figure 15: Comparison of monthly mean rainfall of three businesses (Clewett *et al*. 2003)

Mean temperatures at the three properties vary significantly throughout the year (Figure 16). It is generally hotter and drier at CP during the summer (mean summer relative humidity of 30%) compared to RP and MB (68% and 44% relative humidity respectively). This has a substantial impact on the amount of evaporation that can occur, for example the mean pan evaporation at CP in January is 17.1 mm day^{-1} compared to 7.3 mm day^{-1} at RP and 9.6 mm day^{-1} at MB. It is also generally 2 to 3°C cooler at CP during the winter.

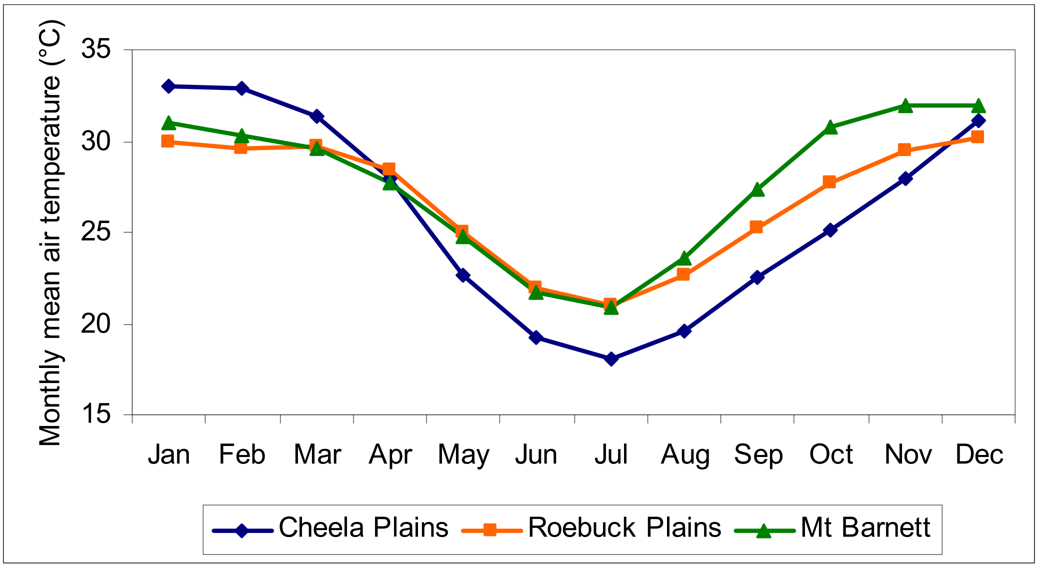


Figure 16: Comparison of monthly mean air temperatures of three businesses (Clewett *et al.* 2003)

2.6 Predicted impacts of climate change on rainfall

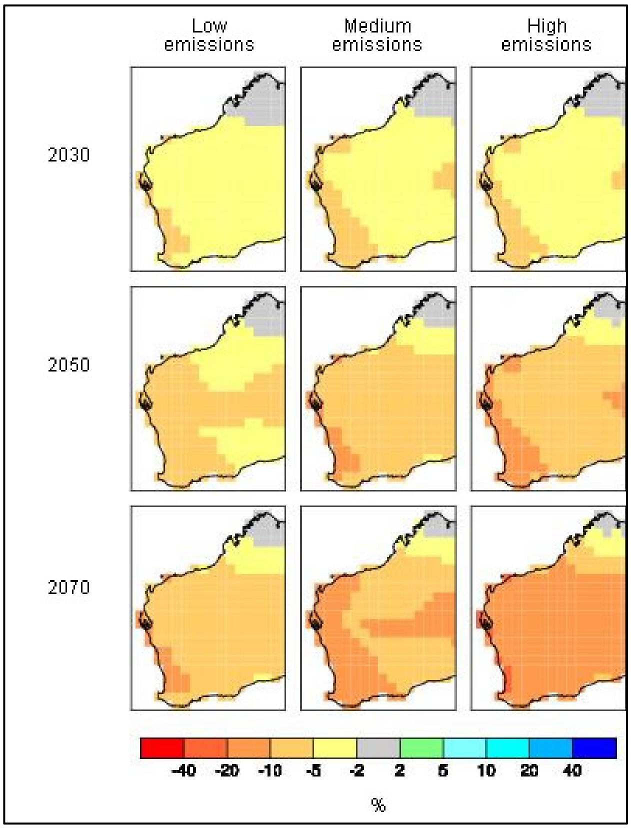


Figure 17: The predicted change in mean rainfall of WA due to climate change (Reproduced from Climate Change in Australia, 2010)

Scientists predict that the rainfall at CP is likely to be reduced by at least 2% (~6 mm) in the coming decades as a result of climate change (Figure 17). RP is likely to have a smaller reduction in mean annual rainfall. In contrast, MB may have an increase of up to 2% (~18 mm). Rainfall in the northern parts of WA is also predicted to become increasingly episodic which may have implications for the length of the growing season and associated pasture growth (Climate change in Australia, 2010).

Climate change is expected to cause an increase in the mean temperatures in the Kimberley-Pilbara region by up to 2.5°C by 2050 (Climate change in Australia, 2010). In combination with increased concentrations of CO_2 and potentially higher evaporation rates, this may have mixed effects on plant physiological processes and landscape function in the region.

2.7 Pastoral potential and infrastructure development

This section identifies the areas which are currently the most valuable for livestock grazing on the three leases. It also details the existing level of infrastructure development on the leases.

2.7.1 Cheela Plains

The most productive area on CP is the Cheela floodplain (see Table 2). Smaller tracts of productive land occur along the Beasley River (River land-system) which drains from the north-east into the Cheela floodplain. The Hardy River flows from the east and is generally confined to a main channel which lies directly south of the floodplain. The Hardy River provides a narrow tract of productive land beyond the west end of the floodplain. There is a diffuse creek-line in the far northeast end of the lease which is also considered to be of high pastoral potential (refer to Appendix 2 for a detailed land-system and infrastructure map of CP).

Figure 18: Centre of a paddock on the Cheela floodplain

The floodplain encompasses approximately 20,000 ha and has been extensively subdivided into 78 paddocks which range in size from 50 to 1200 ha. Paddocks in the most fertile, central area of the floodplain are generally the smallest. Fences are generally single wire electric and in most instances were positioned to conform with the natural contours of the landscape. Lines were not cleared for the majority of the fences and insulators are regularly affixed to trees to avoid them being removed.

There is little to no infrastructure (both redundant and new) in the northeast section of the lease due to the rugged terrain and generally low pastoral potential. The western section of the lease also has little infrastructure. There is little to no boundary fencing as the rugged terrain provides a natural barrier to cattle movement.

CP currently has 38 operating watering points and 12 redundant watering points. The majority of the watering points occur on the floodplain and generally service multiple paddocks as they are at the centre of a rest-based grazing system. The main water supply is pumped from a central bore (Melonhole bore) near the homestead to five 10,000 gallon water tanks which are located on top of a hill. The water is reticulated out to the watering points on the floodplain by gravity. A urea medicator is located with the water-tanks and is used to improve rumen function when protein content of the dietary intake is judged to be limiting livestock performance.

A circular (0 to 15 m diameter), fenced area with a single entry point surrounds the watering point. This discourages livestock from camping in the immediate vicinity and therefore reduces the impacts of the piosphere effect that is common feature of watering points. Paddocks that are being rested have the watering troughs turned off and this limits the impact of non-domestic grazers (viz kangaroos). There is limited natural surface water and it is restricted to ephemeral pools along the Hardy and Beasley Rivers. There are no areas on the floodplain which are beyond 3 km from water. There are no operating watering points in the whole north-east section of the lease. The far western section of the lease also has no operating watering points.

The existing level of infrastructure enables CP to fully utilise the most productive areas of the lease. There are only small tracts of productive land (far west and far north-east) which are not developed but they are isolated areas and bordered by rugged terrain. Continued subdivision of the paddocks on the floodplain in order to improve the evenness and level of utilisation across the paddock was considered to be the only viable option for further infrastructure development.

Table 2: Summary of land-types and pastoral potential at Cheela Plains

Pastoral potential	Land type	Land system	Area (ha)	% of lease	PCC (cu)	Subtotal PCC (cu)
Very high	Alluvial plains with tussock grasslands	Cheela	20,802	11.1	1,891	1,891
High	River plains with grass woodlands and tussock grasslands	River	6,591	3.5	300	300
Moderately high	Alluvial plains with halophytic shrublands	Edward	503	0.3	15	66
	Stony plains with acacia shrublands	Paraburdoo	2,562	1.4	51	
Moderate	Stony plains with acacia shrublands	Dollar	3,462	1.8	63	546
	Hills and ranges with acacia shrublands	Kooline	34,316	18.2	483	
Low	Mesas, breakaways and stony plains with spinifex grasslands	Robe	3,155	1.7	29	30
	Stony plains with grasslands	Wona	74	<0.1	1	
Very low	Hills and ranges with acacia shrublands	Augustus	81	<0.1	0	598
	Stony plains with spinifex grasslands	Boolgeeda	19,999	10.6	160	
		Platform	1,442	0.8	11	
	Hills and ranges with spinifex grasslands	Capricorn	26,880	14.3	138	
		Newman	23,754	12.6	90	
		Rocklea	44,301	23.6	197	
	Mesas, breakaways and stony plains with mulga and halophytic shrublands	Table	243	0.1	2	
Total			188,165			3,431

A Land Cover Change Analysis (LCCA) tool (Vegmachine^{TM}) was used to investigate the change in total cover on CP from 1989 to 2006 (see Appendix 5 for the methodology of this analysis). The analysis used Landsat imagery (25 x 25 m) on an annual time step. The image on the left indicates the change in total cover that occurred over the assessment period (1989 to 2006). A positive (increasing linear cover trends) is displayed in blue, negative (decreasing cover) in red and no change is black. The plot on the right illustrates the change in the total cover at selected sites (represented by the corresponding hollow coloured circles on the image on the left). Note an increase in the index value on the temporal plot indicates increased reflectance (or bare soil).

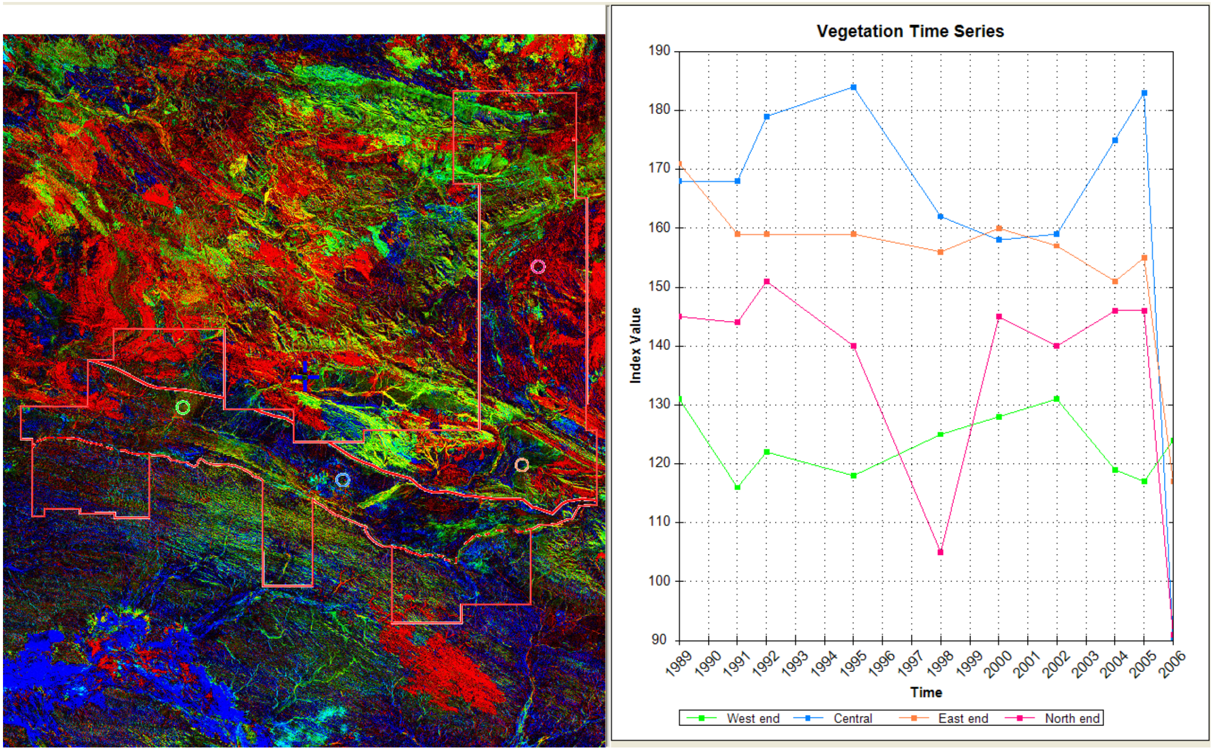


Figure 19: Land cover change analysis of Cheela Plains for the period 1989 to 2006

The analysis suggests that the CP floodplain (the central area on the left image) has had a general increase in total cover since 1989. The trajectories of the four selected sites in the temporal plots highlight the relative temporal and spatial variation (the locations of the selected sites are marked on the image with hollow coloured circles). The ‘West end’ site does not appear to have had any major changes in total cover and any inter-annual variation is most probably due to seasonal responses. The ‘Central’ site appeared to be on a plane of increasing total cover from 1995 to 2002. In 2006, the Central site had a significant increase in total cover which is most probably due to a combination of well above-average summer rainfall and rest from livestock grazing. The ‘East end’ site appears relatively stable throughout the assessment period except for an increase in total cover in 2006 which may also be explained by the well-above average summer rainfall. The trajectory of the ‘Northern end’ appears to be the most erratic which is likely to be an artefact of the higher frequency of uncontrolled fire in this area.

Twenty two pasture monitoring sites were installed on CP in 2002 (McCartney and Shrubb, 2002). These sites have been monitored according to the Western Australia Rangeland Monitoring System (WARMS) protocol which incorporates the Landscape Function Analysis (LFA) technique. The sites were re-recorded in 2003, 2004 and 2005. No monitoring of these sites has been completed since. In general, the LFA data suggests a positive trend for most of the sites between 2003 and 2005.

2.7.2 Roebuck Plains

Roebuck Plains is comprised of a saline floodplain and dense *Acacia* sandplains with red and yellow soil (refer to Table 3). The floodplain is on the western end of the lease and it flows directly into Roebuck Bay. The floodplain is surrounded by sandplains and low woodlands which shed water onto the plain during significant rainfall events. There are a number of shallow drainage tracts throughout the sandplains that concentrate the flow of water onto the floodplain.

Figure 20: Taylor's lagoon, Roebuck Plains

The floodplain is over 42,000 ha and is the primary grazing area on the lease. The floodplain soils are fine-textured dark saline clays that merge to a massive mottled light-coloured clay with shell fragments. Topsoils are whitish grey and powdery and hence highly susceptible to wind erosion and scalding when there is a reduction in the cover of marine couch grass (*Sporobolus virginicus*). The fringing plains provide a mix of palatable grasses including: buffel grass (*Cenchrus ciliaris*), birdwood (*Cenchrus setiger*), bundle bundle (*Dichanthium fecundum*) and native couch (*Cynodon dactylon*).

A series of permanent lagoons occur along the northern margin of the lease which are fed by drainage run-off out of the *Acacia* sandplains. These support large numbers of waterbirds. The perennial pans tend to act as foci for grazing activity particularly in the late dry season. Management sought to address this issue by installing fences around the lagoons in order to periodically exclude livestock.

There are 44 artificial watering points on RP (one per 6,460 ha). Salt levels in the operating bores are low (220 to 1870 mg L^{-1}) except for Tagarana which, although higher (4460 mg L^{-1}), is still well within the limits for beef cattle[10].There is a higher concentration of watering points on the western end of the lease and the distance between the watering points increases towards the eastern end of the lease.

There is a very limited area of the floodplain which is not within a 3 km radius of water and therefore it is likely to be fully utilised under the current management regime. In contrast,

[10] Salt level limit for young stock and lactating cows is 6000 mg/L and 9000 mg/L for dry adult cattle.

there are substantial areas of sandplain in the eastern end which are well beyond the 3 km radius from water.

During the reconnaissance survey it was noted that historical overgrazing has resulted in increaser plant species encroaching into areas of the floodplain which should be treeless marine couch grassland[11]. These mainly included paperbark (*Melaleuca acacioides*) and samphire (*Halosarcia* spp.) on the western end of the floodplain. Scrub invasion is typical on heavily grazed areas and/or where drainage gutters have cut back resulting in the soils becoming desiccated. In an undisturbed state, samphire typically occurs on the more saline areas and marine couch on less saline areas. The expansion of samphire into areas dominated by marine couch indicates thinning of the grass cover and the development of scalded topsoils better suited to samphire. Despite these symptoms of historical overgrazing, 90% of RP remains in fair to good rangeland condition and the current RP management team have a grazing strategy in place to address these issues on the lease. Refer to Appendix 3 for a detailed land-system and infrastructure map of RP.

Table 3: Summary of land types and pastoral potential at RP

Pastoral potential	Land type	Land system	Area (ha)	% of lease	PCC (cu)	Subtotals PCC (cu)
High	Paleo-tidal coastal plains and tidal flats with saline soil	Roebuck	42,529	15	3,479	12,474
High	Low lying sandplains and dune fields	Wanganut	97,278	34.4	8,995	
Moderate	Coastal flats, associated sandy margins and dunes	Carpentaria	1,599	0.6	88	8,606
Moderate	Extensive dune fields, pindan and other low woodlands	Camelgooda	55	0.05	8	
Moderate	Sandplain with scattered hills and minor plateaux, red soils	Reeves	94	0.05	4	
Moderate	Sand plain, deep red and yellow sands, pindan and tall woodlands. Curly spinifex and ribbon grass	Yeeda	141,767	50	8,506	
Total			283,322			21,080

(Source: WA Stock State Database, 2010)

[11] Increaser species are usually less palatable plant species and their density and distribution usually increase under heavy grazing. They tend to be woody plants and are typically tolerant of limited moisture and nutrient conditions.

A land cover change analysis (LCCA) was conducted on RP using Vegmachine™ (see Figure 21) using the same process as the CP analysis. The LCCA suggests that large areas of the Roebuck floodplain have had a reduction in total cover between 1989 and 2006 (illustrated by the bright red area on the western side of the lease). The fringing areas of the floodplain appear to also have had a reduction in total cover, particularly between 2000 and 2005 (green line on the plot). In 2006 the fringing areas of the floodplain had a considerable increase in ground cover. There appears to be a major increase in cover in the southern sandplain (red line on the plot) between 1995 and 1998. However, this increase in cover was largely negated in 2000 which was most likely due to an uncontrolled fire. The amount of total cover in the southern and eastern regions dominated by *Acacia* sandplain appears to be unchanged and in some areas it has slightly increased. The LCCA suggests that there has been a general increase in total cover in the northern sandplain area.

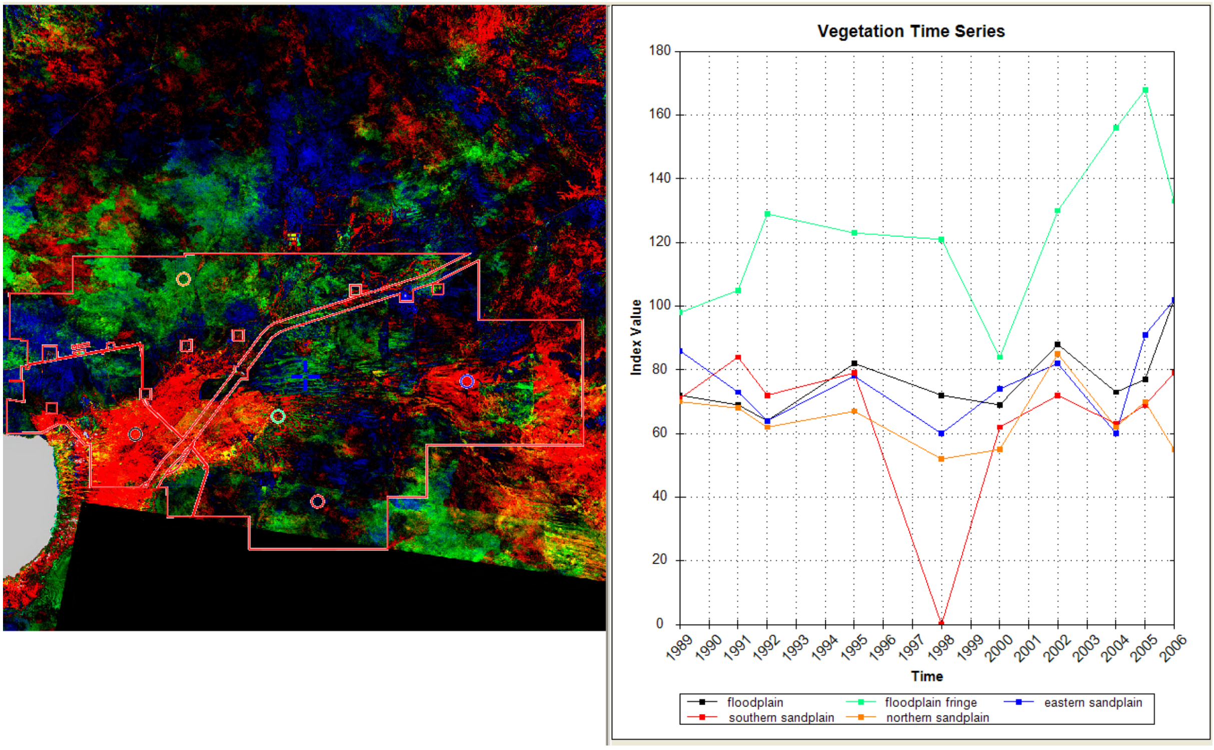


Figure 21: Land cover change analysis of Roebuck Plains for the period 1989 to 2006

Historical overgrazing in conjunction with extended below-average seasons are most likely to be the cause of the reduction in total cover in some areas of the floodplain. To address the historical degradation issues, RP is now periodically spelling areas of the floodplain and is making a concerted effort to adjust grazing pressure in accordance with seasonal conditions.

2.7.3 Mount Barnett

Mount Barnett comprises 125,303 ha of which almost half is unsuitable for cattle production due to poor accessibility and low pastoral potential. The remaining area of the lease is moderately productive and can carry 1,153 CU. MB was one of the earliest pastoral leases to be taken up in the North Kimberley in 1910. There were approximately six changes of ownership before the current owners, the Kupingarri Aboriginal Corporation (KAC), acquired the lease.

The most productive land-systems are confined to the Barnett and Police Valleys. The Barnett River extends from the northwest end of the lease eastwards until it merges with the Hann River. Harris Creek extends from the far eastern end of the lease and also merges with the Hann River near the middle of the valley. The Hann River meanders down from the north and dissects the lease in a southwest direction. Despite there being no artificial watering points, the lease is well-watered by natural springs, soaks, creeks and rivers. The pastures in close proximity to these areas are susceptible to over-grazing.

The majority of the land-systems on MB are in fair to good condition. The more acute impacts of overgrazing appear on the fertile areas of the Barnett and Police valleys. In some areas, the productive perennial grasses have been replaced by shallow-rooted annual grass species and to a lesser extent woody plants.

Currently, there is limited fencing on MB. There is only one fenced paddock (18 km cattle fence) on the lease which is used to hold cattle whilst they are mustered and drafted for sale. There are limited sections of boundary fencing with neighbouring leases.

The lack of fencing and abundant water supply has meant that the only restriction to cattle grazing has been accessibility. The managers of MB advised that as the dry season progresses the cattle migrate eastwards as the surface water dries up. Thus the areas which are known to provide permanent water are most likely to have had disproportionate levels of grazing levels. Table 4 provides a summary of the land-types on MB and their associated pastoral potentials.

Table 4: Summary of land-types and pastoral potential at MB

Pastoral potential	Land-type	Land-system	Area (ha)	% of lease	PCC (cu)	Subtotals PCC (cu)
Moderate	Gently undulating volcanic country with open forest vegetation	Kennedy	28,819	23	1,153	1,153
Low	Hilly volcanic country with grassy woodland vegetation and shallow stony or leached soils	Napier	7,518	6	188	501
	Gently sloping with some hills and scarps on sandstone country.	Pago	12,530	10	313	
Very low	Gently sloping or undulating shale country with sandstone capped scarps with grassy woodlands and shrubby forests with leached or stony soils.	Karunjie	17,542	14	175	175
Unsuitable – low	Mountainous sandstone and quartzite country with steep escarpments and narrow restricted basalt valleys.	Buldiva	58,892	47	0	0
Total			125,301			1,829

(Source: WA Stock State Database, 2010)

In comparison to CP and RP, the spatial and temporal pattern of change in total cover across MB was more erratic. This is most probably due to the high frequency of uncontrolled fire. It is difficult to draw any definitive conclusions concerning the overall trajectory of total cover across the lease.

Figure 22: Recently burnt areas of the Mount Barnett Valley

The LCCA suggests that from 1991 to 2000, most areas on MB had an increase in total cover. This was surprising given that only three out of those nine years were above the annual average rainfall (Figure 22). There was a significant decrease in total cover (increased reflectance) across the majority of the lease in 2002 which is likely to be the result of a significant uncontrolled fire**.** The substantial increase in total cover (decreased reflectance) in 2004 suggests a rapid recovery of the vegetation post the 2002 fire. A major uncontrolled fire appears to have occurred again in 2005 and this is followed by an increase in total cover in 2006. The majority of MB appears to be stable and has not had a significant long-term change in total cover. The far western end and the far north-eastern ends of the lease appear to be the only areas of reasonable size where total cover has decreased significantly.

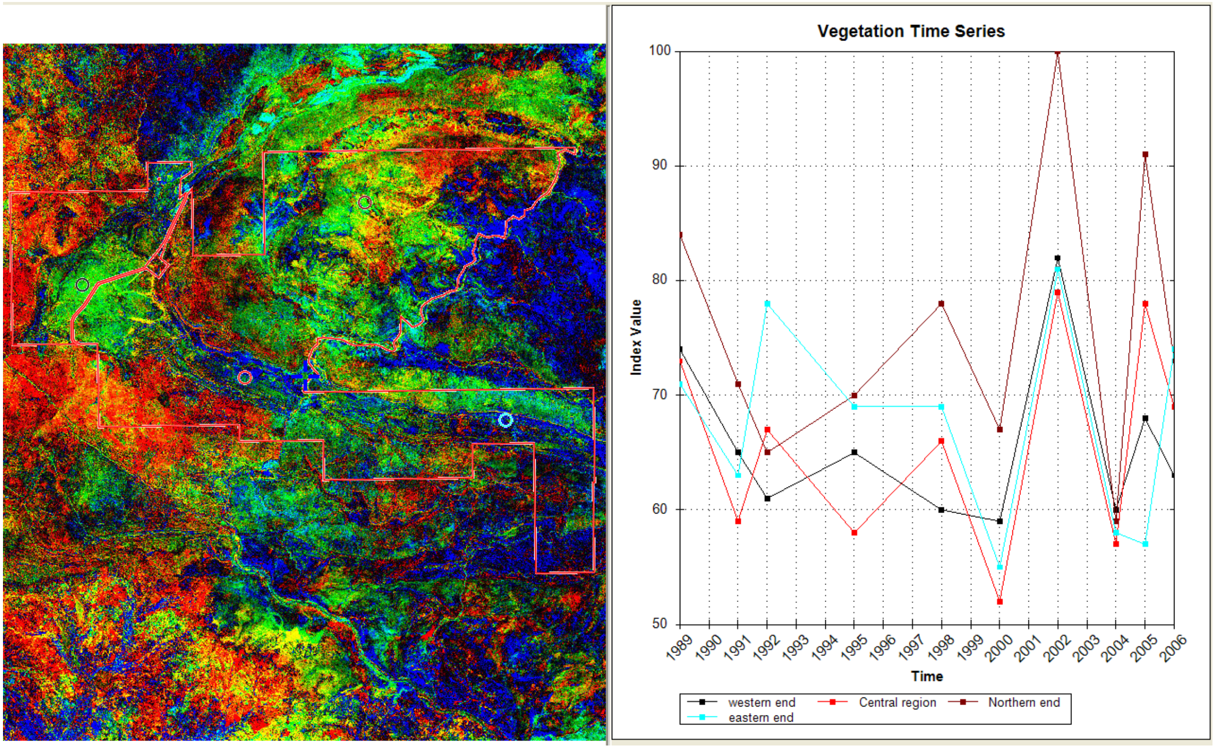


Figure 23: Land cover change analysis of Mt Barnett for the period 1989 to 2006

Ten pasture monitoring sites were installed on MB by the Department of Agriculture WA in 1989 (Edwards and Lambert, 1989). The majority of the sites have been re-monitored in 1993, 1994 and 2003. A list of plant species present within the site was recorded and a photograph of the site was taken. Some of these sites were used to visually evaluate the relativity of the LCCA on MB. Visual appraisal of the photo monitoring site records of MB suggests that there has not been a substantial change in plant species density, distribution or diversity at these sites since 1989. Refer to Appendix 4 for a detailed land-systems and infrastructure may of MB.

2.8 Fire frequency

Figure 24: The effects of severe fire at Mount Barnett

Knowledge of areas susceptible to disturbance on the case study leases is useful as it can identify risk-prone areas which may require additional management in order to store carbon in the long term.

Fire frequency data for the three leases was purchased from Landgate WA. The fire frequency data was for the period 1989 to 2008 and converted into a shape file and imported into Geomedia™ for analysis. The fire frequency information was based on data from the NOAA series of satellites which is recorded every nine days and has a 1 km resolution. There were some gaps in the WA

State Archive[12]. This information was used in statistical analyses to determine if uncontrolled fire had a significant effect on the amount of carbon stored in the soil and vegetation pools (refer to Chapter IV).

The incidence of uncontrolled fire is a major issue on MB and RP and to a lesser extent on CP. Frequent, hot fires result in excessive loss of nitrogen and carbon from the ecosystem and can cause reductions in pastoral potential due to a loss of perennial grasses (Heckbert *et al.* 2009).

Between 1997 and 2008 a substantial proportion of CP was burnt regularly, particularly in the northeast section of the lease which is dominated by hills and ranges with spinifex grasslands (Figure 25). Fire also appears to be a relatively common occurrence near the northwest end of the lease. The majority of these fires are ignited from lightning strikes and the limited access to these areas means that they tend to burn until they run out of fuel or meet a natural or artificial firebreak. The incidence of uncontrolled fire is reduced on the floodplain. The spinifex grasslands appear to be adapted to fire and this level of disturbance is likely to be beneficial to their ecological stability. Widespread, unmanaged fires have been mitigated on the CP floodplain by regular livestock utilisation of the vegetation.

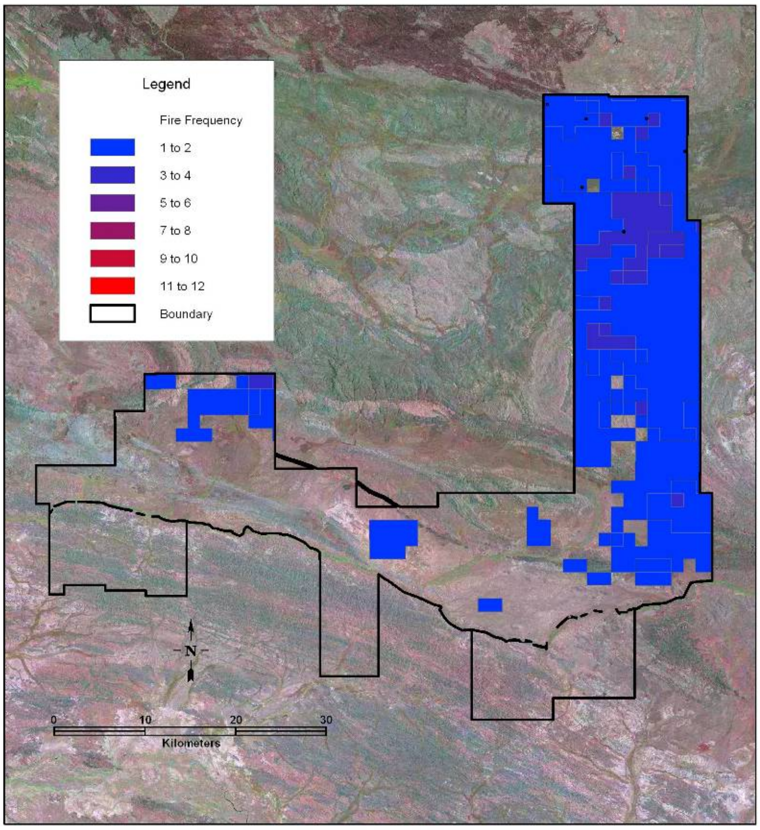


Figure 25: The number of fires that have occurred on Cheela Plains from 1989 to 2008

[12] Gaps in WA State Archive included: July 1992 to April 1993; 1993 data only includes the Kimberley region; 1994 and 1995 data are mapped from April to December only.

Widespread, unmanaged fire is currently a regular feature of RP (Figure 26). The eastern end of the lease which is dominated by *Acacia* sandplain is burnt the most frequently. The majority of the floodplain has tended to avoid the regular burns, although substantial areas were burnt in 1998 and 1999. Most of the fires are human-induced and occur late in the dry season. The lease is only 30 km from the Broome township and therefore the landscape is particularly susceptible to influences from the travelling public and activities of local people. The frequent fires make the task of resting pastures from grazing difficult. CSIRO researchers estimate that the current fire regime on RP emits 18,400 t CO_2-e per annum (Heckbert *et al.* 2008). In their study, Heckbert *et al.* (2008) reported that if RP could impose an effective controlled savanna burning regime the business could reduce emissions by an estimated 6,898 t CO_2-e per annum (Heckbert *et al.* 2008). This offset volume would be equivalent to taking more than 1,500 vehicles off the road every year.

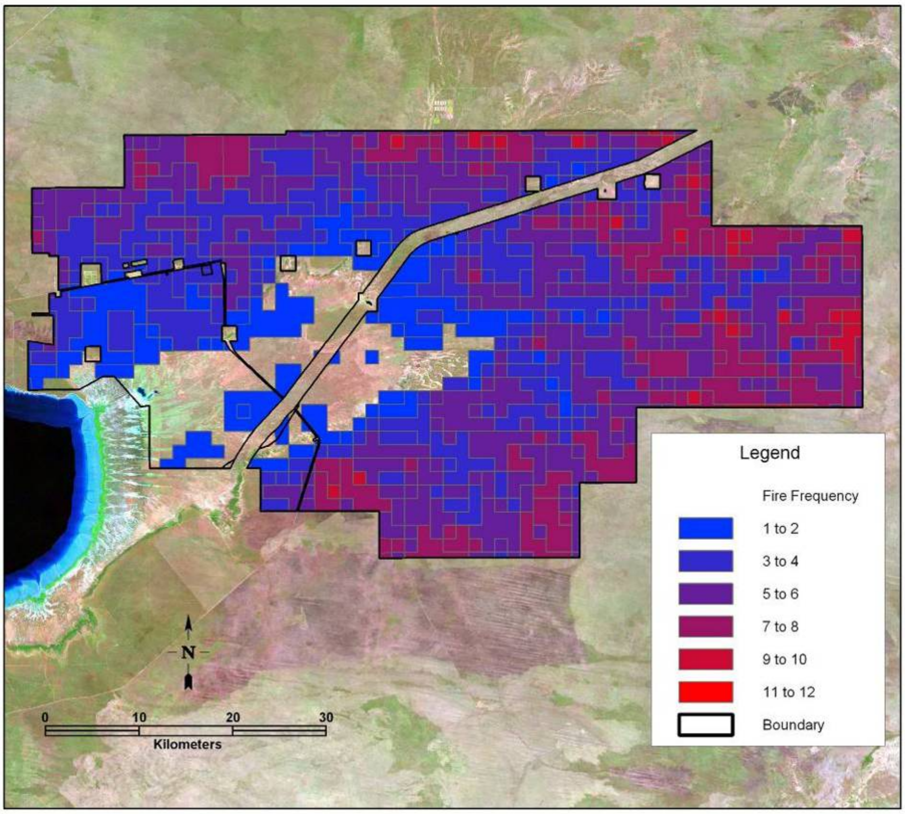


Figure 26: The number of fires that have occurred on Roebuck Plains from 1989 to 2008

Except for a small area around the community itself, the entire area of MB is frequently burnt as a result of lightning strikes and deliberately lit fires. Most areas of the lease are burnt every three years (Figure 27). Depending on the time of year and the effectiveness of the preceding wet season, these fires will be a mixture of ground fires and those which can also consume the tree canopy. Fire is a natural feature of the North Kimberley, however the fire frequency is thought to have increased since both Indigenous and European settlement. The negative impacts of intense, frequent fire may have been exacerbated by uncontrolled cattle grazing because livestock are drawn to fresh regrowth following fire. Therefore, repetitive, overgrazing in conjunction with savanna burning may limit the density, distribution and diversity of the desirable perennial grasses within the Barnett and Police valleys. Annual sorghum has been recognised as increasing with regular burning.

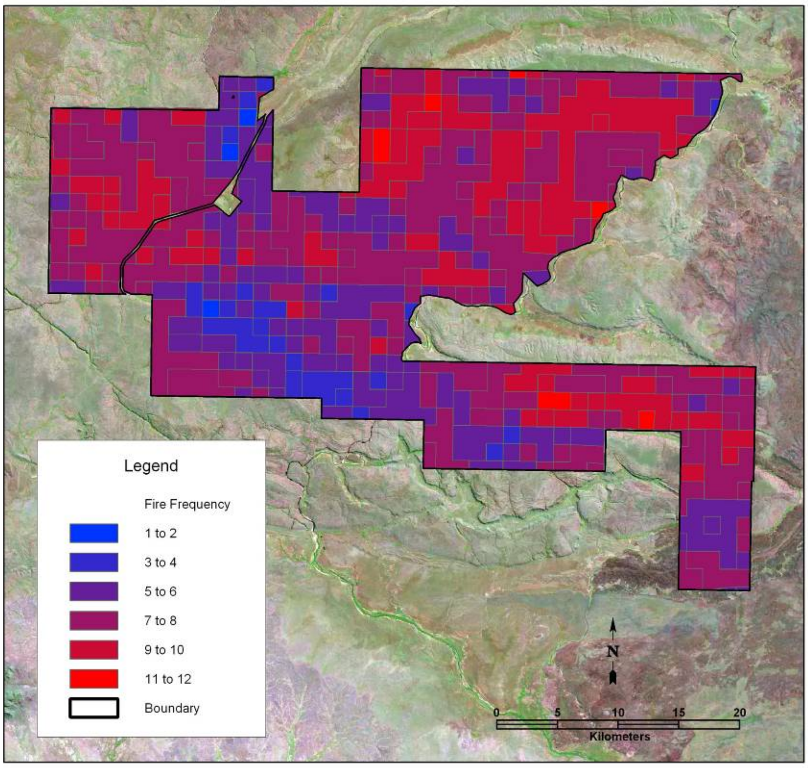


Figure 27: The number of fires that have occurred on Mount Barnett from 1989 to 2008

2.9 Areas susceptible to flood and erosion

Figure 28: Degraded *Acacia* shrubland in the Pilbara

The areas on CP that are susceptible to flooding tend to be limited to braided low lying areas on the Cheela floodplain. The Hardy River is known for its ability to channel water from the east which can flood out into broad tracts across the plain. The Beasley River originates from the Hamersley Ranges to the north and due to its elevation it tends to channel water at a higher velocity which fans out across the plain.

Historical overgrazing has resulted in moderate canalization of the Hardy River which used to regularly distribute water more broadly across the plain. Despite the increase in ground cover between 1999 and 2008, the Cheela floodplain still relies on major rainfall events in order to have a short-term inundation. The heavy cracking clay soils on the plain require substantial amounts of water in order to bring it to field capacity and stimulate plant growth.

Erosion was identified as an issue at a number of areas across CP, particularly within the main drainage channels of the Beasley and Hardy Rivers. The erosion in the Beasley River has been exacerbated by the highway construction because it has concentrated the flow and caused aggressive scouring and deepened the channel.

The drainage pattern on RP is fairly simple compared to CP. The lower lying areas in the sandplain channel the water to the floodplain, which can become inundated with water for a brief period. King tides can flood the frontage area of the floodplain with hyper-saline water. Deep Creek, which flows from Kilto station in the north, is one of the main drainage tracts. The very subtle nature of the slope has prevented the development of any serious drainage issues (e.g. gully erosion). RP receives fog and heavy dews mainly in the Autumn through to the mid-Winter period (March-July) which can provide sufficient moisture to trigger growth of the grasses in recently burnt areas. The reduced ground cover in some areas of the floodplain has made the soil surface susceptible to moderate wind erosion.

MB has a complex web of drainage tracts which are a part of the catchment for the Manning Creek, Barnett River, Harris Creek and eventually the Hann River. The Barnett and Police valleys are regularly inundated during the wet season and the water can remain in localised pools for extended periods. There are erosion concerns at certain points along the banks of the main drainage channels which can only be addressed through grazing control and appropriate development of access tracks.

2.10 Biodiversity 'hotspots'

The confluence of the highest number of land-systems in a five kilometres radius area is termed an ecojunction (Tinley, *pers comm*. 2009). These areas tend to contain the highest natural diversity and as such are valuable benchmark areas for monitoring rangeland condition and change under different disturbances. The ecojunction is an area for management self-instruction and assists in understanding how different land-systems respond to various disturbances (flood, drought, fire or grazing) as indicated by the plant density, distribution and diversity. Depending on the mixture of abutting land systems, ecojunctions are usually favoured by grazers. It was important to identify these areas as they needed to be taken into consideration when designing future management scenarios to ensure they are protected from overgrazing.

Three individual ecojunctions were identified on CP. Dr. Ken Tinley suggested that the ecojunction which comprised of seven different land-systems was likely to be the most important because it included the permanent Cheela Spring. The spring is one of a few permanent sources of water which is available to fauna throughout the year. There were also a number of areas in the northeast section of the lease which were habitat for brushtail rock wallabies. The semi-permanent Woongarra pool provides water for the wallabies and habitat for a suite of migratory water birds.

The implementation of rest periods from grazing has had a very positive impact on the density, distribution and diversity of perennial grasses across the floodplain. Buffel grass (*Cenchrus ciliaris*) and Bardi bush (*Acacia victoriae*) were the primary colonisers of the floodplain, however they are gradually being replaced by higher order perennial grass and sub-shrub species. During the reconnaissance survey, a number of patches of the highly favourable Mitchell grass (*Astrebla* spp.) were identified and a number of recent recruits indicated that these patches were expanding. Roebourne plains grass (*Eragrostis xerophila*), Queensland bluegrass (*Dicanthium serecium*), Ribbon grass (*Chrysopogon fallax*), Neverfail (*Eragrostis setifolia*) and Silky brown top (*Eulalia fulvia*) have all also become dominant species on the Cheela floodplain.

There was only one ecojunction identified on RP which comprised a total of four land-systems. The ecojunction was located near Jabiru paddock and the land-systems represented were: Carpentaria, Roebuck, Wanganut and Yeeda. This area will be excised from the lease for conservation purposes in 2015. It is unique in the sense that it is a part of the floodplain frontage that feeds into Roebuck Bay as well as including the transition zone of the sandplain community.

The eastern lagoons (Taylors lagoon, Lake Campion and Lake Eda) on Roebuck Plains are nationally important wetlands. There has been a recorded presence of more than 45 EPBC[13] Act listed migratory bird species, with a subset of these (20 species) occurring regularly (Watkins and Jaensch, 2007). At least three species of migratory shorebirds occur in internationally important numbers (Little Curlew, Oriental Plover and Oriental Pratincole). The lease also has a recorded presence of two nationally threatened species (Australian Painted Snipe and Greater Bilby). The lease is adjacent to the Roebuck Bay Ramsar Site (Watkins and Jaensch, 2007).

A recent report which assessed the environmental values of the lease with a specific focus on bird populations made a number of recommendations for management (Watkins and Jaensch, 2007). These primarily were orientated around maintaining good ground cover in order to provide suitable habitat and to prevent further alterations of the drainage pattern of the floodplain. Issues such as monitoring the ground water level and construction of new watering points were also raised as concerns in the report (Watkins and Jaensch, 2007).

Figure 29: Hann River, Mount Barnett

MB has one ecojunction which comprises a total of four land-systems and is located in the northwest section of the lease. It involves the confluence of the open woodlands of the Barnett Valley and the rugged sandstone-spinifex hills which shape the unique Manning Gorge. The riparian corridors of the Mount Barnett and Hann Rivers also support a diverse range of flora and fauna.

2.11 External influences that may limit scope for biosequestration

It was important to identify the location and the impact of influences that are external to the existing pastoral enterprise operations. Despite many external influences being outside the full control of a pastoralist (e.g. main road, gas pipe-line, mine exploration), it is necessary that they are recognised and considered in the planning and implementation of a carbon offset based enterprise.

[13] In 1999 the Australian Government adopted new legislation for environmental protection *(The Environment Protection and Biodiversity Conservation Act,* or "EPBC Act"). In 2003, the Act was amended to include new provisions related to heritage. These changes established a new heritage system to identify, protect and manage the natural, Indigenous and historic heritage values of places under Commonwealth Government ownership or control.

The Cheela floodplain has been impacted by the construction of the Nanutarra-Wittenoom sealed road and a 1 m levee bank which runs across the entire length of the lease. Previously the water would have shed off the hills and ranges in a diffuse manner across the Cheela floodplain and in major events this water would have reached the Hardy River. The concentration of the water into shallow floodways and into the Beasley River has caused canalisation and incised drainage channels. This causes the floodplain to drain far quicker than it would have in its natural state. A gas pipe-line dissects CP floodplain from east to west and this has caused minor erosion in isolated areas. There are seven small quarries scattered across the lease, generally to the north of the highway. These have caused minimal disturbance to operations and landscape processes. There has been a reasonable amount of exploration across the lease, but to date they have not had a major impact from this activity.

RP has significant external disturbances due to its close proximity to Broome and the fact that the Great Northern Highway dissects the lease. The disturbance is generally related to local townsfolk accessing the lease for recreational purposes without the permission of the manager. Issues such as arson, slaughter of livestock, damage/destruction of infrastructure and gates being left open are a common occurrence on RP. These disturbances result in significant financial costs and can cause stress for management. This level of disturbance may also restrict the potential management options. The Great Northern Highway runs directly through the middle of the floodplain, however the manager stated that it does not greatly impede the surface flow of water because the road base has a modest elevation. The Highway meets a T-junction to the north of the floodplain and then runs east through the northern end of the lease. Due to the sandy nature of the soil in the northern end of the lease, the highway has a limited impact on the surface flow in this area. It appears that the main channel of Deep Creek has been deepened by concentrating the flow to a narrow tract underneath the highway. This may have caused minor water starvation to higher areas.

The primary external influence on MB is the deliberate ignition of fires that can result in substantial removal of the standing biomass. The Gibb River Road dissects the western end of MB and therefore during the dry season there are a substantial number of tourists in the area. Manning Gorge is near the MB community and tourists pay a nominal fee in order to visit the Gorge and to camp the night. Generally these tourists respect the environment and cause minimal disturbance. The Gibb River Road itself is not an 'all-weather' road and therefore it generally does not impede the natural flow of water across the landscape. The presence of diamonds on the lease has resulted in a moderate level of mining exploration. This has principally been focussed in the eastern end of the Barnett Valley and has resulted in disturbances such as track erosion, localised clearing and quarrying.

2.12 Grazing management and stocking rates

Grazing is a major disturbance which can impact landscape processes. Grazing can have either a positive, benign or adverse impact on the pasture community and soil surface stability depending on how its frequency, intensity and timing are managed. This study collated detailed stocking rate records on an individual paddock basis from the three businesses. The period of time of stocking rate data varied between the three leases. The stocking rate records were uploaded into a geographical information system (GIS).

2.12.1 Cheela Plains

Prior to 1999, the accessible areas of CP were continuously, set-stocked and mustering generally occurred once a year. The breeders were scattered in multiple herds across approximately 188,000 ha of the lease. Between 1976 and 1983 the Cheela floodplain was virtually de-stocked because the pasture resource had been degraded to the point where it could no longer produce adequate forage. Watering points were at least 5 km apart which resulted in impacts characterised by the piosphere effect. In 1999, CP implemented a four-paddock rotation incorporating the entire Cheela floodplain. After less than 12 months, management observed ecological, production and logistical benefits of the four-paddock system and the paddocks were subsequently subdivided. In 2008 the rest-based grazing system involved 60 individual paddocks.

CP now generally runs multiple large herds (1000 breeders in each) within the grazing system. In addition to commencing rest-based grazing, controlled mating was introduced. The investment in bulls was reduced by 54% as the breeders were concentrated on less than a quarter of the original grazing area (Bartle, unpublished). Stocking rate adjustments on CP are now relatively easy as the cattle are mustered, numbers adjusted and back in the paddock within two to three days (Brennan, unpublished).

Agistment of cattle has proven to be a very useful strategy to opportunistically capitalise on the available feed supply. CP generally operates short to mid term contracts with agistment clients and this enables them to maintain liquidity in their livestock numbers should seasonal conditions deteriorate. CP also is placing a greater emphasis on trading cattle.

CP uses Grazing Charts™ to record the stock movements and stocking rates and these in combination with earlier stock journals were used to calculate stocking rates relative to the potential carrying capacity. From 1989 to 1998 the average stocking rate was 61% below the potential carrying capacity (PCC). Between 1999 and 2008 the average stocking rate for the period was 32% below the PCC. This equates to an increase of nearly double the stocking rate since the implementation of the rest-based grazing system. However, stocking rates were still maintained at a relatively low level across the lease. It has only been in the last few years were CP has exceeded its PCC. In fact only 11 out of the 70 paddocks on CP or 11% of the grazed area were above the PCC between 1999 and 2008.

2.12.2 Roebuck Plains

The majority of the RP floodplain is set-stocked. The majority of the sandplain areas of the lease have a relatively short grazing history. Watering points in the far eastern end of the lease were only installed in 1996 (Pauls bore, Fraziers bore and Moyers bore) and prior to this there was no livestock grazing in this area. The area to the west of this newly developed area (Kurrajong paddock) was rested from 2005 to 2007 and then restocked in 2008. The sandplain area to the northwest end of the least has never been grazed by livestock and it tends to burn almost every year. McCords paddock, which is north of the Great Northern Highway, has been rested from livestock grazing since 2007. The grazing system on RP is fairly simple and it has been developed to take advantage of the inherent resilience of the landscape. Breeders are generally run in the less productive sandplain areas to the eastern end of the lease. Weaners are removed and placed onto the floodplain.

Detailed stocking rate records on an individual paddock basis at RP were only able to be obtained for the period 2005 to 2009. However, records of total livestock numbers run across the entire lease were available between 1985 and 2007 (Figure 30). Up until 2001, RP has maintained relatively low stocking rates (Figure 30). More recently, 49% of the area of the lease has maintained stocking rates above the PCC. These paddocks have predominantly comprised of the Wanganut and Yeeda land-systems (*Acacia* sandplain). The higher stocking rates in the Wanganut and Yeeda land-systems have largely been able to be sustained due to the provision of an adequate supplementation program. This study used the combination of the individual paddock records and whole lease stocking rate values from RP as input into the statistical analyses and modelling detailed in Chapter IV.

2.12.3 Mount Barnett

In contrast to the more controlled grazing regimes at CP and RP, cattle on MB have been free to utilise the full extent of the Barnett and Police Valleys since it was first settled by pastoralists in 1910. The cattle tend to migrate to the 'highlands' during the wet season as mobility is restricted on the 'lowlands'. The highlands also provide a fresh pasture growth which can sustain moderate levels of animal production during the wet season. During the dry season the cattle progressively migrate with the availability of surface water towards the low lying areas of the valleys. The lack of paddocks and permanent watering points prevent the acquisition of detailed stocking rate records for defined areas on MB. Figure 30 illustrates that total stocking rates at MB up until 2007 have been below the PCC.

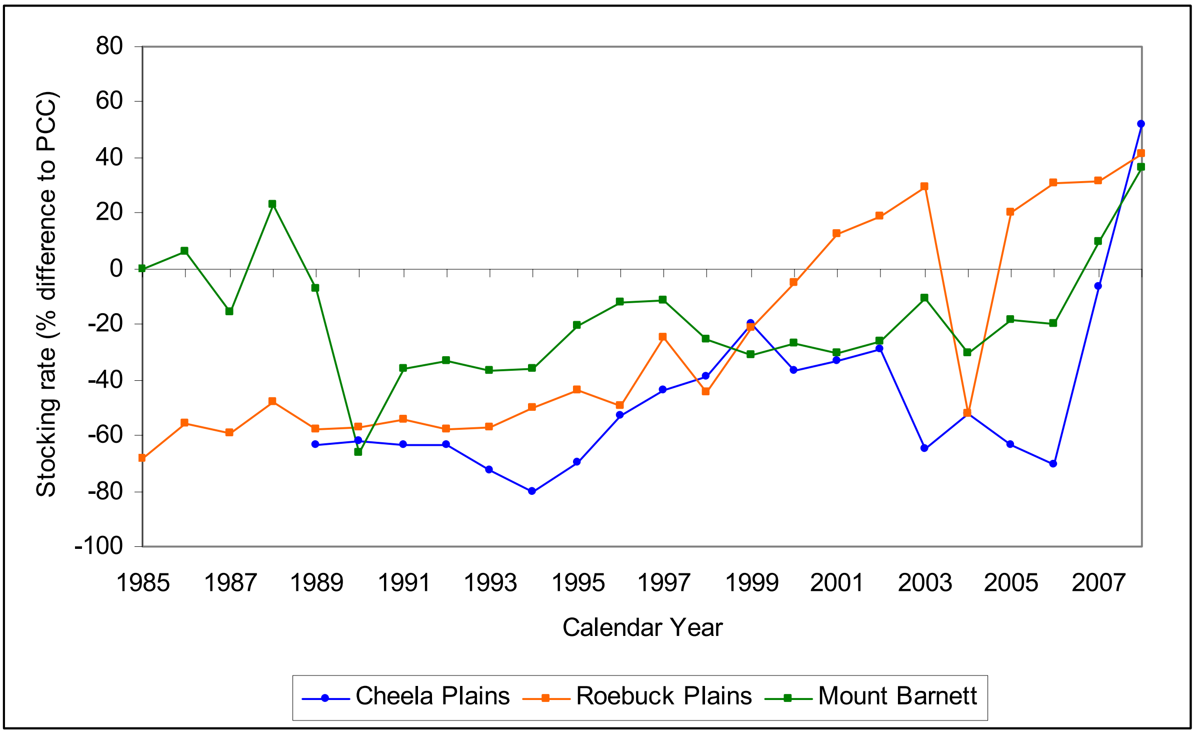


Figure 30: Difference between stocking rate and potential carrying capacity at the three leases between 1985 and 2007

NB: If values are below zero percent then the lease was likely to have been 'understocked' across the entire lease in that year. If the stocking rate value is greater than zero percent then the lease was likely to have exceeded their potential carrying capacity which is estimated by DAFWA surveys. Values were only available for years 1989 to 2008 at CP.

2.13 Financial profiles of case study businesses - benchmarking process

The project sought to obtain financial and livestock productivity data for the most recent five year period from the three case study businesses. The data was intended to provide a benchmark of performance which alternative management scenarios could be evaluated against.

Resource Consulting Services (RCS) was subcontracted by the project to complete the business benchmarking using their Profit Probe™ business analysis system (Figure 31). We compiled the required financial information with the case study businesses and forwarded it to RCS who analysed it using the Profit Probe™ system.

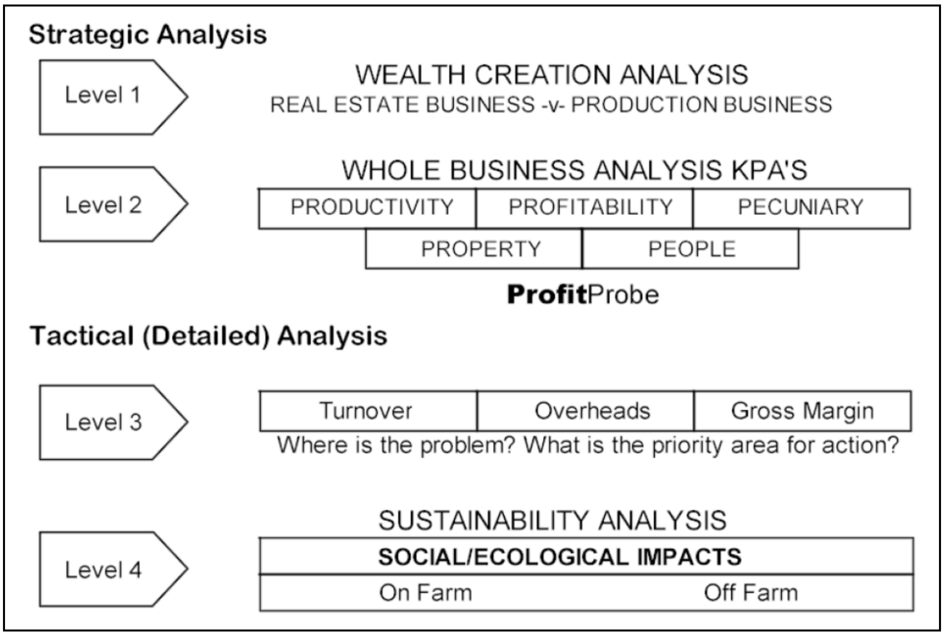


Figure 31: The Profit Probe™ business analysis system approach (Reproduced with permission from Resource Consulting Services, 2010)

CP had the most complete record of financial information available. Information for five financial years was obtained from CP (years included in the analysis were 2003/04, 2004/05, 2005/06, 2006/07 and 2007/08). Three years of detailed information was available from RP (financial years included in analysis were 2005/06, 2006/07 and 2007/08). Detailed information from MB was unable to be obtained in order for the business to undergo the Profit Probe™ analysis. However, information within a recent business plan prepared for MB (Shaw and Donation, 2008) was used in order to estimate the present productivity and profitability of the cattle enterprise.

Table 5 provides a selection of the key performance indicators (KPIs) that were calculated for CP and RP. Refer to Appendix 6 for a full list and description of the KPIs involved in the Profit Probe process™.

Table 5: Key performance indicators of case study businesses

	Cheela Plains average KPIs*	Roebuck Plains average KPIs**
1. Profitability (economics)		
Return on Assets (%)	0.3	1.2
EBIT ($/ha)	-0.1	1.5
Overhead ratio (%)	94.4	63.3
2. Productivity		
Meat produced (kg/ha)	3.8	6.7
Break Even ($/kg)	3.0	1.3
Meat costs ($/LSU)	155	95
Meat gross margin ($/ha)	2.8	2.3
3. People		
Gross product ($/FTE)	162,911	248,909
LSU managed per FTE	1098	2165
Training (days/FTE)	4	2
Holidays (days/FTE)	7	18
4. Profit drivers		
Meat productivity (kg/LSU)	63	76
Branding rate (%)	83	67
Mating ratio (%)	2	2
Death rate (%)	3.0	2.6

***Average based on Profit Probe™ data output 2003 and 2008.**
****Average based on Profit Probe™ output between 2005 and 2008.**

Output from the Profit Probe™ and information from the MB business plan (Shaw and Donation, 2008) were used to identify the key features of the existing cattle enterprises that are having a major influence on the productivity and profitability. These features included:

- **High overhead ratios**. The overhead ratio (overheads as a percentage of gross product) for both CP and RP are quite high, but for different reasons. CP actually has quite low overhead costs for the scale of its operation, however it is not producing enough sale cattle and/or running enough agistment cattle which would increase its gross product and reduce the ratio (effectively spreading the overhead costs over a greater number of 'units'). In contrast, RP has relatively high overhead costs due to the large amount of infrastructure and the number of staff it employs as a part of its pastoral and Indigenous training programs. To reduce its overhead ratio it could also increase the number of sale cattle and/or re-evaluate its future requirements for plant, equipment and permanent staff. For

MB to improve its existing enterprise we suggest that its overhead costs will need to be increased (*viz*. plant, equipment and infrastructure), however this will facilitate a commensurate increase in gross product.

- **High breakeven cost**. Compared to the benchmark CP and RP both had a high breakeven cost (breakeven cost is the total cost including direct and overheads excluding finance, tax and development to produce a kilogram of beef). To reduce the breakeven cost they could find efficiencies in their existing cattle enterprises and thereby reduce the direct costs (e.g. supplementation and mustering) and/or reduce overheads. The lack of infrastructure and regular management at MB results in minimal cost to the business. However, the profit-sharing arrangement that the business has with mustering contractor may result in the forfeiture of a significant amount of gross income.

- **Efficient use of labour**. CP and RP appear to use labour in an efficient and productive manner and there appears to be limited scope for improvement. The labour efficiency of MB could not be evaluated due to inadequate records.

- **Adequate productivity.** The results suggest that the herds on CP and RP are relatively productive. The branding and mortality rates are both average to above-average for the regions in which the businesses are located. Productivity (branding) could be improved on CP and RP in order to increase turnover. Based on previous records, we estimated that MB calving percentage was 45% for mature cows and 20% for maiden heifers. Mortality rates were estimated as 5%. Clearly, there is scope for improvement in the overall productivity of the MB herd. This could be achieved with higher management inputs.

2.14 Livestock methane, savanna burning and other greenhouse gas emissions of case study businesses

In the 2007 National Greenhouse Gas Accounts, livestock emissions were 69% of the total emissions produced by Australian agriculture. However, livestock emissions accounted for only 10% of the nation's total emissions. Furthermore, livestock in WA accounted for an estimated 6.3 Mt CO_2-e in 2007 or just 1.1% of the nation's reported greenhouse gas emissions (Department of Climate Change, 2009). Clearly, livestock make a relatively minor contribution to the national emission accounts; however they may be of higher importance to the overall GHG profile at the scale of an individual pastoral business. Consequently, it was important for this study to estimate the methane emissions from livestock and other greenhouse gases that are produced by the case study businesses. Methane is particularly harmful GHG because it has a global warming potential of 23 (see footnote[14]).

There is speculation that the current estimate of methane emissions from beef cattle in northern Australia is too high because the factors used in the accounting process are primarily based on intensive production systems (Charmley *et al*. 2008). Consequently, significant research is underway to improve the estimation of livestock methane emissions in northern Australia (Charmley *et al*. 2008; Kennedy *et al*. 2007). Preliminary results suggest that the emission factors may be lower than the those given in the IPCC guidelines (Bray and Willcocks, 2009). However, the data is yet to be verified and accepted by the administrators of Australia's national greenhouse gas accounts. Therefore, the methane emission and fossil

[14] Global warming potential (GWP) is a measure of the atmospheric heat-trapping ability of a given GHG expressed in terms of an equivalent amount of CO_2.

fuel conversion factors used in this study were those provided in the IPCC Guidelines (IPCC, 2006)[15]. These include:

- methane emissions for cows and heifers are 1.63 t CO_2-e head^{-1} yr^{-1} (based on 71 kg CH_4 head^{-1} yr^{-1} multiplied by a GWP of 23);
- methane emissions for bulls and steers are 1.40 t CO_2-e head^{-1} yr^{-1} (based on 61 kg CH_4 head^{-1} yr^{-1} multiplied by a GWP of 23);
- diesel emissions are 2.68 t CO_2-e litre^{-1}; and
- petrol emissions are 2.29 t CO_2-e litre^{-1}.

The data obtained from the Profit Probe™ benchmarking exercise was used to calculate the emissions from methane and fossil fuel use. The estimates are reported in Table 6.

Savanna burning plays an integral role in rangeland landscapes (Heckbert *et al*. 2009). Consequently, it is important to estimate the amount of greenhouse gases that are emitted from fire events on the case study businesses. CO_2 (carbon dioxide), N_2O (nitrous oxide) and CH_4 (methane) are gases that are emitted during fire events and are covered under the Kyoto Protocol. It should be recognised that the IPCC LULUCF (land use, land use change and forestry) Guidelines recommend that CO_2 emissions from savanna burning not be included in emission estimates, since it is assumed that an equivalent amount of CO_2 is removed by vegetation regrowth in the following year (Department Climate Change, 2007). However, this restriction does not apply to the emissions of other Kyoto-defined greenhouse gasses, namely N_2O and CH_4. Therefore, the emissions reported for savanna burning in this study only include N_2O and CH_4.

To estimate the N_2O and CH_4 emissions from savanna burning this study used the method outlined by the Department Climate Change (2007). This method outlines the process of accounting for GHG emissions from savanna burning at a jurisdiction level (e.g. WA *cf* NT). Consequently, the emission estimates should only be seen as indicative because there can be scaling issues when the method is used at an individual pastoral lease scale. Notwithstanding this limitation, for the purposes of this study the information required to make an estimate on an individual pastoral lease basis included:

- area of the lease which annually burns (averaged over 19 years of fire frequency data);
- fuel loads (mean amount of material that is available to be consumed by a fire event);
- burning efficiency (the proportion of material that is actually consumed in a fire event); and
- the composition of the biomass which is burnt and specific emission factors for each land type.

The area burnt was calculated on an individual pastoral lease basis from the fire frequency datasets that were reported in Section 2.8. Fuel loads and burning efficiencies were assumed to be constant from year to year and throughout the year (i.e. early, mid and late fire seasons) (Department of Climate Change, 2007). The estimates of fuel loads and burning efficiencies that were used in the calculations were those provided by the DCC (2007, p.59). These estimates are largely based on findings of studies completed by Meyer (2004) and Tolhurst (1994). Estimates of the composition of the biomass (i.e. the carbon mass fraction and the nitrogen to carbon ratio) are based on measurements from fires in Australia (Hurst *et*

[15] Methane emission factors for cows, heifers, steers and bulls were from Table 10A.2 (Oceania region selected) on page 10.73 of the IPCC Guidelines (2006).

al. 1994a,b; Carter and Henry 2003; Russell-Smith *et al*. 2004). Finally, the emission factors used in the DCC methods are derived from direct measurement of fire plumes from experimental savanna fires in the Northern Territory (Hurst *et al*. 1994a and 1994b).

Using the equations provided in the DCC methods (2007, p.61) we calculated the mass of fuel lost per annum and the contributions of N_2O and CH_4 in the total emissions that resulted from the fire events.

Table 6 provides a summary of the average annual methane and other GHG emissions of the case study businesses.

Table 6: Average annual livestock methane and other GHG emissions of the case study businesses

	Cheela Plains	Roebuck Plains	Mount Barnett
Livestock methane emissions (t CO_2-e)	3,490	31,828	2,889
Diesel emissions (t CO_2-e)	88,028	405,564	80,400
Petrol emissions (t CO_2-e)	0	47,077	0
Savannah burning (t CO_2-e) (inclusive of N2O and CH4 only)	1,113	25,748	17,221
Total (t CO_2-e)	92,631	510,217	100,510
Total per head (t CO_2-e)	42.5	25.4	54.4

Rounding errors may occur

One of the salient findings of the summary is that the consumption of diesel and petrol produces far more GHG emissions compared to livestock methane and savanna burning. This would suggest that investment and research efforts to reduce the emission profiles of the businesses should be principally focused on redesigning infrastructure and operations so as to reduce the dependence on fossil fuels. Given that the majority of the fossil fuel consumption on the pastoral leases is associated with carrying out routine checks of water storage and livestock, an emphasis on improving efficiency of these tasks should be a priority. For example, installation of telemetry technology to monitor waters and/or reducing the number of paddocks which are grazed at any one time to reduce the frequency of routine checks.

The large spatial size and scale of the cattle operation at RP results in it producing a considerable amount of emissions compared to the other businesses. However, on a per head basis, RP produces almost half the level of emissions compared to CP and MB. This suggests that RP may create less GHG emissions for every kilogram of beef it produces compared to the other two businesses. This significant difference is due to the fact that the diesel and fuel consumption at RP is able to be distributed across a greater number of cattle.

Up until recently, the three businesses produced their own electricity from diesel powered generators. CP and RP both now have solar powered generators which are able to produce a significant proportion of the base-load power, although at peak periods diesel generators are often used. Consequently, the consumption of diesel at CP and RP will decrease in the future. MB continues to use a diesel powered generator, although it may install a solar power generator in the future.

2.15 Conclusion

This chapter provided a background summary of the three case study businesses involved in the project. The information compiled from the natural resource inventories and financial profiles identified a number of key issues which influenced the design and delivery of the other two phases of the study, these include:

- The three leases all encompass large areas and this limits the sampling intensity and the ability to extrapolate carbon estimates with a high degree of statistical confidence.
- The intra and inter-annual rainfall is variable across all three case study businesses. This results in corresponding fluctuations in vegetative biomass and potentially the rate of biosequestration and emissions. Climate change is a factor which should be considered in carbon modelling and prediction processes given its potential to affect the biosequestration potential of the sites.
- RP has the highest proportion of land which has high pastoral potential compared to CP and MB (49.4%, 14.9% and 0% respectively).
- CP has the highest degree of heterogeneity (15 different land-systems) compared to RP (six land-systems) and MB (five land-systems). This may increase the level of complexity in the estimation of biosequestration on CP.
- RP and MB run the majority of their cattle on two different land-systems, whilst the CP grazing system includes five different land-systems. The leases comprise a mixture of open savanna, dense woodlands and stony ranges.
- CP and RP are relatively well developed with a considerable amount of permanent infrastructure. CP has scope to intensify through further subdivision of existing paddocks and the establishment of new water points. Similarly, RP has the opportunity to intensify its operations through subdivision of existing paddocks on the floodplain and developing new infrastructure in the less productive sandplain areas. MB has very limited infrastructure and compared to the other leases it has the greatest scope to increase its existing stocking rate.
- Fire is a regular and natural occurrence on all three leases and management can have an influence on its frequency, intensity and timing in order to mitigate emissions and increase biosequestration.
- There are large areas on all three leases which are susceptible to flooding and erosion. The areas on the leases that are presently degraded may prove to be the most advantageous from a biosequestration perspective.
- Vegmachine™ has highlighted key areas on the leases where major change in the total ground cover is likely to have occurred.
- The management history and availability of stocking rate and financial records from the leases varies considerably and this will have an impact on the accuracy of the final estimates of carbon stores.
- The present financial performance of the cattle enterprises at CP and RP is satisfactory. However, there is scope for improvement, particularly through increasing turnover and reducing overhead costs.
- Fossil fuel is the largest source of GHG emissions on all three pastoral leases.

Information collated in this chapter indicated that the case study businesses have the capacity and flexibility to change their existing management practices and/or land use. Changes in management practices and enterprises may impact on the present rates of biosequestration across their leases. Clearly, the magnitude of change in biosequestration rates and the associated financial benefits/costs will influence the rate of adoption of new enterprises and practices. Chapter III outlines the process used to estimate the existing levels of carbon in the soil and vegetation on each of the leases.

CHAPTER III – OVERVIEW OF CARBON ACCOUNTING METHODOLOGY

> "There is considerable potential for biosequestration in rural Australia. The realisation of this potential requires comprehensive emissions accounting" (Garnaut, 2008).

Robust estimations of carbon levels in rangeland environments is currently both expensive and time-consuming. The remoteness and large geographical area of the rangelands partly explain why the majority of the accounting effort to date has occurred in the more intensive agricultural and forestry regions of Australia. Nonetheless, if the potential of the rangelands as a carbon sink is to be fully examined, then we have to be able to accurately measure changes in carbon levels in a statistically rigorous, transparent and cost-effective way.

This chapter outlines the carbon accounting methodology that was used to baseline the three businesses as a part of Phase II of this study. Specifically, this chapter includes details related to:

1. Site selection and design of the carbon accounting survey
2. Site design and sampling protocol of individual carbon pools
3. Calculation of carbon estimates
4. Statistical analysis and reporting of the results

The sampling design and protocols used in this project were based on the guidelines in the relevant NCAS Technical Reports. The main reports included:

- *NCAS Technical Report 14 - Sampling, Measurement and Analytical Protocols for Carbon Estimation in Soil, Litter and Coarse Woody Debris* (McKenzie *et al*. 2000)
- *NCAS Technical Report 31 – Protocol for sampling tree and shrub biomass* (Snowden *et al*. 2002)
- *NCAS Technical Report 44 – Spatial estimates of biomass in 'mature' native vegetation* (Raison *et al*. 2003)
- *NCAS Technical Report 25 – Review of unpublished biomass related information: Western Australia, South Australia, New South Wales and Queensland* (Grierson *et al.* 2000)

Local adaptation in some instances was required where the NCAS reports were not overly explicit in the specific detail of the protocols or where modifications needed to be made in order for it to be relevant to a rangeland environment. The specific details of these modifications were peer reviewed via two workshops with key personnel from the CSIRO Sustainable Ecosystems group in Darwin and the Queensland Department Natural Resources and Water in Brisbane[16].

[16] Workshop participants included: Dr. Gary Cook, Dr. Richard Williams, Dr. Anna Richards, Dr. Adam Liedloff, Dr. Alan Anderson, Jon Schatz (Darwin). Dr. Ram Dalal, Dr. Diane Allen, Dr. Steven Bray, Grant Fraser, Grant Stone (Brisbane).

3.1 Site selection and design of the carbon accounting survey

To account for the significant heterogeneity on the pastoral leases the carbon accounting survey was based on a stratified random sampling approach. The sampling sites were stratified based on land-system. Four land-systems from each of the pastoral leases were selected to be sampled (12 land-systems in total). The land-systems chosen to be surveyed had to comprise a proportionally large area on the lease and/or they had to be areas which were actively managed (which usually meant that they were of moderate to high pastoral potential). The survey was designed to baseline the various carbon pools at a total of 100 sites per lease (25 sites per land-system).

Figure 32: ATV and quad motorbikes were used to access most sites

The locations of the sites were randomly selected across the lease by a GIS technician. Sites were located at least 500 m from access tracks and permanent watering points. An emphasis on the survey design was to achieve a good distribution of sites across the full extent of the leases. To achieve optimal logistical efficiency, sites were often clustered in a series of four to five sites, A distance of at least 1 km between sites was maintained. The GPS coordinates of the sites were provided to the survey team and an activity schedule was drafted for each lease. Due to poor access and logistical constraints the final number of sites which were actually sampled varied to the original design for a number of the individual land-systems. Table 7 presents the total number of sites which were sampled on the three leases. In some instances the pre-selected sites were relocated because they could not be accessed by the survey team (e.g. site was located on the side of a gorge or a stream dissected the site). Furthermore, some of the sites were relocated by the survey team because the field technicians made an assessment that the sites had been severely compromised by anthropogenic disturbances (e.g. access track, quarry). Across the three leases, a total of seven pre-selected sites were relocated by the survey team.

Table 7: Distribution of sampling sites within the carbon accounting survey

Business	Land-system	No. sites
Cheela Plains	Boolgeeda	28
	Capricorn	25
	Cheela	25
	River	26
	TOTAL	**104**
Roebuck Plains	Carpentaria	10
	Roebuck	30
	Wanganut	31
	Yeeda	32
	TOTAL	**103**
Mount Barnett	Buldiva	29
	Karunjie	18
	Kennedy	24
	Pago	16
	TOTAL	**87**

Figure 33 provides representative photographs of the different 12 land-systems surveyed in this study.

Boolgeeda land-system – Cheela Plains | **Capricorn land-system – Cheela Plains**

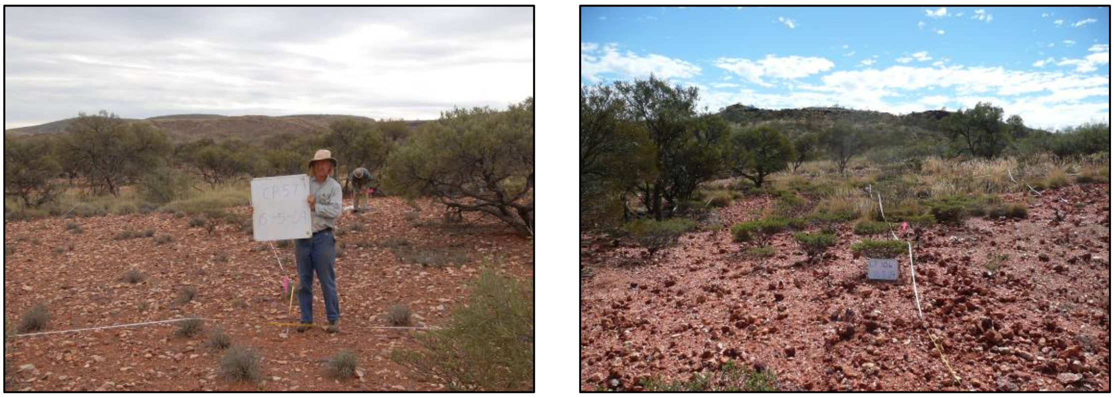
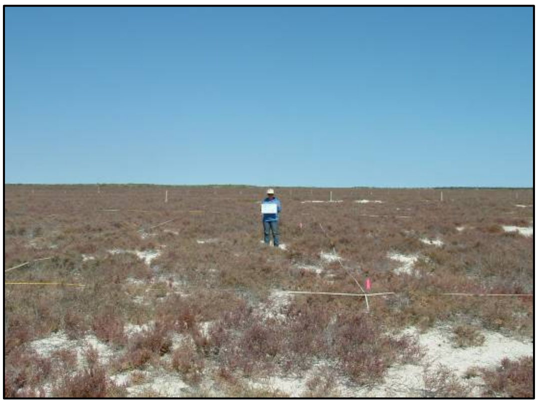


Figure 33: Land-systems included in the carbon accounting survey

Cheela land-system – Cheela Plains

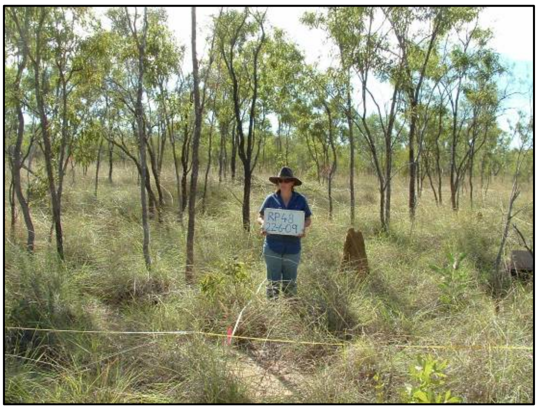
River land-system – Cheela Plains

Carpentaria land-system – Roebuck Plains



Roebuck land-system – Roebuck Plains

Wanganut land-system – Roebuck Plains



Yeeda land-system – Roebuck Plains

Buldiva land-system – Mount Barnett

Karunjie land-system – Mount Barnett

Figure 33 (continued): Land-systems included in the carbon accounting survey

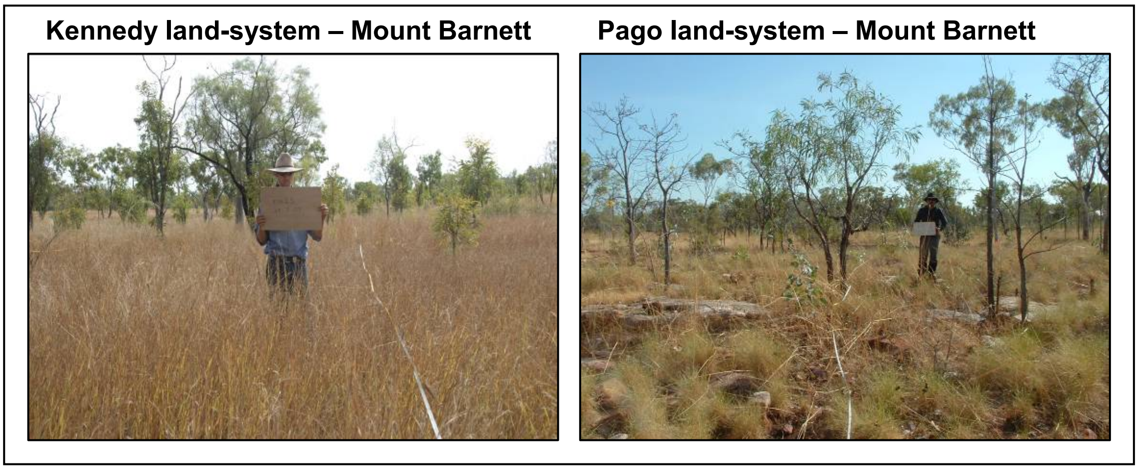


Figure 33 (continued): Land-systems included in the carbon accounting survey

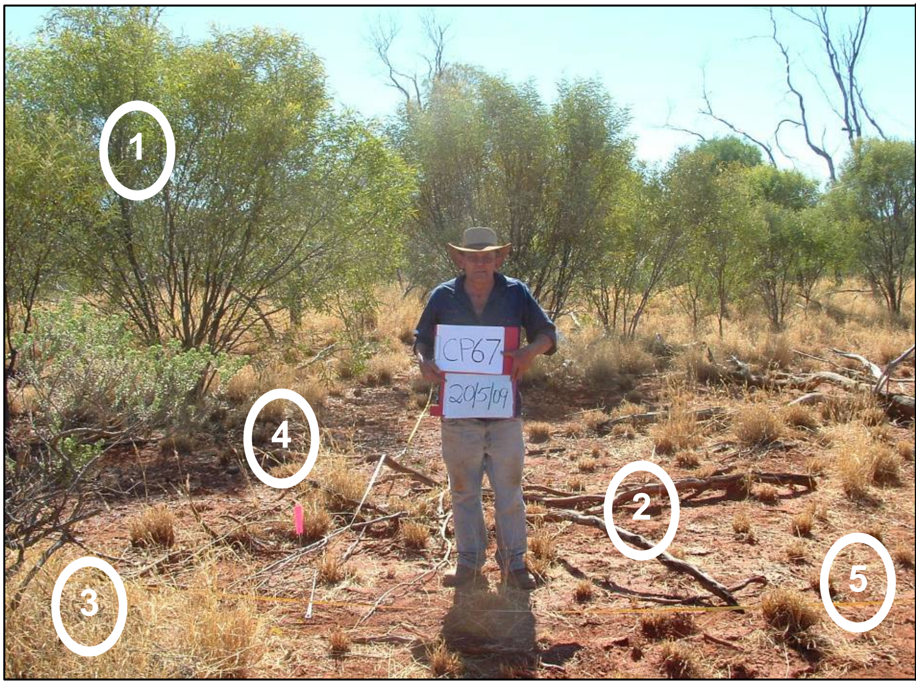
3.2 Site design and sampling protocol of individual carbon pools

Each site was 25 x 25 m which conforms to the Australian map grid. This grid size was selected as it was envisaged that resampling of the sites could assist in the calibration of satellite imagery for the local region. The grid is also sufficient in size to limit the significant variation that is known to occur at a patch scale (< 5 m^2) in the rangelands (Alchin, in press). The description of the soil profile characteristics for each site was obtained from the appropriate Land Survey Bulletin (Van Vreeswyk *et al.* 2004a, Speck *et al.* 1960). The preselected GPS waypoint was the centre of a site.

It was important that there were clear boundaries between the different carbon pools so that when the estimates of the total carbon were derived all sources of carbon were counted and no pool was counted more than once (Snowden *et al.* 2002). The carbon at a site was partitioned into five major pools (Snowden *et al.* 2002):

1) Woody plant carbon (inclusive of aboveground and belowground living and dead woody biomass)
2) coarse woody debris (CWD)
3) standing herbaceous material
4) herbaceous surface litter
5) soil carbon

Figure 34 depicts the different carbon pools in the field. At each site measurements were taken in order to derive an estimate of the amount of carbon in each of these pools.



1. Woody plant carbon
2. Coarse woody debris
3. Standing herbaceous material
4. Herbaceous surface litter
5. Soil carbon

Figure 34: Partitioning of the carbon at survey sites

The following sections provide a summary of the carbon accounting protocols for each of the pools.

3.3 Woody vegetation carbon

Woody carbon biomass, and subsequently carbon storage, of individual trees and shrubs can be estimated by applying pre-determined statistical relationships to simple tree measurements such as stem diameter and tree height (Snowden *et al*. 2002). A total of three 25 m x 1 m belt transects were undertaken per site to measure the individual trees and shrubs. Figure 35 illustrates the layout of the belt transects at a site. The following measurements were taken for every tree and shrub that exceeded 0.5 m in height and its trunk was within or partially within the belt transect[17]:

- Plant species name
- Basal width – measured at or as close as possible to ground level.
- Diameter at Breast Height (DBH) – measured at a height of 1.3 m. For multi-stemmed plants the DBH of each individual stem was recorded and summed. A notation was made on the recording sheet to indicate that this sample was multi-stemmed and hence a different allometric equation was applied.
- Crown width – the widest length of the canopy.
- Condition status – was the tree or shrub visibly alive or dead.
- Crown visibility (%) – based on photo-standards provided by McDonald *et al*. (1998).

Dead trees or shrubs that were no longer rooted in the ground were recorded as coarse woody debris. A total of 3,121 trees and shrubs were measured by the survey.

[17] If part of the basal area of a tree or shrub was within the belt transect then it was included.

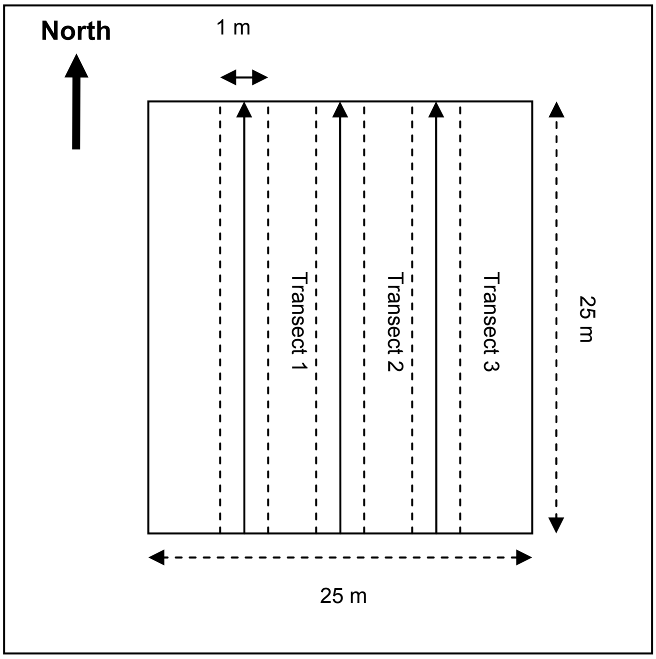


Figure 35: Layout of transects used to measure the woody plant carbon at a

The belt transects were also used to measure the percentage area of ground cover at a site[18]. The protocol for measuring ground cover was based on the Landscape Function Analysis (LFA) methodology (refer to Tongway *et al*. 2003 for details on LFA). The length of individual patch and interpatch types were recorded at each belt transect. Patches and interpatches were stratified into three major types: bare soil surface (includes rock); grass and litter; and shrub/tree patch. The lengths of the individual patch and interpatch types were summed for each transect and the percentage ground cover was calculated[19]. Figure 36 provides an example of the different patch and interpatch types that were recorded at the sites. An example of the recording sheet used for the belt transects is provided in Appendix 7.

The availability of adequate allometric equations for the survey regions meant that a limited amount of destructive sampling was undertaken. However, a total of 10 individual trees and shrubs (*viz*. *Eucalyptus tetrandonta*) were destructively sampled from the Kennedy land-system on MB. The destructive sampling was undertaken as outlined in Snowden *et al*. (2002). Subsamples of the leaves, branches and trunk of the trees were labelled and analysed for carbon and nitrogen at the ChemCentre laboratories.

[18] Ground cover in this study was defined as material (litter, grass tussocks, CWD, tree basal area) that provides direct protection to the soil surface. It does not include the cover that is provided by tree and shrub canopies that are suspended above the soil surface.
[19] Percentage surface ground cover = total length of grass/litter and shrub tree patch types / 25 m belt transect multiplied by 100.

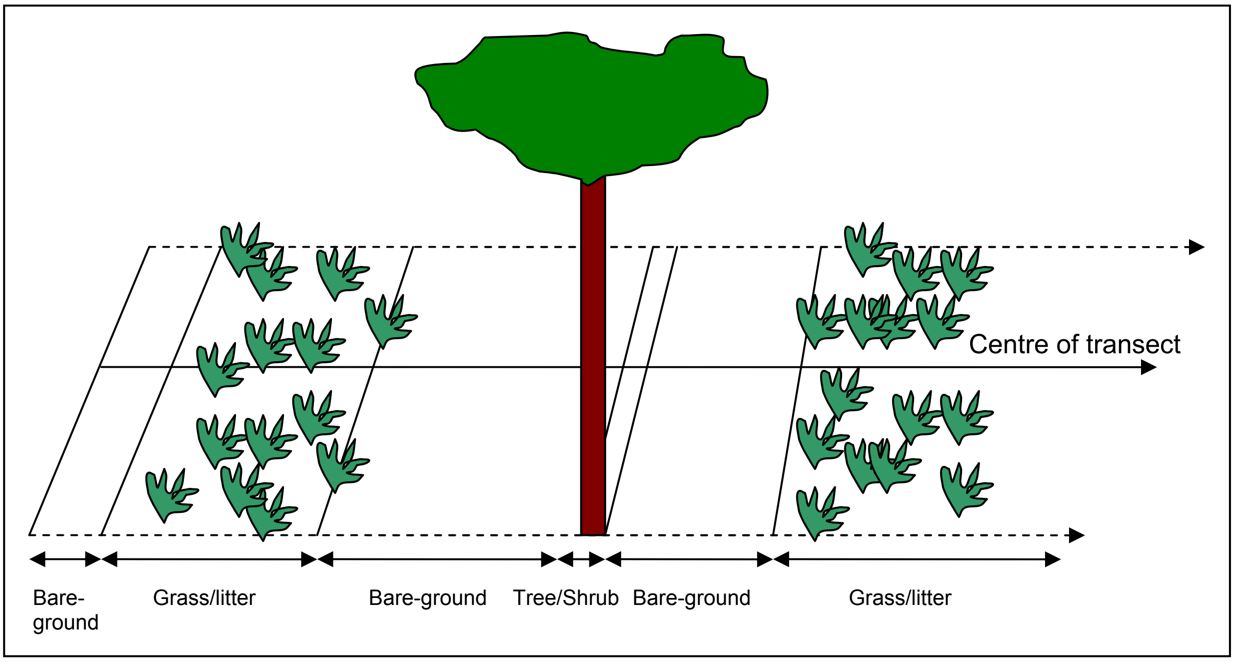


Figure 36: Protocol used to stratify different patch and interpatch types at a survey site

A fundamental tool in carbon accounting is tree-based allometry, whereby easily measured variables (such as DBH) can be used to estimated aboveground biomass (Williams *et al*. 2005). Adams *et al.* (2001) developed the allometric equations for the dominant tree species in the Pilbara region. Therefore, the dimensions of trees and shrubs from the CP transects were converted to plant dry weight (kg) using these allometric equations. These equations were in the form of:

$Y = aX + b$
Where 'Y' is the plant dry weight (kg) 'a' is a constant, X is canopy area (m^2) and B is a constant.

We recognised that the use of these equations required both length and width in order to derive the canopy area. We calculated canopy area by measuring only the crown diameter and assumed the trees had a circular shape. Consequently, this may result in an overestimation of the total woody carbon at the CP sites.

Robust allometric equations have been developed for the dominant tree species found in the northern savannas of Australia (Williams *et al*. 2005 and Williams *et al*. 2008). Eight equations have been developed and are able to be applied depending on the type of dimensions that are measured at a site (Williams *et al*. 2008). The following equation was applied to all the tree and shrub samples at RP and MB:

ln(total dry weight tree) = ln(diameter breast height) + constant.

Root:shoot conversion factors were used to calculate the biomass of the coarse and fine roots of the trees and shrubs (Mokany *et al*. 2006). For trees and shrubs at CP a conversion factor of 1.837 was used (Mokany *et al*. 2006; shrubland biome, p. 91). A conversion factor of 0.642 was used for trees and shrubs at RP and MB (Mokany et al. 2006; savanna biome, p. 91).

The aboveground and belowground estimates of dry weight were summed for all three transects at a site and were multiplied by 0.5 in order to derive the total woody carbon per site.

3.4 Carbon in coarse woody debris

Coarse woody debris (CWD) comprised logs, branches, stumps and large charcoal pieces on the soil surface that had a cross-sectional diameter of >25 mm (McKenzie *et al.* 2000). Pieces of CWD that were smaller than 25 mm were included within the herbaceous surface litter carbon pool. CWD was assessed at the sites using two different methods depending on the number of pieces of CWD at each site. At sites were there was ≤10 pieces of CWD, every piece of CWD had their dimensions measured to estimate total CWD volume per unit area (Method 1). The dimensions that were measured for each piece of CWD included (McKenzie *et al.* 2000):

- length;
- diameter;
- internal diameter (was required if CWD branch or log pieces were hollow, had gaps, or were eroded in order to subtract the missing volume); and
- condition status (i.e. was the CWD piece sound or rotten?; rotten CWD was determined by whether it could be dented with the heal of a boot).

A belt intersect technique was used at sites where there were >10 pieces of CWD (Method 2). This method involved taking the same measurements of every piece of CWD that intersected the centre belt transects (McKenzie *et al.* 2000).

Figure 37: Taking measurements along the belt transects

The decision concerning which method to use at a site was made by a visual appraisal of the site and if the assessor was unsure, they counted the pieces of CWD to determine if there was > 10. In situations where there was very long grass and it was difficult to visually appraise the site, assessors were encouraged to use Method 2. Assessors recorded which method they used to ensure the appropriate approach was used in calculating the estimate of CWD carbon for the site. Refer to Appendix 8 for an example of the recording sheet used to assess the CWD at a site.

To convert the CWD measurements that were taken using Method 1 into estimations of carbon on a per hectare basis the following calculations were made (McKenzie *et al*. 2000):

- Calculate the volume of each piece of CWD (cm^3) using the formula for volume of a cylinder ($\prod r^2 * H$).
- Convert the volume of each piece of CWD into mass of wood by multiplying by the appropriate woody densities.
- Carbon density was then calculated by summing the total mass of the pieces of wood and multiplying it by 0.5.
- Carbon density per hectare was then calculated by multiplying the carbon at the site ($kg/625\ m^2$) by 16.

The same procedure was used to calculate the CWD carbon at sites which used Method 2 (belt transect) except that carbon density was multiplied by 400. This was because the measurements were only taken from a 25 m^2 area not the whole site.

A total of 1,912 individual pieces of CWD were measured by the carbon accounting survey.

3.5 Carbon in standing herbaceous material and surface litter

The herbaceous component of a site varies quite considerably over time in response to seasonal conditions. The standing herbaceous material was defined as all the material at a site that was standing and was <0.50 m in height. Specifically, it included tree and shrub recruits, low shrubs, legumes and grasses. In contrast, herbaceous surface litter included all material that was on the soil surface. Surface litter comprised dead leaves, twigs, branches, insect detritus, animal scats, charcoal and other organic matter situated on the soil surface (McKenzie *et al*. 2000). Any woody debris with a diameter <25 mm was also included as surface litter.

To measure the standing material and surface litter, five quadrats (30 x 30 cm) were located along the centre transect at a site at distances of 5 m, 10 m, 20 m and 25 m The specific procedure involved:

- The quadrats were always on the left hand side of the tape.
- An assessment was made of the percentage of bare ground within each quadrat.
- An assessment was made of the percentage composition of the surface litter (grass material, tree leaves, manure, woody debris).
- All the standing material within the quadrat was clipped down to ground level and the material was placed into a labelled sample bag.
- All the surface litter within the quadrat was collected into a separate labelled sample bag. Any material that was hanging outside of the quadrat was trimmed off and disregarded.
- The samples were oven dried at 75°C for 48 hours and then weighed.

The dried weights of the herbaceous biomass were multiplied by 0.5 to convert them to estimates of carbon per unit area (Snowden *et al*. 2002). The belowground carbon per unit area of the standing herbaceous material was calculated by using a root:shoot ratio of 1:1 (Synman, 2009; Boot and Mensink, 1990). A total of 1,470 quadrats were measured by the carbon accounting survey.

3.6 Soil carbon

Soil carbon measurements were taken at five locations within each survey site (from the four corners and the middle). Samples were taken to a depth of 30 cm and included three intervals (0 to 10 cm; 10 to 20 cm; 20 to 30 cm). Preference was given for the sampling cores to be taken using a hydraulic drilling rig (Figure 38). However, where this was not possible due to access or logistical constraints, then a hand-held auger was used. The five samples from each interval at a site were bulked into a metal bucket and were mixed thoroughly before a subsample was scooped out and placed into a labelled bag. The soil samples were sent to the ChemCentre laboratories where they were oven-dried, sieved to 2 mm and analysed for total and organic carbon, total and organic nitrogen using the Walkley-Black Technique and the Leco Combustion analysis. The MB samples were also analysed for phosphorous.

Soil bulk density samples were taken from the centre of every survey site to the same depth and with the same intervals as the soil carbon measurements. The diameter of the bulk density rings was 50 mm and the height was 51 mm. The samples were placed in labelled bags and were oven-dried at 75°C for 48 hours and weighed. The following formula was used to calculate the bulk density of the samples:

Bulk Density: $D\ (g/m^3) = (W_2 - W_1) / V$
where
W_2 (g) = weight of oven dried soil and storage container
W_1 (g) = weight of storage container
V (cm^3) = volume of soil subsample interval

Soil carbon (t/ha) was then calculated by multiplying the percentage of organic carbon by the soil bulk density of the site. A total of 3,080 individual soil samples were taken as a part of the carbon accounting survey. 616 bulked samples were analysed for carbon.

Figure 38: Collection of soil samples from Roebuck Plains using a hydraulic drilling rig

At least two technicians were required to complete the measurements at each site. With two people it took approximately 1.5 to 2 hours to complete the woody carbon, CWD and standing herbaceous and surface litter assessments. This excludes commuting time between sites which typically was 30 min. Sites which had high densities of woody plants and CWD obviously took much longer to assess.

Sampling of the soil carbon and soil bulk density involved two technicians and it took approximately 30 min per site excluding commuting time.

We estimate based on the project financial record that the cost of obtaining the data was $688 per site. Approximately 60% of this cost was for salaries and the remainder was for operating expenses. We anticipate that subsequent carbon accounting surveys in the region could be delivered at a much reduced cost due to the technical and operational knowledge and experience that has been developed as a result of this project. However, the high cost per site does highlight the level of expenditure that is required due to the remoteness, ruggedness and large geographical area of the study region.

3.7 Statistical analysis

All data collected was compiled and thoroughly queried for obvious errors in a *Microsoft Access* database. Analyses were performed with GENSTAT 12th Edition™. Interrogation of the datasets primarily involved the use of one and two-way ANOVAS, regressions and general linear mixed models. Specific detail of the analyses is provided in Chapter IV.

3.8 Conclusion

The carbon accounting survey (Phase II) utilised a significant proportion of the resources and time allocated to this study. The survey of each lease took a minimum of three weeks to complete this period included the time associated with the transportation of field equipment and staff to the remote locations (in the case of CP the commuting distance was 2000+ km). A total of 294 sites were sampled in the carbon accounting survey. At each site the following procedures were taken:

- woody plant carbon (three 25 m x 1 m belt transects);
- coarse woody debris (every piece of CWD was measured or one 25 m x 1m belt transect);
- standing herbaceous matter and surface litter (five 30 x 30 cm quadrats per site);
- soil carbon (five 30 cm soil cores with three depth intervals); and
- soil bulk density (one 30 cm soil core with three depth intervals).

The data reported and discussed in the subsequent chapters of this report is based on:

- dimension measurements of 3,121 individual trees and shrubs;
- dimension measurements of 1,1921 pieces of CWD;
- 1,470 samples of herbaceous standing and surface litter; and
- 3,080 individual soil samples which were bulked and 616 were analysed for carbon and nitrogen.

The carbon accounting survey produced significant datasets, however we recognise that the area sampled only represented a minor component of the leases (<1% of the lease area). Therefore, the level of uncertainty in the carbon estimates and capacity to extrapolate the results over a large area are constrained by this issue of scale and sampling intensity. Nonetheless, the carbon accounting survey completed by this study demonstrated how the NCAS protocols can be applied in a rangeland environment to achieve an estimate of the main carbon pools. The data obtained from these surveys provides an adequate baseline from which changes in carbon levels due to management and seasonal conditions can be measured on the leases.

We expect that continued investment in carbon accounting in the Australian rangelands will progressively reduce the cost of the surveys as robust remote sensing tools are calibrated with comprehensive on-ground datasets. The development of remote sensing tools is integral to the potential commercialisation of carbon offsets in the Australian rangelands. A range of remote sensing tools and products have already been developed by both research and government organisations and the immediate opportunity is to have these tools available to the key stakeholders in the emerging carbon industry (*viz.* landholders, offset project developers and carbon brokers, Indigenous Land Councils, carbon offset investors and the relevant State and Federal government agencies).

CHAPTER IV – THE IMPACT OF GRAZING AND FIRE ON CARBON SINKS

> "Climate Change is such a dire problem that if we are to tackle it, optimism, entrepreneurial innovation, steadfast conviction and systematic changes in global, social and economic infrastructure must be combined in amounts never before orchestrated" (Vitale, B. 2009).

What is the baseline carbon level of a pastoral business in the Kimberley-Pilbara region? Can grazing management and controlled savanna burning increase baseline carbon levels? The impact of grazing management and controlled savanna burning on biosequestration in the soil and vegetation has been investigated by a limited number of studies (Derner and Schuman, 2007). There is evidence which suggests that grazing and savanna burning in the rangelands can have a positive, negative or benign impact on biosequestration depending on how they are applied across the landscape (Ash and Stafford Smith, 1996; Earl and Jones, 1996; Watson *et al.* 1997; Hodgkinson *et a*l. 1989; Heitschmidt *et a*l. 1989; Taylor *et a*l. 1997; McCosker, 2000; Savory, 1978; Sayre, 2001; Cooke *et al*. 2005, Williams *et al*. 2008; Heckbert *et al.* 2008; CSIRO, 2009).

To trade carbon offsets, landholders in the Kimberley-Pilbara region will require an accurate estimate of the baseline carbon and quantification of the impact of grazing and savanna burning. In this chapter we report the results from the carbon accounting field surveys and evaluate whether the previous grazing and savanna burning regimes have had an impact on the amount of carbon stored on the three case study pastoral leases. Specifically, we sought to address three primary questions:

1. What are the present baseline levels of carbon on the three pastoral leases?

2. What impact has the historical grazing and savanna burning regimes had on the baseline levels of carbon?

3. Are they any relationships between carbon levels and indicators of rangeland condition?

The carbon accounting methodology used to compile the results was provided in Chapter III.

4.1 Summary of baseline carbon levels at a whole lease scale

Table 8 provides a summary of the estimated baseline carbon levels on the three pastoral leases. The total values reported only include the land-systems which were surveyed in the carbon accounting field survey.

It was estimated that Cheela Plains (CP) had a total of 11,757 kt CO_2-e of carbon stored within the surveyed land-systems on the lease. The four land-systems on CP each made a reasonable contribution to the total baseline carbon levels. The majority of the carbon (68% of the total) on CP was stored within the Boolgeeda and Capricorn land-systems (stony plains, hills and ranges with spinifex grasslands). This is primarily a function of the larger area that these two land-systems covered and the significant amount of accumulated coarse woody debris (CWD). The value of CWD is demonstrated by the fact that this pool accounted for over half of the total amount of carbon stored in the Boolgeeda and Capricorn land-systems.

The Cheela land-system (alluvial tussock grasslands) had the highest amount of soil carbon compared to the other land-systems on CP. It is important to note that this approximation of the baseline carbon on CP significantly underestimates the total for the whole lease because only 39% of the total lease area was included in the calculations. The remaining area of the lease comprises of land-systems that were similar to the surveyed land-systems, however we considered that extrapolation of the estimates to these areas would have compromised the accuracy of the estimation.

It was estimated that Roebuck Plains (RP) had a total of 74,286 kt CO_2-e of carbon stored within the four surveyed land-systems on the lease[20]. The vast majority (>90% of the total) of the carbon on RP is presently stored in the Wanganut and Yeeda land-systems (*Acacia* sandplain). This is primarily because these two land-systems comprised over 84% of the total surveyed area and had large amounts of woody carbon. The *Acacia* sandplain land-systems included high densities of *Acacia* and *Eucalyptus* spp. which had an average woody carbon level of more than 190 t CO_2-e ha^{-1} (this is inclusive of above and belowground material). The absence of woody vegetation on the marine floodplain (Carpentaria and Roebuck land-systems) meant that the majority of the carbon in this area was stored in the soil. The variability in carbon levels in the *Acacia* sandplain land-systems was far higher than the marine floodplain land-systems.

It was estimated that Mount Barnett (MB) had a total of 28,125.9 kt CO_2-e of carbon stored within the four land-systems which were surveyed on the lease. The majority of the carbon (72%) on MB is presently stored in the Kennedy (open woodlands) and Buldiva (spinifex sandstone ranges and scarps) land-systems. The reason for this is similar to the other two leases, these two land-systems encompass the majority of the survey area (72% of the total) and they have a high density of woody vegetation. The presence of a significant amount of rock prevented soil sampling within the Buldiva and Pago land-systems (sandstone ranges and scarps with spinifex). Hence, it was assumed that there was no soil carbon within the Buldiva and Pago land-systems in the baseline carbon estimates. The results indicate that the Kennedy land-system stores the highest amount of carbon and this is primarily held in the woody and CWD carbon pools. The approximation of the baseline carbon levels on MB would be higher if the total lease area was included in the calculations. 6% of the lease area (or 7520 ha) was excluded from the calculations because it comprised of land-systems which were not included in the carbon accounting survey.

The relative standard error (RSE) is the standard error expressed as a percentage of the estimate itself and is used to highlight the level of uncertainty in an estimate. The RSEs for the 12 different land-systems across the three leases ranged from 3 to 69%. This primarily indicates that the carbon levels within some land-systems were more variable than in others. The RSEs for the three leases were all relatively similar and ranged from 28 to 35%. We expected this level of variability given the scale and intensity of the accounting survey.

[20] Please note one kilotonne is 1000 tonnes or 10^3.

Table 8: The estimated baseline carbon on three pastoral leases ± the standard error

Pastoral lease	Land-system	No. sites	Total (ha)	Estimated amount of carbon in various pools (kt CO_2-e)				Total carbon for surveyed lease area (kt CO_2-e)	Relative standard error (%)
				Soil C*	Woody vegetation**	Herbaceous vegetation***	Coarse woody debris		
CP	Boolgeeda	28	19,999	892.9 ± 46.3	588.8 ± 147.6	167.5 ± 58.8	2,288.4 ± 752.8	**3,937.7 ± 1,005.5**	26
	Capricorn	25	26880	711.4 ± 53.3	473.4 ± 146.0	654.4 ± 166.7	2,265 ± 1,218.4	**4,104.2 ± 1,584.4**	39
	Cheela	25	20802	1,251.4 ± 42.0	341.7 ± 100.8	151.6 ± 31.5	335.8 ± 180.9	**2,080.4 ± 355.1**	17
	River	26	6591	508.1 ± 23.8	618.8 ± 207.7	93.9 ± 11.9	414.9 ± 150.6	**1,635.7 ± 394.1**	24
	TOTAL	**104**	**74272**	**3,363.8 ± 165.5**	**2,022.7** ± **602.1**	**1,067.4 ± 268.9**	**5,304.1** ± **2,302.6**	**11,757.9 ± 3,339.1**	**28**
RP	Carpentaria	10	1599	149.1 ± 5.5	0 ± 0	20.6 ± 5.8	0 ± 0	**169.7 ± 11.3**	7
	Roebuck	30	42529	5,504.1 ± 119.8	0 ± 0	871.4 ± 83.8	699 ± 255	**6,376.3 ± 203.9**	3
	Wanganut	31	97278	4,540.3 ± 71.6	20,952.6 ± 9,099.9	1,347.8 ± 122.2	1,424.6 ± 227	**28,265.4 ± 9,520.9**	34
	Yeeda	32	141767	7,266.3 ± 125.1	27,449.3 ± 9,254.9	2,670.3 ± 253.3	2,089.6 ± 481.3	**39,475.5 ± 10,114.6**	26
	TOTAL	**103**	**283,173**	**17,459.8** ± 322.1	**48,401.9 ± 18,354.8**	**4,910.1** ± **465.2**	**3,514.9** ± **708.6**	**74,286.9 ± 19,850.7**	**27**
MB	Buldiva	29	58892	0 ± 0	8,132.1 ± 1,626.4	696.5 ± 80.8	541.9 ± 193.1	**9,370.5 ± 1,900.3**	20
	Karunjie	18	17542	700.4 ± 26.3	3,335.5 ± 1,152.4	221.7 ± 67.6	165.4 ± 88.9	**4,422.9 ± 1,335.1**	30
	Kennedy	24	28819	2,412.1 ± 66.1	6,386.6 ± 2,375.5	349.4 ± 45.9	1,622.4 ± 1,536.1	**10,770.6 ± 4,023.3**	37
	Pago	16	12530	0 ± 0	3,289.5 ± 2,370.0	142.9 ± 13.2	129.5 ± 72.9	**3,561.9 ± 2,456.2**	69
	TOTAL	**87**	**117,783**	**3,112.5 ± 92.4**	**21,143.6 ± 7,524.3**	**1,410.6 ± 207.2**	**2,459.2 ± 1,891.1**	**28,125.9 ± 9,714.9**	**35**

***Soil C results are based on a profile depth of 30 cm. **Woody vegetation is the total of the above-ground and below-ground carbon in trees greater than 0.5 m in height.**
*****Herbaceous vegetation is the total of the carbon measured as the standing material and surface litter (including belowground material).**
Shaded cells relate to the total estimate on a whole lease basis. Rounding errors may occur.

Figure 39 illustrates the contribution that each of the different carbon pools (soil, woody vegetation, herbaceous vegetation and CWD) makes to the total carbon levels on the three pastoral leases. There is a distinct contrast in the composition of total carbon levels between CP and the other two leases. CWD makes a much larger contribution to the CP total compared to the totals of RP and MB. Soil carbon is also a larger percentage of the CP total. In comparison, the woody vegetation pool comprises more than half of the total carbon stored at RP and MB. We suggest that this contrast is the result of differences in the inherent climatic conditions and existing fire regime between the three leases. CP has a relatively low and erratic rainfall compared to RP and MB. Therefore, there are lower fuel loads and a lower incidence of fire. This enables a significant accumulation of CWD on CP and when a fire does occur the vegetation can be restricted in its growth response by limited moisture. In contrast, RP and MB have a much higher annual rainfall which results in higher fuel loads and more frequent, intense fires. This prevents any substantial accumulation of CWD and the availability of adequate moisture and nutrients enables the fire-adapted vegetation to maintain a high amount of woody biomass. MB has a low proportion of soil carbon because it is dominated by large areas of sandstone ridges and scarps.

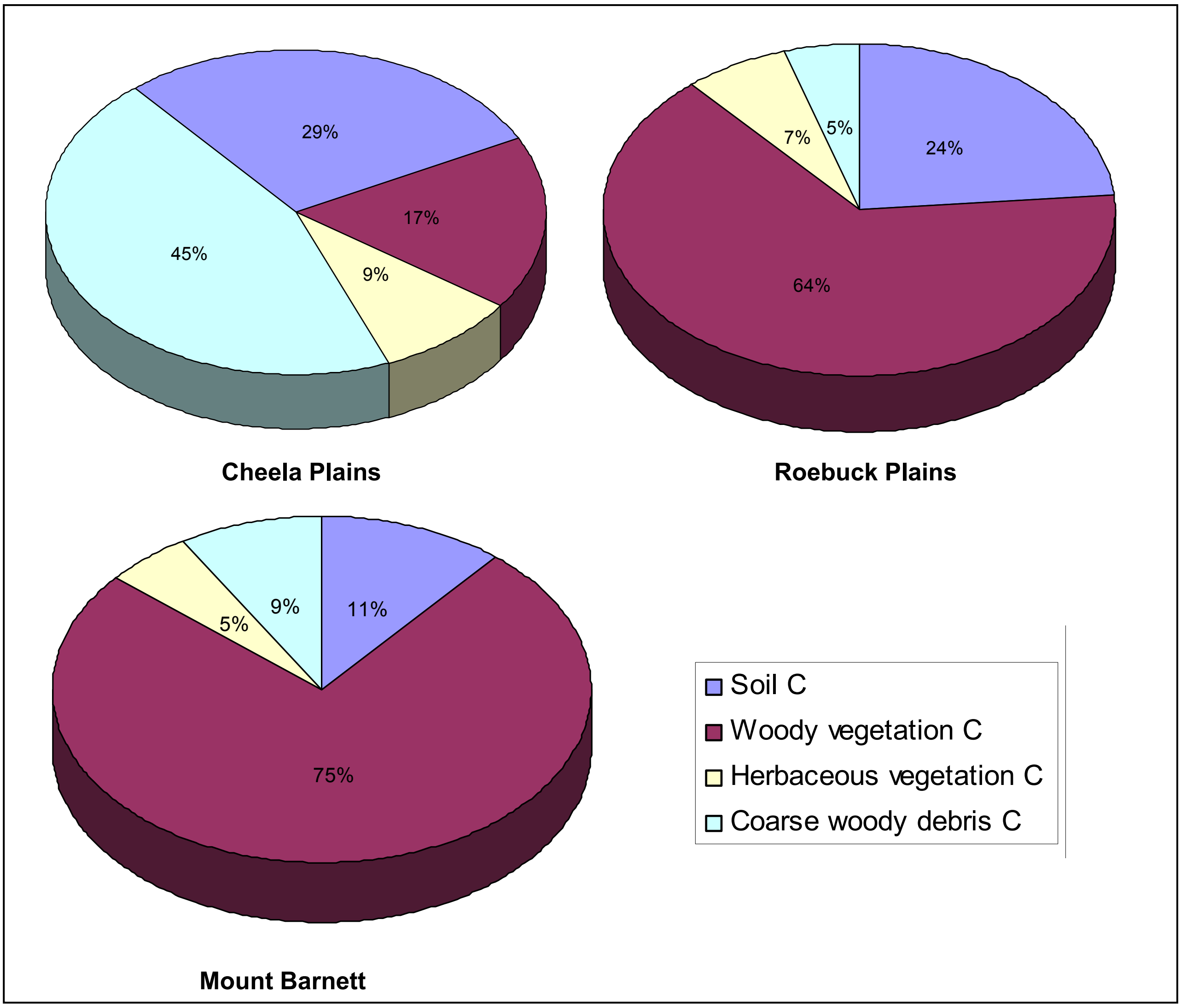


Figure 39: Composition of the estimated total carbon levels on the three pastoral leases

The baseline carbon results provide valuable information for the planning of management alternatives for the three case study pastoral businesses. The results highlight which land-systems presently store the most carbon, and the contribution of each of the carbon pools on a land-system and whole lease basis. This information was used to develop the management scenarios that were modelled in Chapter V.

4.2 Variation in carbon pools due to land-system

How much variation exists in the levels of carbon between different land-systems? An ANOVA was conducted in order to test for significant differences in total carbon levels (inclusive of soil, woody and herbaceous vegetation and CWD pools) between the 12 land-systems that were surveyed. The least significant difference (LSD) of the means ($P<0.05$) was calculated and used to determine whether the differences between the land-systems were significant. Figure 40 illustrates the differences in total carbon between the land-systems and the level of variability within each.

Based on a 5% LSD, the only significant difference was between the Cheela on CP (100 t CO_2-e ha^{-1}) and Kennedy on MB (373.7 t CO_2-e ha^{-1}) land-systems. The variation within the land-systems (expressed in RSE) ranged quite considerably from as low as 3% (Roebuck land-system at RP) to a maximum of 69% for the Pago land-system at MB.

The high variability within the carbon estimate of the Pago land-system was partly due to the fact that only 16 sites were used in the analysis. The limited variation within the carbon levels of the Carpentaria and Roebuck land-systems is probably due to the fact that their total carbon stores were largely comprised of soil and herbaceous carbon. These two pools typically were not as variable as the woody vegetation and CWD pools. A weak relationship was found between the amount of woody vegetation carbon within a land-system and the level of variation of the estimate ($R^2 = 0.44$). This result suggests that increasing proportions of woody vegetation within an area may increase the uncertainty of a baseline carbon estimate. This result would have been affected by the fact that the allometric equations used to derive the biomass estimates of the woody vegetation were not species specific. We would expect the variation of the woody carbon estimates to substantially decline if we had applied species specific allometric equations which were relevant for the study region.

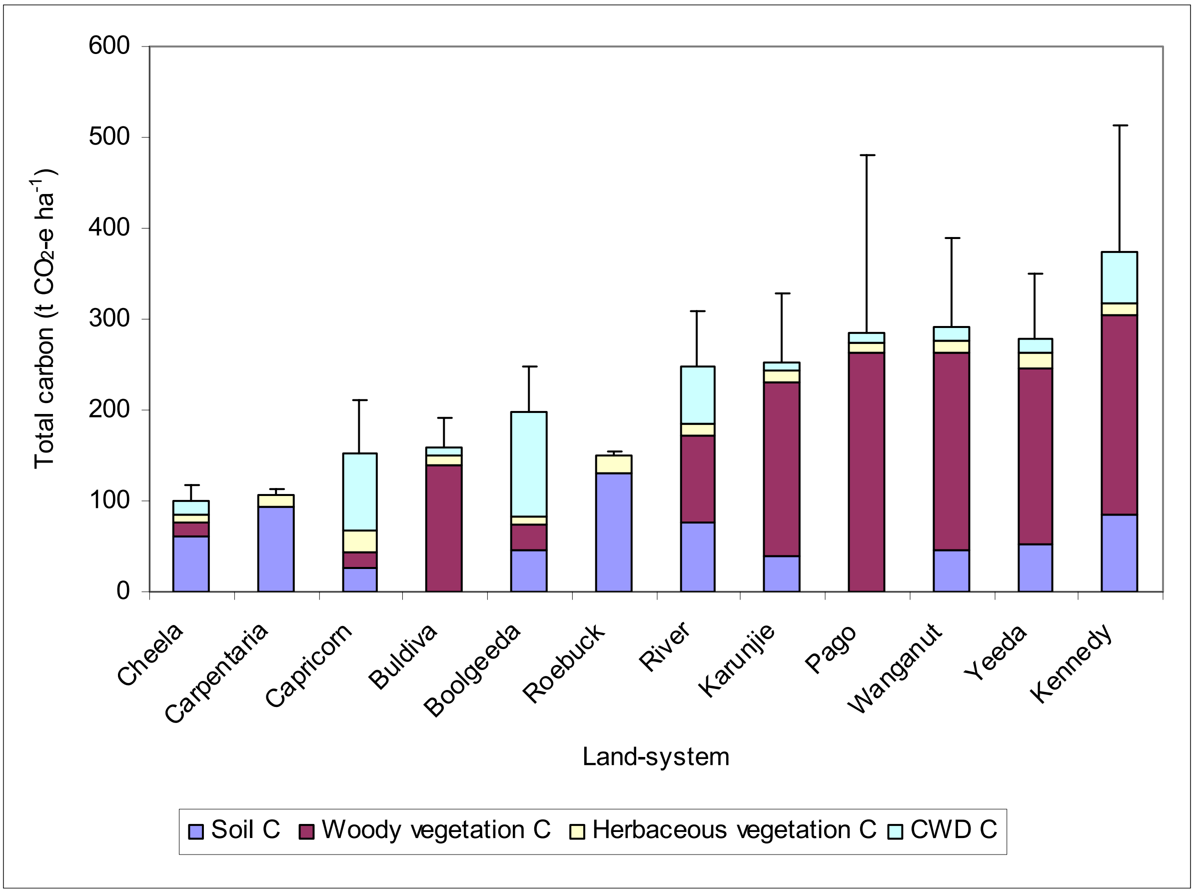


Figure 40: Variation in the estimated total carbon levels between different land-systems
Data shown are means with standard error bars.

The absence of a clear positive relationship (R^2 = 0.001) between land-systems with high pastoral potentials (i.e. high livestock carrying capacity) and high levels of carbon was unexpected. The results indicate that some of the least productive land-systems (Yeeda, Wanganut and Pago) had high levels of total carbon. This is largely explained by the high proportion of woody vegetation within these land-systems. The land-systems with the higher pastoral potentials (Kennedy, River, Roebuck, Carpentaria and Cheela) did have significantly more soil carbon ($P<0.001$) compared to the land-systems with low pastoral potentials. This result is consistent with other evidence which demonstrates a relationship between levels of soil carbon and pastoral productivity (Metherell *et al.* 1993; Gill *et al*. 2002; Del Grosso *et al.* 2008).

In summary, there were differences in the total carbon levels between some of the 12 land-systems surveyed in this study. The differences between the individual pools of carbon (i.e. soil, woody and herbaceous vegetation and CWD) were greater than the differences between the combined totals of the pools. Therefore, because the contribution that the four carbon pools make to the total varies between land-systems, we suggest that this knowledge could be integrated into the design of subsequent carbon accounting surveys. Practically, this may mean that the sampling intensity of the carbon pools which make greater contributions to the total carbon level may be increased at the expense of the pools which make the least contribution. The objective of taking such an approach would be to reduce the level of variation of the total estimate. The extent to which this approach could be applied will be influenced by the sensitivity of the individual carbon pools to the effects of management. The effects of stocking rate and fire frequency are examined in the following sections.

4.3 Impact of stocking rate on carbon pools

Do higher stocking rates result in less stored carbon? A number of comprehensive studies and reviews have investigated the potential impact that various stocking rates and grazing systems may have on vegetation and soil dynamics in rangeland landscapes[21]. None of these studies dealt explicitly with the impact of stocking rates on biosequestration. However, they do provide an understanding of the potential impacts of stocking rate on carbon levels because there is evidence that many of the parameters they used in their analyses (e.g. perennial ground cover, soil stability, soil infiltration and bulk density) are correlated with carbon (Alchin, in press). The majority of these studies concluded that increasing stocking rates caused negative impacts on the vegetation and soil environment. This is largely due to the fact that stocking rates were not aligned with the seasonal carrying capacity.

To determine whether stocking rate changed carbon levels on the three pastoral leases, a general linear model with step-wise forward and backward elimination was tested. In this analysis stocking rate was based on the percentage difference between the long-term stocking rate and the potential carrying capacity for a site. These differences were converted into a grazing index using a scale of 1 to 5 (1 = very high stocking rate and 5 = very low stocking rate). The factors (F) and variates (V) used in the model included: land-system (F), previous year fire history (F), historical stocking rate (V), long-term fire frequency (V) and total carbon (V). For full details of these parameters refer to Chapter III.

When all the sites from the three leases were collectively analysed (a total of 197 sites[22]), the model found significant differences in the total amount of carbon[23] at the sites due to stocking rate (P=0.012). However, there was no clear trend in the effect of stocking rate. Table 9 provides a summary of the total carbon level estimates based on the historical stocking rates and land-systems. The results indicate that for the majority of the land-systems, higher stocking rates did not result in reduced levels of carbon. In fact, it is difficult to draw any definitive conclusion from the results except that they suggest that stocking rate has not had a clear impact on the carbon levels on the leases.

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[21]References include: (Ash and Stafford Smith, 1996; Graetz, 1986; Hunt, 2000; Earl and Jones, 1996; Watson *et al.* 1997; Hodgkinson *et al*. 1989; Heitschmidt *et al*. 1989; Wilcox, 1973; Hart *et al.* 1993; Knight *et al*. 1980; Yan *et al*. 1996; Barnes and Denny, 1991; Taylor *et al*. 1997; Fuhlendorf and Smeins, 1999; Holm *et al.* 2003; Greene *et al*. 1994; Cipriotti and Aguiar, 2005; Jacobo *et al*. 2006; Anderson *et al*. 1996; Danckwerts *et al*. 1991; Chaieb *et al.* 1996; Dowling *et al.* 2005).

[22] Land-systems with two or less stocking rate classes were excluded from the analysis.

[23]Total carbon is the combination of the soil, woody and herbaceous vegetation and CWD pools.

Table 9: Effect of the historical stocking rates on the estimated total carbon levels (t CO_2-e ha^{-1})

	Historical stocking rate*				
Land-system**	**Very High**	**High**	**Moderate**	**Low**	**Very Low**
Boolgeeda		72.9 ± 43.2 n = 2	265.5 ± 63.5 n = 16	80.4 ± 16.4 n = 3	58.5 ± 10.8 n = 7
Capricorn			122.6 ± 45.9 n = 13	68.3 ± 12.8 n = 6	244.7 ± 127.6 n = 6
Cheela				103.6 ± 15.3 n = 14	83.6 ± 22.1 n = 11
River			249.6 ± 61.6 n = 9	222.1 ± 62.2 n = 12	201.8 ± 54.5 n = 5
Roebuck	145.8 ± 7.3 N = 24	111.4 ± 0.2 n = 2	193.8 ± 29.7 n = 4		
Wanganut		135.9 ± 20.3 n = 8		140.0 ± 17.2 n = 14	129.4 ± 44.3 N = 9
Yeeda	258.8 ± 58.3 n = 4	124.1 ± 22.7 n = 9	137.5 ± 24.2 n = 4	251.6 ± 8.5 n = 3	194.4 ± 27.5 n = 12

***Historical stocking rates are relative to the potential carrying capacity of the land-system (i.e. percentage above or below the PCC). **Land-systems with less than two different stocking rates were not included in the Table. Shaded cells indicate that no sites were surveyed with this combination of land-system and stocking rate. Mean total carbon levels, ± standard error and the number of samples are shown.**

The general absence of a distinct stocking rate effect was unexpected and is inconsistent with other studies which have reported significant effects (either positive or negative) on various biophysical properties of the soil and vegetation[14]. However, the results are somewhat confounded by inherent variation within the same land-system. Sites which had inherently more carbon (particularly soil carbon) probably support greater amounts of pasture production and therefore may have been disproportionately grazed (i.e. higher stocking rate class). Consequently, a greater residual amount of carbon may have enabled these sites to be grazed at high stocking rates for an extended period of time before the total carbon reached levels similar to sites which had lower residual levels and were stocked at lower rates. The extent to which this inference would apply is likely to be proportional to the level of inherent variation within each land-system. Hence, land-systems which have a higher degree of inherent variation (e.g. Capricorn, Pago and Kennedy) may have a higher propensity to be selectively grazed and therefore any stocking rate effect will be confounded. To prevent this from occurring it would be necessary to take repeated measurements from the same site over time and calculate the percentage change in carbon levels for a range of stocking rates.

Figure 41 illustrates the weak effect of the various stocking rates on the different carbon pools. Stocking rate did have a significant effect on the woody vegetation carbon pool (P=0.022). However, it is suggested that this trend is primarily due to the inherent pastoral potential of the sites. The sites which had a high density of woody vegetation generally provides less understorey pasture available for cattle grazing and therefore these sites were either not stocked or very lightly stocked. Stocking rate had no significant effect (P>0.05) on the other three carbon pools.

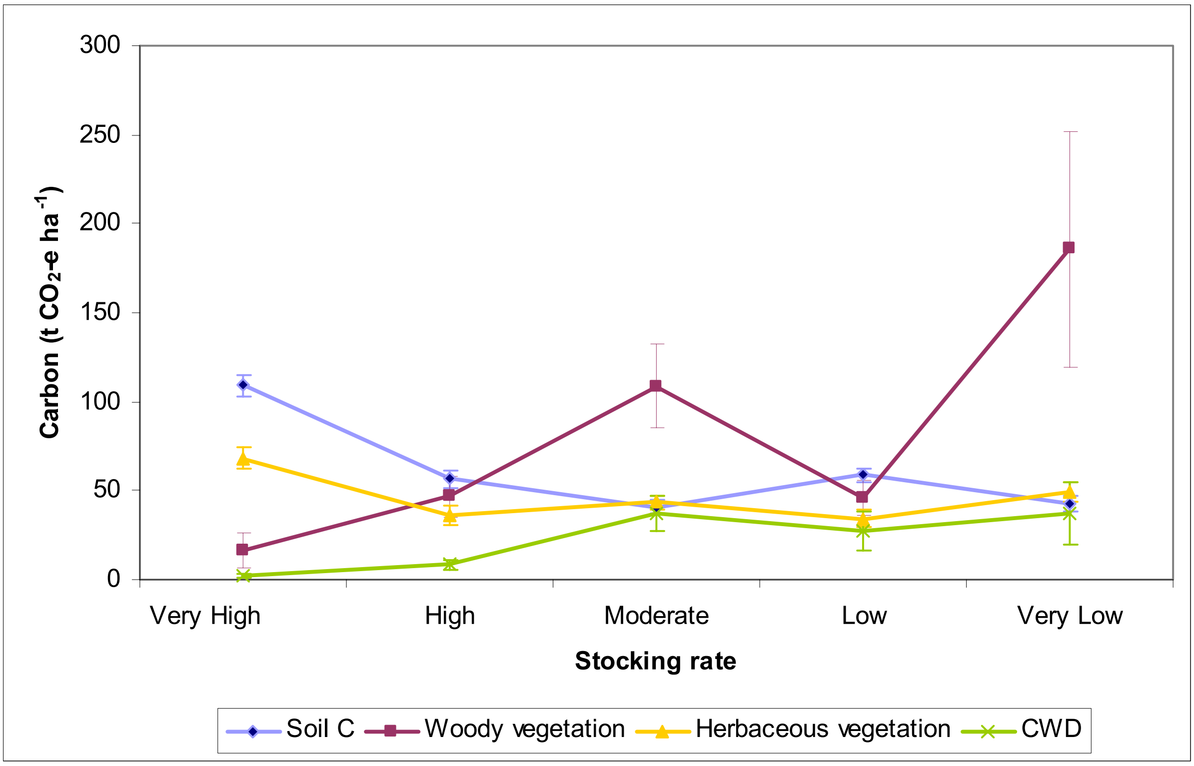

Figure 41: Effect of stocking rate on individual carbon pools
Data shown are means of all sites with standard error bars.

In summary, this study found that stocking rate did have a significant effect on the levels of total carbon. However, there was no clear relationship in the effect and the level of impact is likely to be land-system dependent. The inherent variation within each of the land-systems confounds the stocking rate effect and limits the conclusiveness of this finding. We recognise that is very problematic to detect clear stocking rate effects in a commercial scale environment. Repeated carbon survey measurements at paired sites over an extended period (5+ years) is likely to be the only way stocking rate effects can be detected in rangeland environments. The period would be much longer for semiarid environments (10+ years) due to the cyclical nature of the seasonal conditions.

4.4 Impact of fire frequency on carbon pools

Does increased fire frequency reduce the total carbon stored at a site? Savanna burning is an integral part of the landscape processes of northern Australia and therefore its behaviour, impacts and role in the region have been thoroughly investigated (Dyer *et al*. 2001). The majority of studies which examined the impact of savanna burning on stored carbon generally conclude that increasing fire frequency, fire intensity and unsuitable timing of fire can cause a reduction in carbon levels (Dyer *et al*. 2001; Williams *et al*. 2008).

To determine whether fire frequency had an impact on carbon levels on the three pastoral leases, a general linear model with step-wise forward and backward elimination was tested. Fire frequency in this study is defined as the number of fires which occurred between 1989 and 2008 (20 year time period). Fire frequency during this 20 year period across the 294 survey sites ranged from 0 (no fires) to 10 years (equal to a fire every second year). The factors (F) and variates (V) used in the model included: land-system (F), previous year fire history (F), historical stocking rate (F), long-term fire frequency (F) and total carbon at a site (V).

When all the sites from the three leases were collectively analysed, the model found that fire frequency had no significant effect on the total amount of carbon stored at a site (P=0.419). The model also indicated that there was no significant difference in the amount of carbon between sites which had either been burnt or unburnt in the year prior to when the survey was conducted (P=0.768).

It was expected that there would be an interaction between the land-system and fire frequency factors because some land-systems are known to have a higher propensity to burn than others (e.g. Wanganut *cf* Boolgeeda). However, no significant effect was found. Analyses which grouped sites based on an individual lease were conducted, but this had little effect on the significance level (P<0.05) of the fire frequency effect. Figure 42 illustrates the effect of fire frequency on the total carbon stored at the sites. No clear trend was able to be identified in the data. This suggested that sites which had a very low fire frequency had similar amounts of stored carbon to sites which had been burnt more frequently.

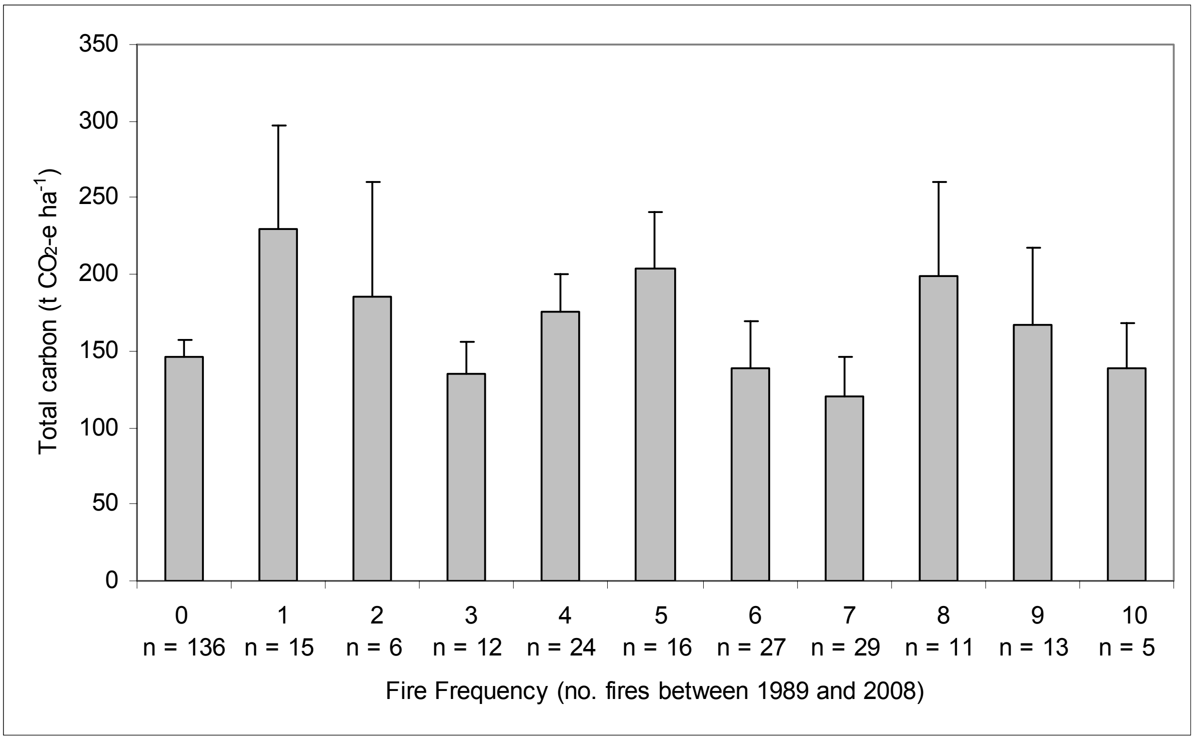

Figure 42: The effect of fire frequency on the estimated total carbon stores at survey sites
Data shown are means with standard error bars.

Analyses were conducted in order to determine if the effect of fire on total carbon was more pronounced in individual land-systems. The small number of sites in some of the fire frequency classes in certain land-systems limited the extent to which a definitive conclusion could be made. However, the Wanganut and Yeeda land-systems provided the most comprehensive dataset and the relationship was still not significant (P>0.05). The lack of significant effects due to fire frequency was unexpected and inconsistent with other studies which have demonstrated clear relationships between fire frequency and vegetative biomass and the soil environment (Williams *et al*. 2008). One would expect less carbon to be stored at a site if it is burnt more frequently, particularly if the fires were intense. Therefore, it was considered that the effect of fire frequency may be more evident in the individual carbon pools (soil, woody and herbaceous vegetation, CWD). Hence, these were individually analysed using the general linear model.

Fire frequency had no significant effect on any of the individual carbon pools (P>0.05). The soil carbon pool had the lowest P value (P=0.206) compared to the woody and herbaceous vegetation and the CWD pools (P=0.260, P=0.798, P=0.684 respectively). A P value of 0.206 is noteworthy, given the inherent heterogeneity of the survey environment and the sampling intensity of the survey itself (Speijers, *pers comm*. 2010). The P values of the soil and woody vegetation pools suggest that approximately 80% of the sample sites would indicate an effect due to fire frequency on these two carbon pools. Figure 43 shows the effect of fire frequency on the four carbon pools. The woody vegetation pool exhibited the most distinct trend (i.e. more carbon at a moderate fire frequency), however it also had the highest degree of variability. Figure 44 illustrates how the structure and density of the woody vegetation may have been affected between sites due to fire frequency in the Wanganut land-system on RP.

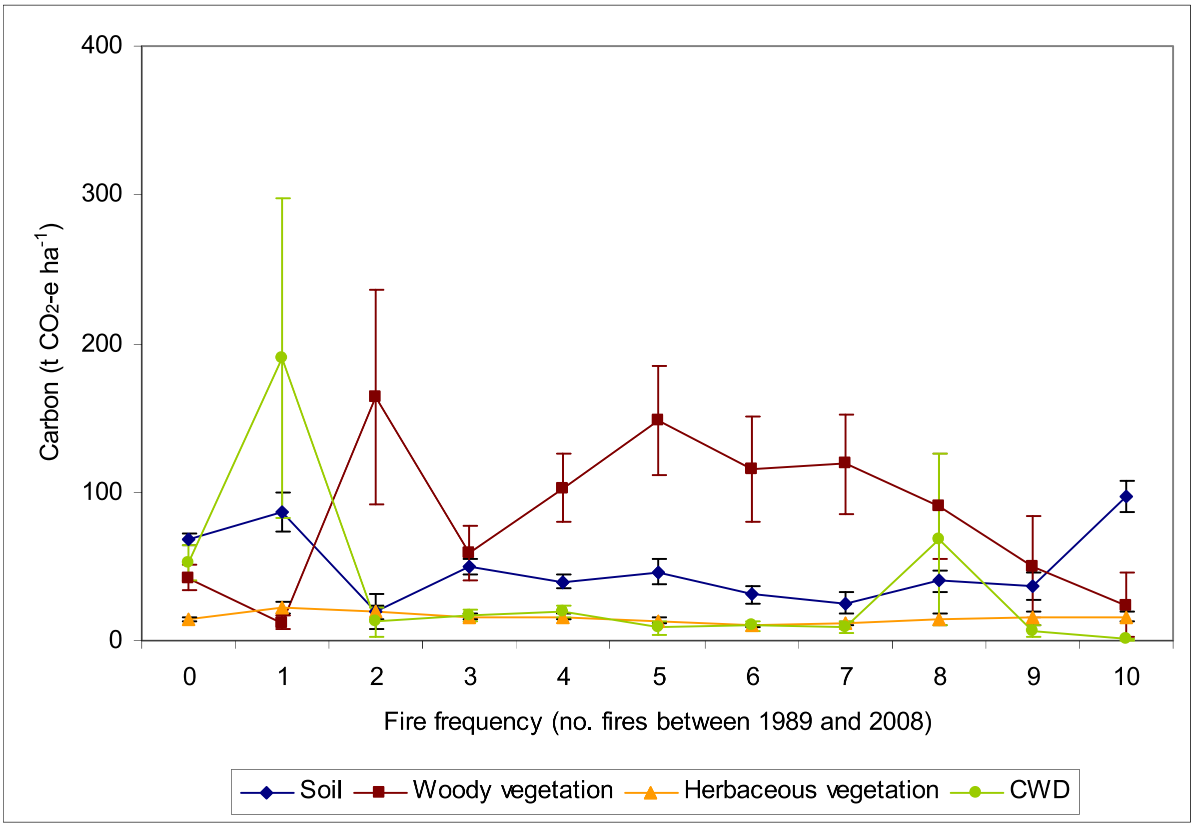

Figure 43: Effect of fire frequency on individual carbon pools

Top left:
Site RP46 with ‘low’ fire frequency – 48.6 t CO_2-e ha^{-1} woody carbon

Above:
Site RP51 with ‘moderate’ fire frequency – 100.6 t CO_2-e ha^{-1} woody carbon

Left:
Site RP70 with ‘high’ fire frequency – 34 t CO_2-e ha^{-1} woody carbon

Figure 44: *Acacia* sandplain (Wanganut land-system) sites on RP with low, moderate and high fire frequencies NB: Low, moderate and high fire frequency equates to 0, 4 and 8 fires between 1989 and 2008 respectively (or 0%, 20% and 40% incidence of fire).

In summary, this study was unable to find any significant effects due to fire frequency on the total amount of carbon stored at the survey sites when tested at the 95% confidence level. The study also found that the most recent fire history (i.e. had the site burnt in the year prior to the field survey) did not effect the carbon levels at a site. This does not necessarily mean that different fire frequencies have had no effect on carbon levels at the sites. Rather, the lack of distinct effect may be caused by a combination of the following factors:

- the scale and sampling intensity of the field survey may have been inadequate in order to cope with the inherent heterogeneity in the land-systems;
- fire intensity and timing of the burn (early dry *cf* late dry season) may have a greater influence on levels of carbon than fire frequency (the absence of data on these two factors prevented any exploration of this issue); and
- the vegetation dynamics may change in such in a way which enables the ecosystem to compensate for any major carbon losses that may result from fire (e.g. frequent fires may promote fire adapted species which can biosequester equal amounts of carbon compared to species which are unadapted to fire due to a less frequent fire regime).

Despite the result not being statistically significant, we suggest that a moderate fire frequency (a fire every four to fire years) could result in higher levels of stored woody carbon. This is due to the fact that a moderate fire frequency may limit the number of severe, intense fires through the regular consumption of the accumulated fuel load whilst allowing the vegetation community to reach maturity and escape the ‘fire trap’. In reaching maturity, most vegetation communities will store a significant proportion of the carbon in large wood (> 100 mm width) which is less volatile and therefore can persist in the ecosystem for much longer.

4.5 Change in soil carbon with profile depth

Studies have shown that the majority of the carbon in the soil is stored in the top 10 cm. This is because this zone (A1 soil horizon) is the most biologically active (McKenzie *et al*. 2004). A reduction in the amount of soil carbon with profile depth was observed in all the land-systems which were surveyed in this study. The decline with profile depth was more pronounced in some land-systems than in others. Figure 45, 46 and 47 illustrate the change in soil carbon with profile depth for the CP, RP and MB land-systems respectively.

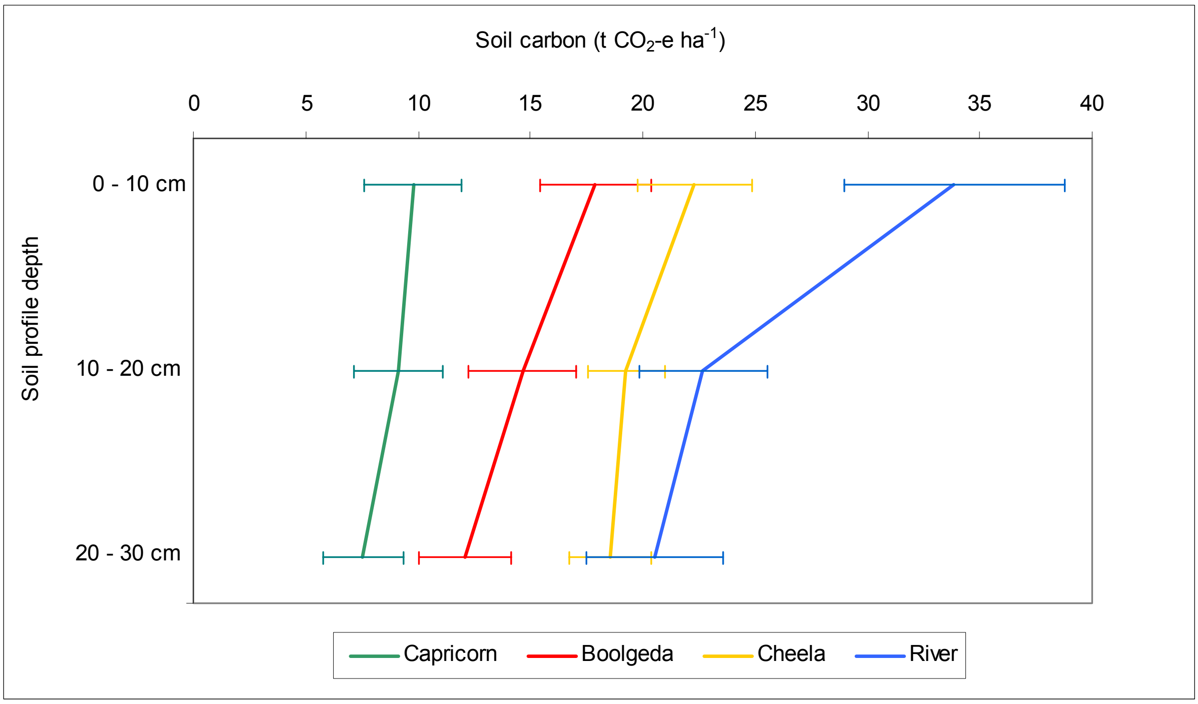

Figure 45: Change in soil carbon with profile depth of the CP land-systems
Data shown are means with standard error bars.

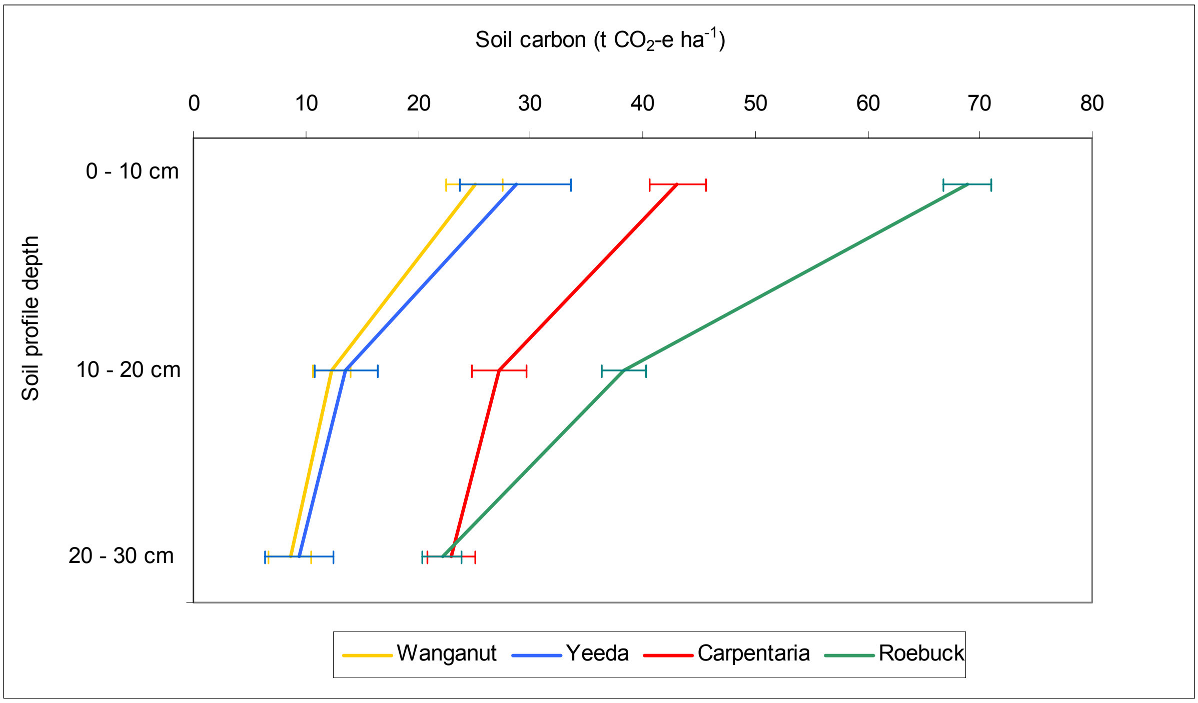

Figure 46: Change in soil carbon with profile depth of the RP land-systems
Data shown are means with standard error bars.

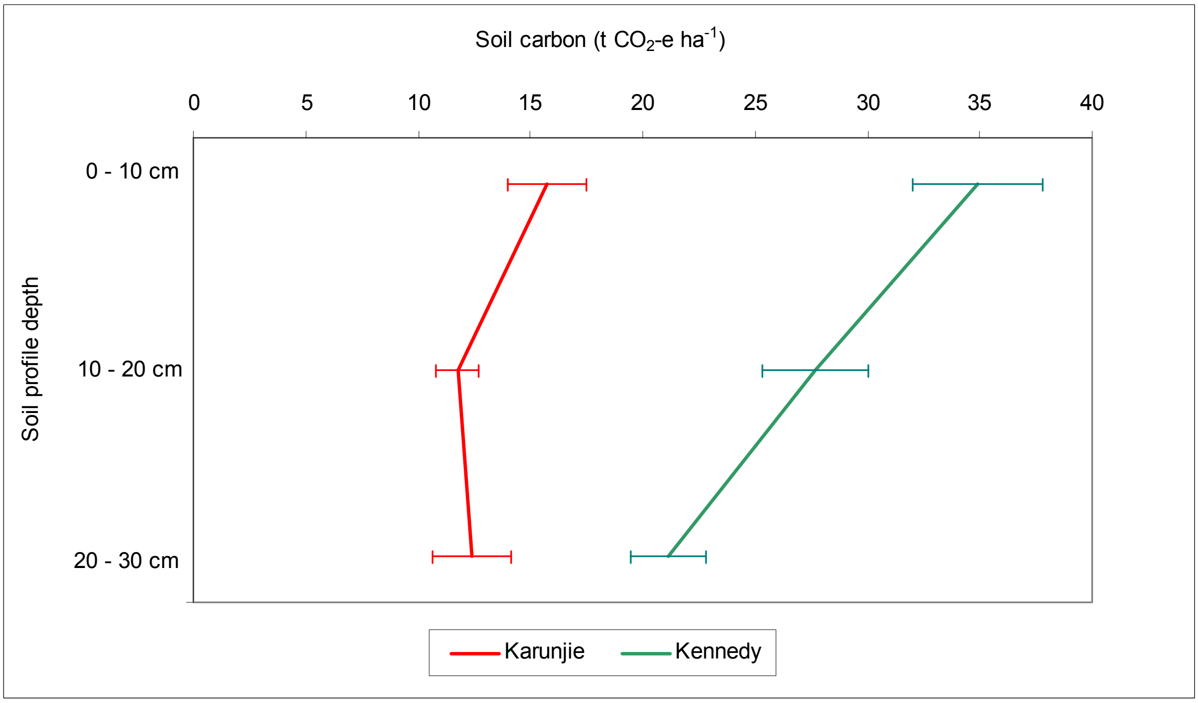

Figure 47: Change in soil carbon with profile depth of the RP land-systems
Data shown are means with standard error bars. NB: Buldiva and Pago land-systems are not shown as no soil samples were taken from these land-systems.

There appears to be a general trend whereby the land-systems which have the higher amounts of total soil carbon (*viz*. River, Roebuck and Kennedy) have a more dramatic reduction in soil carbon with profile depth. These land-systems all have moderate to very high pastoral potentials, which reflect their capacity to produce higher amounts of herbaceous material. This material in conjunction with higher carbon inputs arising from more coarse and fine roots probably causes the higher concentration of carbon within the top 10 cm. Soil microbes play a critical role in increasing the amount of carbon in the top 10 cm because they breakdown the structural material and convert it into more stable fractions of carbon within the soil (Brady and Weil, 2002).

The Capricorn land-system on CP had the least change in soil carbon with depth. This land-system has shallow, skeletal soils and therefore it has inherently low levels of soil carbon. Net primary production is very low in this land-system and consequently the inputs into the soil and associated biological activity is low.

In summary, this study found a clear change in soil carbon levels with profile depth. This finding highlights the importance of sampling soils at 10 cm intervals to at least a depth of 30 cm.

4.6 Relationship between total ground cover and soil carbon

Presently, carbon accounting in the rangelands is an expensive and time-consuming exercise. One of the impediments of trading carbon offsets in the rangelands is the cost associated with base-lining carbon sinks and measuring the change in carbon levels over time. Remote sensing has the potential to provide a more spatially and temporally extensive inventory of carbon sinks (Wallace, J. *pers comm*. 2009). However, remote sensing tools still require a substantial investment in order to calibrate them for different regions and localised conditions (e.g. soil colour and condition, vegetation structure, seasonal variation). The utility of remote sensing in carbon accounting will largely be determined by the correlation between carbon and parameters that can be measured by the imagery.

Total ground cover (%) can be used as an indicator of rangeland condition. An estimate of total ground cover can be made using remote sensing. Therefore, to identify the potential scope for remote sensing to estimate carbon levels the relationship between total ground cover and soil carbon was examined. Total ground cover (%) in this study is defined as the total area which is not bare ground (includes areas occupied by litter, CWD, grass tussocks, shrubs or trees). Refer to Section 3.3 for details of how this was calculated at each survey site.

Figure 48 illustrates the relationship between total ground cover and soil carbon when all the sites samples for soil carbon were collectively analysed (n=227). Extreme outliers were removed from the analysis. The analysis indicated a weak linear relationship between total ground cover and soil carbon ($R^2 = 0.15$). This suggests that increasing ground cover in itself may not lead to increased soil carbon levels.

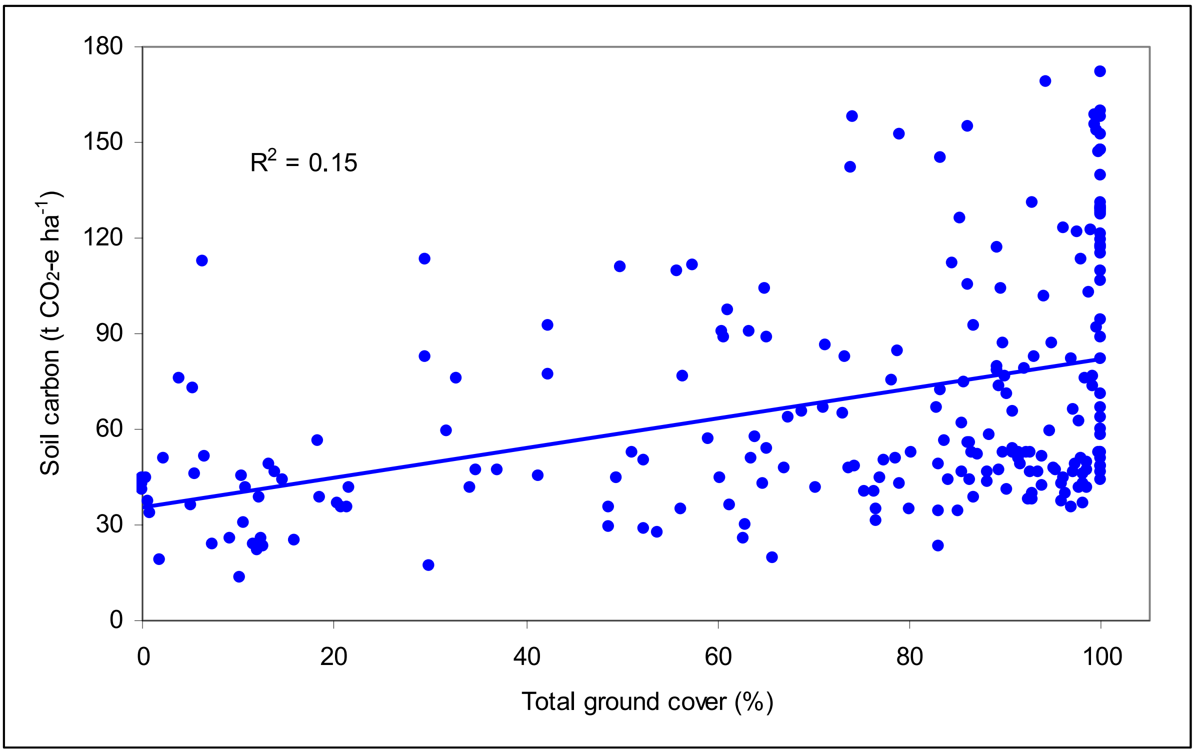

Figure 48: Relationship between total ground cover (%) and soil carbon inclusive of data from all land-systems
Data are the mean levels of soil carbon at each survey site to a depth of 30 cm.

Analyses were conducted on a land-system basis in order to determine if the relationship between total ground cover and soil carbon was more pronounced. Figures 50, 51 and 52 illustrate the two land-systems which demonstrated the strongest relationship on CP, RP and MB. The Boolgeeda and Cheela land-systems on CP had the strongest relationship between the two factors. We suggest that this is due to the fact that the drier climate causes the land-systems to increase the heterogeneity of water and nutrients in an effort to optimise productivity. In contrast, the virtually non-existent relationships between total ground cover and soil carbon in the land-systems in the subtropical climates of RP and MB may be symptomatic of the fact that soil carbon is more homogenously distributed throughout the landscape. Hence, sites at RP and MB may have lower ground cover, but this does not necessarily mean that they will have lower levels of soil carbon. The results suggest that ground cover plays a much more important role in biosequestration in semiarid ecosystems compared to subtropical ecosystems. Increased sample sizes would validate the veracity of this finding.

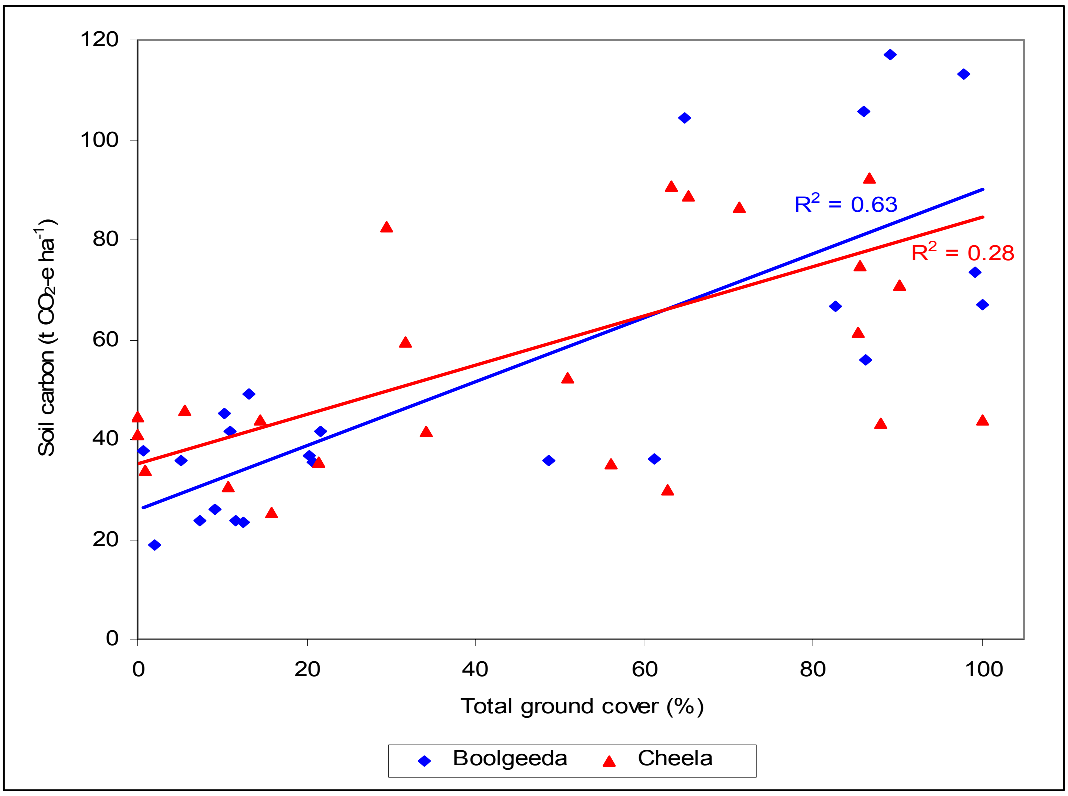

Figure 49: Relationship between total ground cover (%) and soil carbon in selected land-systems at Cheela Plains

Data are the mean levels of soil carbon at each survey site to a depth of 30 cm.

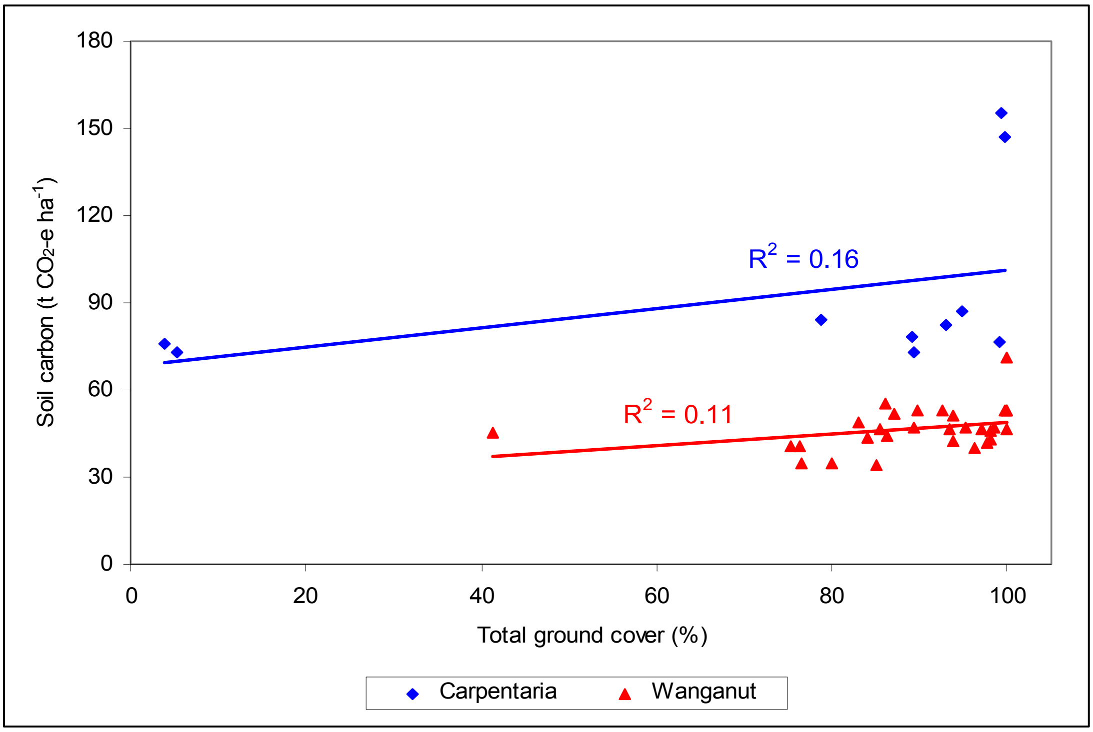

Figure 50: Relationship between total ground cover (%) and soil carbon in selected land-systems at Roebuck Plains

Data are the mean levels of soil carbon at each survey site to a depth of 30 cm.

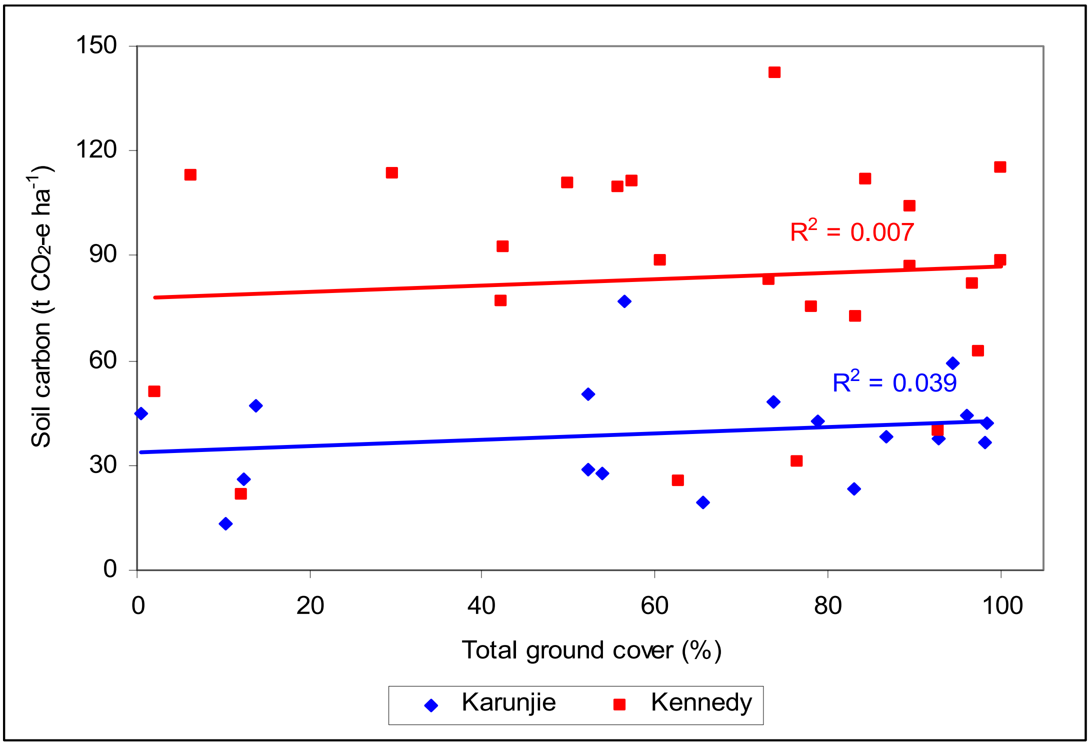

Figure 51: Relationship between total ground cover (%) and total soil carbon at sites in selected land-systems at Mount Barnett
Data are the mean levels of soil carbon at each survey site to a depth of 30 cm.

4.7 Relationship between soil carbon and soil bulk density

Bulk density can be a good indicator of soil changes due to grazing and has the advantage of being easy to measure (Greenwood and McKenzie, 2001). The compaction of soils by livestock and the removal of vegetation through excessive defoliation may decrease water infiltration, increase soil erosion, decrease plant growth and result in a higher soil bulk density (Greene *et al.* 1994; Owen-Smith, 1999). In contrast, increased organic matter, microbial biomass and length of fungal hyphae under pasture soils increase the stability of macro-aggregates and reduce soil bulk density (Tisdall, 1994).

The majority of soil microbes are aerobic and use oxygen as the electron acceptor in their metabolism, therefore good aeration promotes their activity. In semiarid soils, the top 10 cm layer is where most of the microbial activity occurs, and the compaction or the removal of this layer can have adverse consequences on nutrient cycling and the ability of the ecosystem to attract and retain water and nutrients (Greene and Tongway, 1989). Therefore, soil bulk density is intrinsically linked with soil stability and biosequestration rates.

The results from this study demonstrated a general negative relationship between soil bulk density and soil organic carbon (%). Figure 52 illustrates that the level of soil organic carbon is reduced as soil bulk density increases. The relationship between the two variables did become more pronounced when the data was analysed on an individual land-system basis. Therefore, to increase carbon levels in the soil, management should identify and implement practices that are known to improve soil stability and structure. This will principally involve increasing the input levels of organic matter into the soil and limiting adverse disturbances (*viz*. compaction, pulverisation) to the upper soil layers. Studies and anecdotal evidence have shown that this can be achieved through sustainable grazing management (Sayre, 2001).

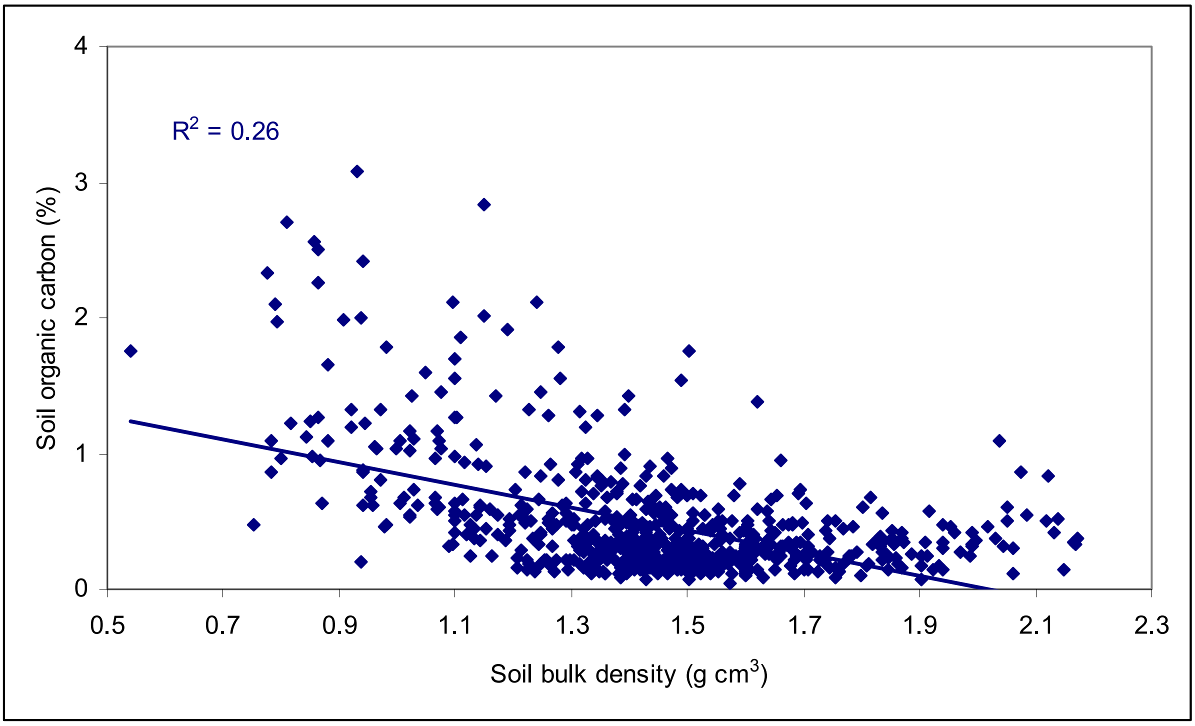

Figure 52: Relationship between soil bulk density and soil organic carbon (%) at sites
NB: soil organic carbon and bulk density values are based on 10 cm intervals to a depth of 30 cm.

4.8 Conclusion

We estimated the baseline levels of carbon on three pastoral leases in the Kimberley-Pilbara region. The baseline carbon results provided the data necessary for the planning of alternative management scenarios which are modelled and discussed in Chapter V. There were significant differences in the total carbon levels between some of the 12 land-systems surveyed in this study. The differences between the individual pools of carbon (i.e. soil, woody and herbaceous vegetation and CWD) were greater than the differences between the combined total of the pools. An important finding in this chapter was the quantification of the level of variation in carbon levels across different land-systems.

We found that stocking rate did have a significant effect on the levels of total carbon. However, there was no clear relationship in the effect and the level of impact is likely to be land-system dependent. We did not find any significant effects due to fire frequency on the total amount of carbon stored at the survey sites. We also found that the most recent fire history (i.e. had the site burnt in the year prior to the field survey) did not effect the carbon levels at a site. This does not necessarily mean that fire has had no effect on carbon levels at the sites. Rather, the lack of distinct effect may be caused by confounding factors which masked the effect and/or inadequate research design. We found that ground cover may play a much more important role in biosequestration in semiarid systems compared to subtropical systems. The results also suggested that there is a positive relationship between soil carbon and total ground cover.

CHAPTER V: THE POTENTIAL FOR BIOSEQUESTRATION IN THE KIMBERLEY-PILBARA REGION

Can a change in management practices or land-use significantly increase the rate of biosequestration in the Kimberley-Pilbara region? Is there a genuine financial opportunity for pastoral businesses if carbon is commercialised in the WA Rangelands? Despite the large geographical area and general recognition of the potential of the rangelands to act as a carbon sink, few studies have financially quantified the opportunity. This is primarily because, in the absence of a regulatory market, the current demand for offsets is able to be met by projects which can provide less uncertainty (*viz*. Article 3.3 forestry projects in temperate regions). However, regardless of whether a regulatory market is adopted in Australia, it is predicted that the voluntary market will continue to grow. Hence, offset project developers will be attracted to the rangelands when the supply of offsets from the more readily available sources is largely exhausted and/or a critical price threshold is reached (i.e. development of offset projects in the rangelands becomes financially competitive). Clearly, in order to make informed financial decisions concerning management practice and land use, pastoral businesses require robust analyses which compare different management options. In this context this study examined the scope for the pastoral businesses to increase the baseline level of carbon and evaluated if the potential income from the sale of the offsets could justify a change in management.

In this chapter we report the results from Phase Three of the project and sought to address the following questions:

1. Can a change in management practices or land-use increase biosequestration rates on the case study pastoral leases?

2. What are the primary biological drivers of biosequestration on the case study businesses and how do they influence the result?

4. Is it financially feasible for the case study businesses to trade carbon offsets in the voluntary market?

3. What are the major barriers and risks associated with the different management scenarios?

4. What impact would the different management scenarios have on landscape processes and biodiversity?

5. Are there any other co-benefits which could be derived from the different management scenarios?

To address these questions, comprehensive carbon modelling and detailed financial analyses were conducted on the three case study businesses. The following section outlines the process.

5.1 Modelling changes in biosequestration

The CENTURY carbon model (Version 4.5) was used to predict the change in carbon levels under different management scenarios. The CENTURY model can simulate the long-term dynamics of carbon, nitrogen, phosphorus and sulphur for grasslands, agricultural crop systems, forests and savannas (Parton *et al*. 1987; Parton *et al*. 1988; Sanford *et al*. 1991 and Metherell *et al*. 1993). The grassland/crop and forest systems have different plant production sub-models which are linked to a common soil organic matter sub-model (Metherell *et al.* 1993). The model has been calibrated for rangeland ecosystems around the world since its development in the 1980s and it has significant utility for the WA Rangelands.

The advantage of using the CENTURY model in rangeland ecosystems is that there are over 300 input variables that can be altered in order to simulate conditions which correspond closely to the dynamics of the natural ecosystem. The model can also generate over 160 output variables which provide empirical detail of the individual components of an ecosystem. These output variables enable comprehensive interrogation of the carbon dynamics in order to identify what are the primary drivers of biosequestration within an ecosystem.

Dr. Bill Parton (Colorado State University) was one of the original architects of the CENTURY model and he assisted in the initial application of the model in this project. He also provided advice concerning the modelling process in order to verify the procedures, the assumptions and validate the final model output.

The model was used to calibrate the soil, grass and tree components of the 12 different land-systems. Default CENTURY files similar to the soil, grass and tree components of the land-systems were initially used in the model and key variables of these files were adjusted where necessary. The data derived from the carbon accounting survey conducted in this study was used to calibrate the key variables of the model for the different land-systems. Net primary productivity data for the land-systems was based on data reported in a range of sources (*viz*. Grosso *et al*. 2008; McKenzie *et al*. 2004; Novelly and Baird, 2001; Mokany *et al*. 2006; Adams *et al*. 2001; Yamada *et al*. 1999). CENTURY files which simulated different management treatments (e.g. set-stocking 15% utilisation, moderate fire) were developed based on data from a number of sources (*viz*. Cooke *et al.* 2005; Ash and Stafford Smith, 1996; Dyer *et al*. 2001; Tainton *et al*. 1999; Sayre, 2001).

The model was repetitively run and adjusted until the predicted values of the model were reconciled with the mean observed values derived from the carbon accounting survey. Once the land-systems were calibrated, the model was then programmed to simulate alternative management scenarios to determine the effects on biosequestration.

5.2 Description of alternative management scenarios

Management scenarios were developed for each land-system and the modelled output from CENTURY was amalgamated for each pastoral business. The scenarios were developed in consultation with the business owners of the three case study leases. The modelled period was from 2010 to 2040. This period was selected because it was considered that it would enable any clear differences between the various scenarios to become clear. The specific scenarios were developed to derive the most divergent business options (e.g. a full destock *cf* a high level of intensification). Three scenarios were modelled for CP, whilst five alternative scenarios were developed for RP and MB. This was because fire plays a greater role on RP and MB, and more scenarios were required in order to examine the various different combinations of management practices. It is recognised that in the construction of these management scenarios there is a significant amount of generalisation and interpretation in the sequence of historical events and cycles of future events. It is for this reason that a conservative approach was taken in the development of the scenarios to augment the integrity of the analyses.

5.2.1 Management scenarios on Cheela Plains

Table 10 provides a summary of the three scenarios and specific treatments that were modelled for each of the four land-systems of CP.

The previous management history on CP from year 0 to 2009 was modelled using CENTURY. This involved making a number of assumptions regarding the historical grazing and fire regimes. Grazing commenced on CP in 1880 and the vegetation of all the land-systems except for Capricorn (Spinifex hills and ranges) was utilised at an average rate of 15%. Utilisation rate in this study is defined as the percentage of the total annual pasture production that is removed within a year. Prior to pastoral development, a major fire event was assumed to have occurred once every 10 years due to the build up in volatile fuel loads. Grazing would have reduced the incidence of fire in the land-systems which were utilised by livestock to a frequency of once every 20 years (this is supported by the fire frequency data from Landgate). Fires frequency remained the same in the ungrazed Capricorn land-system throughout the entire period from 0 to 2009 because it is practically unmanageable because of the terrain and physical access.

Scenario One (full destock) on CP involves the complete removal of domestic livestock from the lease in 2010. The assumption was that by destocking there would be an increased build up in the amount of organic matter in the ecosystem (except for the Capricorn land-system) of which a proportion may be stabilised and permanently stored as carbon in the soil and large wood. This permanent increase in carbon could be sold as offsets into the voluntary market. In this Scenario, CP would redesign its operations and infrastructure in order to best manage the carbon commodity on the three main land-systems.

Scenario Two (Recommended best practice) involved simulating a set-stocking grazing system at 15% utilisation rates. This is currently the recommended 'Best Practice' for grazing management in the region (Van Vreeswyk *et al*. 2004b). CP is presently managing a rest-based grazing system which exceeds the requirements of the recommended best practice. However, scenario two was conducted in order to evaluate the potential difference in the amount of carbon stored under the recommended best practice compared to the existing rest-based grazing system at CP. Therefore, data generated from scenario two was used as the baseline trajectory in which to compare changes in management practices.

Scenario Three (Intensification) involves a high level of intensification of the existing infrastructure and pastoral operations. Specifically, the infrastructure improvements for this scenario involved:

- installation of 262 km of new fencing,
- laying of 6.8 km of poly pipe,

- four new permanent watering points (equipped with telemetry units); and
- upgrades to six existing permanent watering points (also to be equipped with telemetry units).

The aim of the infrastructure improvement program is to reduce the existing size of paddocks to better control the grazing pressure over the area. The present rest-based grazing system on CP will continue and grazing periods will become progressively shorter and aim to achieve an average five day grazing period and 361 day rest period. Each of the paddocks will be approximately 220 ha in size and there will be three separate herds rotated throughout the paddocks. Higher utilisation rates (20%) were used for the Cheela and River land-systems because they are more productive and resilient than the Boolgeeda land-system. This grazing regime will begin from 2010 and was simulated through to the end of 2040.

The infrequent incidence of fire on CP meant that no specific fire management program was simulated. Management on CP generally controls fire as a function of their routine pastoral operations and it was considered that they would be unable to reduce the already low fire frequency.

5.2.2 Management scenarios on Roebuck Plains

Table 11 provides a summary of the five scenarios and specific treatments that were modelled for each of the four land-systems of RP.

In the lead-up period to the management scenarios (0-1885), no grazing by livestock occurred until 1886 and it was predicted that a moderate fire occurred every four years[24]. When grazing commenced, utilisation rates were likely to be 30% and this was largely sustainable due to the resilience of the land-systems and the supplementation program. Grazing suppressed fire on the floodplain (Carpentaria and Roebuck land-systems) and changed the fire frequency to once every 15 years (based on fire history mapping). Fire frequency remained the same in the *Acacia* sandplain regions (Wanganut and Yeeda land-systems).

Scenario One (Full destock) this option is similar to that of CP. No grazing occurs and the landscape effectively reverts back to a pre-pastoral development management regime.

Scenario Two (Recommended best practice) this is based on the general best practice recommendation for grazing management in the Kimberley region to operate a set-stocking regime at 15% utilisation rates (Chilcott *et al*. 2009). Fire remains suppressed on the floodplain due to the maintenance of low fuel loads by grazing.

Scenario Three (Intensification) this involves a significant investment in infrastructure and a substantial change in the way grazing and fire is managed on the lease. The proposed infrastructure upgrade for this scenario includes:

- 800 km of new fencing
- 44 km of poly pipe
- eight new permanent watering points (equipped with telemetry units); and
- upgrades to 14 existing permanent watering points (also to be equipped with telemetry units).

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[24]The level of material removed in a cool, moderate or hot fire is dependent on the component (i.e. fine branches, large wood, fine and coarse roots, surface litter) and the land-system.

In this scenario, a rest-based grazing system at an average 20% utilisation rate will be managed on the floodplain (Carpentaria and Roebuck land-systems). The system will have an average five day grazing period and 328 day rest period. The *Acacia* sandplain (Wanganut and Yeeda land-systems) is less productive and therefore the returns from the additional infrastructure are less likely to be realised. Hence, paddocks in this area will be rested every second wet season. Fire is likely to remain suppressed on the floodplain (once every 15 years) under the rest-based grazing system. Management will have to implement firebreaks and other strategies in order to reduce the risk of fire in rest paddocks. It was assumed that management will also make a more concerted effort to reduce the incidence of fire in the *Acacia* sandplain. Therefore, fire frequency in this region was reduced from once every 4 years to once every five years.

Scenario Four (Business-as-usual) involves a continuation of the existing grazing and fire regime (i.e. set-stocking at 30% utilisation rates and a fire occurs every 15 years on the floodplain and every 4 years in the *Acacia* sandplain). The modelled output from this scenario will provide the baseline trajectory in which to compare the other four scenarios.

Scenario Five (Full destock with controlled savanna burning) is the same as Scenario One of RP except that it involves a higher level of investment in the proactive management of fire on the lease. Specifically, this scenario evaluates the impact on carbon levels if the managers of RP burnt in May so that only cooler fires occurred across the lease (primarily resulting in reduced consumption of large wood).

5.2.3 Management scenarios on Mount Barnett

Table 12 provides a summary of the five scenarios and specific treatments that were modelled for each of the four land-systems of MB.

No grazing by livestock occurred on MB until 1910 and it was predicted that a moderate fire occurred every four years prior to pastoral development. The lease was assumed to have been set-stocked at a utilisation rate of 20%. The spinifex ranges (Buldiva land-system) are largely inaccessible to cattle. The incidence of fire was predicted to have increased from once every four years to once every three years post-pastoral development due to increased human activity.

Scenario One (Full destock) is similar to that of CP. No grazing occurs and the landscape effectively reverts back to a pre-pastoral development management regime. The only exception was that trespassing on the lease is likely to result in a higher fire frequency compared to the pre-pastoral period (a three fire cycle *cf* four year cycle).

Scenario Two (Recommended best practice) involves maintaining a set-stocking regime at 15% utilisation rates in the Karunjie, Kennedy and Pago land-systems (Chilcott *et al*. 2009). There is no grazing of the Spinifex ranges (Buldiva land-system).

Scenario Three (Intensification) involves a significant investment in infrastructure and a substantial shift in the way grazing and fire is managed on the lease. The proposed infrastructure upgrade for this scenario involves 572 km of new fencing and 27 new permanent watering points (each equipped with telemetry units). The proposed grazing system on the lease is more complicated compared to the other two leases due to the significant variation in productivity and terrain. The spinifex ranges will continue to be ungrazed by livestock, however controlled savanna burning in May will reduce the incidence of fire from a three year cycle to a four year cycle. The most productive parts of MB (Kennedy land-system) will be grazed intensively under a rest-based grazing system with a 20% utilisation rate. Grazing and resting periods will be on average 5 and 213 days respectively. Paddocks dominated by the less productive Karunjie land-system will be rested every second wet season at utilisation rate of 15%. The fire frequency will remain the same for the Kennedy and Karunjie land-systems, however it will be a cooler fire because management will conduct the burns earlier in May. Access constraints restrict the Pago land-system to set-stocking at a 15% utilisation rate. The fire frequency will be reduced from a three year cycle to a four year cycle in the Pago land-system.

Scenario Four (Business-as-usual) involves a continuation of the existing grazing and fire regime (i.e. set-stocking at 20% utilisation rates and a fire occurs every three years across the lease). The modelled output from this scenario will provide the baseline trajectory in which to compare the other four scenarios.

Scenario Five (Full destock with controlled savanna burning) is the same as Scenario One except that it involves a higher level of investment in the proactive management of fire on the lease. Specifically, this scenario evaluates the impact on carbon levels if the managers of MB burnt in May so that only cooler fires occurred across the lease (primarily resulting in reduced consumption of large wood).

Table 10: Summary of CENTURY modelling script for management scenarios on Cheela Plains

Management Scenario	Time period	Land-system			
		Boolgeeda	Capricorn	Cheela	River
Previous management history	0 – 1879	No grazing. A moderate fire occurs in November every 10 years.	Same as Boolgeeda	Same as Boolgeeda	Same as Boolgeeda
	1880 – 2000	Set-stocking at 15% utilisation. A moderate fire occurs in November every 20 years.	No grazing. A moderate fire occurs in November every 10 years.	Same as Boolgeeda	Same as Boolgeeda
	2001 – 2009	Rest-based grazing at 15% utilisation with a graze period of 5 days and a rest period of 361 days. A moderate fire occurs in November every 20 years.	No grazing. A moderate fire occurs in November every 10 years.	Same as Boolgeeda except grazing utilisation is 20%.	Same as Boolgeeda except grazing utilisation is 20%.
1 (Full destock)	2010 – 2040	No grazing. A moderate fire occurs in November every 20 years	Same as Boolgeeda	Same as Boolgeeda	Same as Boolgeeda
2 (Recommended 'Best Practice')	2010 – 2040	Set-stocking at 15% utilisation. A moderate fire occurs in November every 20 years.	No grazing. A moderate fire occurs in November every 20 years.	Same as Boolgeeda	Same as Boolgeeda
3 (Intensification)	2010 – 2040	Rest-based grazing at 15% utilisation with a graze period of 5 days and a rest period of 361 days. A moderate fire occurs in November every 20 years.	No grazing. A moderate fire occurs in November every 20 years.	Same as Boolgeeda except grazing utilisation is 20%.	Same as Boolgeeda except grazing utilisation is 20%.

Table 11: Summary of CENTURY modelling script for management scenarios on Roebuck Plains

Management Scenario	Time period	Land-system			
		Carpentaria	Roebuck	Wanganut	Yeeda
Previous management history was similar for all three scenarios	0 – 1885	No grazing. A moderate fire occurs in October every 4 years.	Same as Carpentaria	Same as Carpentaria	Same as Carpentaria
	1886 – 2009	Set-stocking at 30% utilisation. A moderate fire occurs in October every 15 years.	Same as Carpentaria	Set-stocking at 30% utilisation. A moderate fire occurs in October every 4 years.	Same as Wanganut
1 (Full destock)	2010 – 2040	No grazing. A moderate fire occurs in October every 4 years.	Same as Carpentaria	Same as Carpentaria	Same as Carpentaria
2 (Recommended best practice)	2010 - 2040	Set-stocking at 15% utilisation. Moderate fire occurs in October every 15 years.	Same as Carpentaria	Set-stocking at 15% utilisation. A moderate fire occurs in October every 4 years.	Same as Wanganut
3 (Intensification)	2010 – 2040	Rest-based grazing at 20% utilisation with 5 days grazing period and 328 day rest period. Moderate fire in October every 15 years.	Same as Carpentaria	Biennial wet season spelling. A moderate fire in October every 5 years.	Same as Wanganut
4 (Business-as-usual)	2010 – 2040	Set-stocking at 30% utilisation and a moderate fire occurs in October every 15 years.	Same as Carpentaria	Set-stocking at 30% utilisation. A moderate fire occurs in October every 4 years.	Same as Wanganut
5 (Full destock with controlled burning)	2010 - 2040	No grazing. A cool fire occurs in May every 4 years.	Same as Carpentaria	Same as Carpentaria	Same as Carpentaria

Table 12: Summary of CENTURY modelling script for management scenarios on Mount Barnett

Management Scenario	Time period	Land-system			
		Buldiva	Karunjie	Kennedy	Pago
Previous management history was similar for all three scenarios	0 – 1909	No grazing. A moderate fire occurs in October every 4 years.	Same as Buldiva	Same as Buldiva	Same as Buldiva
	1910 – 2009	No grazing. A moderate fire occurs in October every 3 years.	Set-stocking at 20% utilisation. A moderate fire occurs in October every 3 years	Same as Karunjie	Same as Karunjie
1 (Full destock)	2010 – 2040	No grazing. A moderate fire occurs in October every 3 years.	Same as Buldiva	Same as Buldiva	Same as Buldiva
2 (Recommended best practice)	2010 – 2040	No grazing. A moderate fire occurs in October every 3 years.	Set-stocking at 15% utilisation. A moderate fire occurs in October every 3 years.	Same as Karunjie	Same as Karunjie
3 (Intensification)	2010 – 2040	No grazing. A cool fire occurs in May every 4 years.	Biennial wet season spelling at 15% utilisation. A cool fire occurs in May every 3 years.	Rest-based grazing at 20% utilisation with a graze period of 5 days and a rest period of 213 days. Cool fire in May occurs every 3 years.	Set-stocking at 15% utilisation. Cool fire in May every 4 years.
4 (Business-as-usual)	2010 – 2040	No grazing. A moderate fire occurs in October every 3 years.	Set-stocking at 20% utilisation. A moderate fire occurs in October every 3 years.	Same as Karunjie	Same as Karunjie
5 (Full destock with controlled burning)	2010 – 2040	No grazing. A cool fire occurs in May every 4 years.	Same as Buldiva	Same as Buldiva	Same as Buldiva

5.3 Projected carbon levels under different management scenarios

In this section we report the results from the CENTURY modelling. Only the values for the soil and woody vegetation pools are reported. This is due to the recognition that these two pools are most likely to be traded as a carbon credit in a voluntary market as compared to the CWD and herbaceous carbon pools.

A summary of the carbon levels under the different management scenarios at a whole lease scale is provided. However, there was variation in the way the different land-systems responded to the same management regime. Therefore, it was considered important to present the results on an individual land-system basis for each of the three leases. The projected carbon results for each land-system are presented in Appendix 9.

This section includes summary tables of the projected change in carbon levels under the different management scenarios for the three pastoral leases. To assist in the interpretation of the tables, definitions of the variables include:

1. **Change in soil C** – the projected change in soil carbon per hectare between 2010 and 2040 based on a three year moving average. The value is weighted based on land-system.
2. **Change in woody C** – the same as 1 except it applied to the woody carbon pool.
3. **Difference in soil C to baseline** – the difference in the change in soil carbon levels of a particular scenario compared to the change in soil carbon levels of the baseline scenario. Scenario 2 (Best Practice) acts as the baseline level of carbon and it is not a static number over time. Therefore, the change in carbon levels (positive or negative) due to the alternative scenarios needs to be compared to the baseline. The value is weighted based on land-system.
4. **Difference in woody C to baseline** – the same as 3 except it applies to the woody carbon pool.
5. **Total change in soil C to baseline** – the projected change in soil carbon compared to the baseline multiplied by the total area that each land-system comprises on the pastoral lease. It effectively represents the total volume of soil carbon credits that could be available for trading purposes.
6. **Total change in woody C to baseline** – the same as 5 except it applies to the woody carbon pool.
7. **Total change in C to baseline** – the sum total of variables 5 and 6. It represents the total volume of potential carbon credits (soil and woody) that could be available for trading purposes.
8. **Total gross carbon income** - the volume of potential carbon credits (variable 7) multiplied by a conservative price of $10 per t CO_2-e. This income would be for a period of 30 years (2010 – 2040).
9. **Gross carbon income per annum** – The income derived from the carbon credits on an annual basis.
10. **Gross carbon income per ha per annum** – The annual income derived from carbon credits on a per hectare basis.

5.3.1 Projected carbon levels 2010 to 2040 at Cheela Plains

Table 13 provides a summary of the projected carbon levels at CP between 2010 and 2040 for the three modelled management scenarios. The results suggest that at a whole lease scale, the intensification scenario biosequesters more carbon than the baseline and full destock scenarios. Intensification of the grazing regime at CP could result in a total increase of 81,329 t CO_2-e (or 1.09 t CO_2-e ha^{-1}) and this is primarily due to an increase in soil carbon in the alluvial floodplain (Cheela land-system).

The full destock scenario biosequesters more soil carbon than the intensification scenario (1.75 *cf* 1.25 t CO_2-e ha^{-1}). However, the full destock scenario results in a reduction in the woody carbon pool when it is compared to the baseline scenario. Hence, the increase in soil carbon is negated by the loss in woody carbon, resulting in a net loss for the full destock scenario. In contrast, the intensification option only had a relatively modest decline in woody carbon over the 30 year period (-0.04 t CO_2-e ha^{-1}) and therefore this did not significantly impact on the total biosequestration levels.

It is important to recognise that both the full destock and intensification scenarios actually had an increase in woody carbon on all the land-systems (except for Cheela which had a modest decline). However, because the baseline scenario biosequestered a greater amount of woody carbon, then the full destock and the intensification scenarios had a net loss (i.e. the woody biosequestration rates of the full destock and intensification scenarios were less than the baseline scenario). Refer to the results in Appendix 9 for further information.

Why would the biosequestration rates of woody carbon be lower in the full destock scenario compared to the intensification and baseline scenario? Firstly, the woody biosequestration rates were only lower in the stony spinifex plains (Boolgeeda land-system) and the river plains (River land-system). The woody biosequestration rate in the alluvial floodplain (Cheela land-system) was 1.04 CO_2-e ha^{-1} greater than the rate of the baseline scenario. The CENTURY model enables manipulation of the amount of material that is removed by a fire. Similar amounts of material were programmed to be removed during a fire event in the different scenarios (20-30% of standing woody material and 80-90% of surface litter and debris). Although, fire intensity was programmed to be 10% higher in the destock scenario in recognition that in the destock scenario there is likely to be a greater build up of herbaceous material. Consequently, the large fuel loads will carry more intense fires which can consume a much greater proportion of the standing woody carbon pool.

The results suggest that the river plains (River land-system) can biosequester the highest amount of soil carbon (6.06 CO_2-e ha^{-1}) and this has the highest chance of occurring when they are fully destocked. However, the full destock scenario is only marginally higher compared to when the land-system is managed with a rest-based grazing system (5.37 CO_2-e ha^{-1}) or is set-stocked at an utilisation rate of 15% (5.57 CO_2-e ha^{-1}). Set-stocking (baseline scenario) did result in a reduction of soil and woody carbon in the Cheela land-system (-3.12 and -2.37 CO_2-e ha^{-1} respectively). The model results suggest that the higher soil carbon levels under the destock scenario is due to the increased surface organic matter and root material which is decomposed and stabilised in the soil.

The baseline scenario had an overall increase in soil carbon. This indicated that even if CP wanted to reduce the intensity of their existing operations (i.e. transition back to set-stocking system), then overall it would still biosequester carbon. However, any increase in carbon could not be sold because the business would fail the additionality criterion associated with the majority of verified offset standards.

The income which could be derived from the sale of carbon offsets would be higher for the intensification scenario compared to the full destock scenario. This is based on the assumption that CP could trade any offsets generated on the lease at an average price of $10 CO_2-e ha^{-1}. The net loss of carbon under the full destock option means that CP would not have any offsets to sell into the market. In fact there may be adverse consequences if this scenario was adopted and in the future the business was covered within a regulatory market (i.e. CPRS). The methane emissions produced by the cattle which are maintained in the baseline and intensification scenarios will affect this result. The financial impact of methane and other GHG emissions on the net GHG balance of the relevant scenarios is examined in Section 5.7.

In general the biosequestration potentials of the land-systems on CP that were surveyed and modelled by this study are low. The scenario which resulted in the highest biosequestration rate still only produced a total of 81,329 t CO_2-e ha^{-1} which equates to less than 300 kg C ha^{-1} (or only 10 kg C ha^{-1} yr^{-1}). Some land-systems have a higher potential than others to biosequester carbon and they would need to be managed differently in order to maximise this potential. The specific implications of the different management scenarios on the present financial, environmental and social profile of CP are examined in Section 5.6, 5.8 and 5.9 respectively.

Table 13: Projected carbon levels 2010 to 2040 at Cheela Plains

	Management Scenarios		
	Scenario 1 - Full destock	Scenario 2 – 'Best Practice' (baseline)	Scenario 3 - Intensification
1. Change in soil C (t CO_2-e ha^{-1} from 2010 - 2040)	1.75	0.11	1.25
2. Change in woody C (t CO_2-e ha^{-1} from 2010 - 2040)	6.11	7.90	7.86
3. Difference in soil C to baseline (t CO_2-e ha^{-1} from 2010 - 2040)	1.64	0	1.14
4. Difference in woody C to baseline (t CO_2-e ha^{-1} from 2010 - 2040)	-1.80	0	-0.04
5. Total change in soil C to baseline (t CO_2-e from 2010 - 2040)	122,014	0	84,657
6. Total change in woody C to baseline (t CO_2-e from 2010 - 2040)	-133,360	0	-3,327
7. Total change in C to baseline (t CO_2-e from 2010 - 2040)	-11,346	0	81,329
8. Total gross carbon income (AUD) (2010 – 2040)	-113,461	0	813,294
9. Gross carbon income (AUD) yr^{-1}	-3,782	0	27,110
10. Gross carbon income (AUD) ha^{-1} yr^{-1}	-0.05	0	0.37

NB: Rounding error may occur

5.3.2 Projected carbon levels 2010 to 2040 at Roebuck Plains

Table 14 provides a summary of the projected carbon levels at RP between 2010 and 2040 for the three modelled management scenarios. The results suggest that fully destocking and implementation of an intensive controlled savanna burning regime (Scenario 5) has the highest biosequestration potential at a whole lease scale. The business-as-usual scenario (Scenario 4) had the lowest biosequestration potential and results in a net loss. Fully destocking without any proactive management of fire (Scenario 1) resulted in a significant increase in the total carbon across the lease. The intensification scenario (Scenario 3) also results in an increase in total carbon. Therefore, if RP sought only to maximise carbon levels at a whole lease scale, then fully destocking and managing fire is likely to provide them with the greatest response.

It is noteworthy that all the scenarios biosequestered soil carbon. However, some clearly had greater potential than others. For example, Scenario 5 biosequestered almost seven times more soil carbon than Scenario 4. The projected increase in soil carbon for all scenarios was relatively modest when it is considered that it took 30 years to achieve these changes. The change in soil carbon ranged from 0.04 to 0.31 t CO_2-e ha^{-1} yr^{-1}. Although these biosequestration rates are relatively low, the large spatial size of the lease causes even modest increases to be significant.

One of the main contributions to the high level of biosequestration in Scenario 5 was the soil and woody carbon from the *Acacia* sandplain (Wanganut and Yeeda land-systems). These land-systems biosequestered significantly more soil and woody carbon compared to the baseline. In contrast, the marine floodplain (Carpentaria and Roebuck land-systems) actually biosequestered less soil carbon in this scenario compared to the baseline scenario. However, the soil carbon loss of the marine floodplain was easily reconciled by the gain in the sandplain.

Scenario 1 and 5 (the two destock scenarios) had an increase in woody carbon whilst Scenarios 2, 3 and 4 (scenarios which involved grazing) had a reduction. This result is primarily driven by the difference in fire intensities which were programmed into the CENTURY simulations and the availability of nitrogen. The intensity of the fires in Scenarios 1, 2, 3 and 4 (moderate fire) was double that which was used in Scenario 5 (cool fire). Specifically, a moderate fire was programmed to remove approximately 40% of the standing woody biomass and 80% of the herbaceous surface material. In comparison, a cool fire was programmed to remove exactly half these rates in Scenario 5. Therefore, reduced fire removal rates in Scenario 5 would enable the woody vegetation to increase in density and biosequester higher amounts of carbon. In contrast, Scenarios 2, 3 and 4 did not involve a controlled savanna burning regime and therefore fire removal rates were programmed to be higher and this led to a reduction in woody carbon over the 30 year period. Scenario 1 had a significant increase in woody carbon considering that it had the same fire intensity as Scenarios 2, 3 and 4 (which all had a reduction). The difference is due to the availability of nitrogen and an increase in the annual production of woody carbon in Scenario 1.

Figure 53 illustrates that the annual production of woody carbon was consistently higher for both Scenarios 1 and 5 throughout the simulation period[25]. This information suggests that the fast growing *Acacia* woody plants in Scenario 1 are responding more rapidly after a fire event as compared to Scenarios 2, 3 and 4 which all involve some form of grazing. This is largely due to the fact that grazing of the vegetation increases the demand for nitrogen and consequently would reduce the amount that could be allocated for wood production in Scenarios 2, 3 and 4. In addition, because Scenario 1 produces more woody biomass, a greater proportion of the biomass can be allocated to the large wood component (>100 mm thickness) which is not as combustible in successive fires. Therefore, the residual amount of woody carbon in Scenario 1 would remain higher post a fire event and this would enable it to respond more rapidly (i.e. more photosynthetic material equates to increased production).

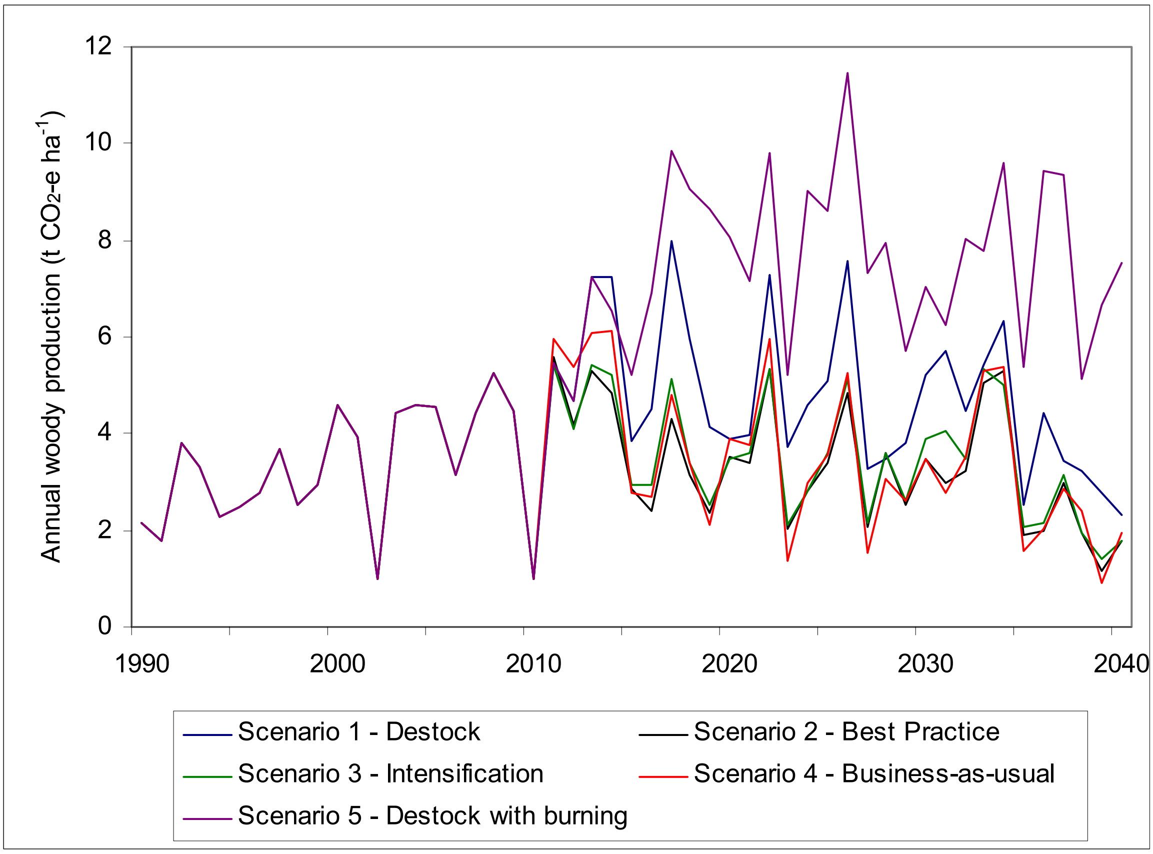

Table 53: Variation in annual woody carbon production between the different management scenarios in the Wanganut land-system at RP

The results suggest that set-stocking at a 15% utilisation rate (Scenario 2) is likely to biosequester more soil carbon on the marine floodplain compared to a rest-based grazing system at a 20% utilisation rate (Scenario 3). The difference in soil carbon between Scenario 2 and 3 was 3.46 and 4.53 t CO_2-e ha^{-1} for the Carpentaria and Roebuck land-systems respectively. This is likely to occur because the higher utilisation rate of the rest-based grazing system reduces the amount of organic matter which can enter into the soil. Although Scenario 3 includes long rest periods from grazing, it appears that these are insufficient to compensate for the effects of the higher utilisation rate. There is a negligible difference in the soil biosequestration rates of the *Acacia* sandplain between the set-stocking (Scenario 2) and

[25]Note that the data presented in Figure 53 is only the woody carbon production for the Wanganut land-system; the woody carbon production in the Yeeda land-system demonstrated a similar phenomenon.

rest-based grazing (Scenario 3) scenarios. It was unexpected that set-stocking at a 30% utilisation rate (Scenario 4 – business-as-usual) resulted in a real increase in soil carbon albeit it was the lowest of all the scenarios including the baseline.

In summary, the projected change in carbon levels at RP highlighted the following:

- the more fertile calcareous soils of the marine floodplain biosequestered more carbon than the ferrosol soils within the *Acacia* sandplain;
- regardless of the grazing or fire management options, the soils on RP biosequestered carbon;
- grazing even at high utilisation rates (30%) still biosequestered soil carbon, albeit a modest amount;
- fire intensity had a significant impact on carbon levels and substantially altered the ratio between the woody and herbaceous components of the *Acacia* sandplains;
- grazing promotes pasture growth which increases nitrogen uptake which can cause limitations of N for woody carbon production;
- fully destocking with controlled savanna burning has the highest biosequestration potential primarily because there is a significant increase in woody carbon.

The biosequestration potential of RP is relatively high and this is primarily driven by its potential to alter the woody vegetation carbon pool. The greatest opportunity on the lease, from strictly a carbon offsets perspective, is increasing the existing stand of woody biomass through controlled savanna burning. Increasing the density of the woody vegetation would have significant impacts on pastoral operations as wood and pasture production are intrinsically linked. The specific implications of the different management scenarios on the present financial, environmental and social profile of RP are examined in Section 5.10.

Table 14: Projected carbon levels 2010 to 2040 at Roebuck Plains

	Management Scenarios				
	Scenario 1 - Full destock	Scenario 2 – 'Best Practice' (baseline)	Scenario 3 - Intensification	Scenario 4 – Business-as-usual	Scenario 5 – Full destock with burning
1. Change in soil C (t CO_2-e ha^{-1} from 2010 - 2040)	2.76	3.87	3.23	1.36	9.51
2. Change in woody C (t CO_2-e ha^{-1} from 2010 - 2040)	9.52	-5.67	-3.19	-6.23	53.66
3. Difference in soil C to baseline (t CO_2-e ha^{-1} from 2010 - 2040)	-1.11	0	-0.63	-2.51	5.65
4. Difference in woody C to baseline (t CO_2-e ha^{-1} from 2010 - 2040)	15.19	0	2.48	-0.56	59.33
5. Total change in soil C to baseline (t CO_2-e from 2010 - 2040)	-314,261	0	-179,622	-711,261	1,598,571
6. Total change in woody C to baseline (t CO_2-e from 2010 - 2040)	4,302,795	0	702,237	-158,120	16,800,996
7. Total change in C to baseline (t CO_2-e from 2010 - 2040)	3,988,533	0	522,615	-869,382	18,399,567
8. Total gross carbon income (AUD) (2010 – 2040)	39,885,334	0	5,226,148	-8,693,815	183,995,666
9. Gross carbon income (AUD) yr^{-1}	1,329,511	0	174,205	-289,794	6,133,189
10. Gross carbon income (AUD) ha^{-1} yr^{-1}	4.70	0	0.62	-1.02	21.66

NB: Rounding error may occur

5.3.3 Projected carbon levels 2010 to 2040 at Mount Barnett

The results suggest that all the management scenarios except the business-as-usual scenario (Scenario 4) could achieve an increase in the amount of carbon biosequestered. The full destock with controlled savanna burning scenario (Scenario 5) is likely to biosequester the largest amount of carbon. The scenario involving rest-based grazing with controlled savanna burning (Scenario 3 - intensification) also biosequestered large amounts of carbon.

The change in woody vegetation carbon was again the primary driver of the total change in carbon relative to the baseline for the management scenarios. The largest increase in the amount of carbon in the woody vegetation generally occurred in the open woodlands of MB (Kennedy and Karunjie land-systems). The difference in biosequestration potentials of the woody vegetation between the various scenarios was chiefly caused by fire intensity and the availability of nitrogen (this dynamic is explained in the previous section). The fire intensities were programmed into the scenarios in a similar manner to the RP scenarios. The exception to this was that in the intensification scenario (Scenario 3), a cool fire was used instead of a moderate fire in recognition that MB would incorporate controlled savanna burning into their management strategy.

Scenarios 1, 3, 4 and 5 all had an increase in soil biosequestration over the 30 year assessment period. The highest soil biosequestration rate under any management scenario was in the Karunjie land-system (9.5 CO_2-e ha^{-1}). This was achieved when the Karunjie land-system was fully-destocked and managed for fire. The Kennedy land-system was the only land-system on MB which had a reduction in soil carbon over the simulation period albeit it was minimal in both instances (-1.3 and -1.4 CO_2-e ha^{-1} for Scenarios 1 and 2 respectively).

We did not expect that the potential change in soil carbon of Scenario 2 would be lower than the change in soil carbon for Scenario 4 given that the only difference between the two was the grazing utilisation rate (15 and 20% utilisation rates respectively). Why would a scenario with a higher utilisation rate biosequester a larger amount of soil carbon? For three out of the four land-systems the change in soil carbon was actually higher for the scenario with the lower utilisation rate (Scenario 1). However, the Kennedy land-system had a net loss in soil carbon in Scenario 1 and a net gain in Scenario 4. Consequently, because the values in Table 15 are weighted averages which are based on the area of each land-system on the lease, the change in soil carbon was negative overall. We were unable to ascertain the exact cause of the disparity in the result, suffice to say that the difference between the scenarios is relatively modest (1.7 CO_2-e ha^{-1} which equates to only 15 kg C ha^{-1} yr^{-1}). It may have simply be an artefact of the stochastic temporal variation which is programmed into the model simulation.

There were a number of reasons why the intensification scenario achieved larger increases in soil and woody carbon compared to the best practice (baseline) scenario. Firstly, the Buldiva land-system was managed with a cool fire as opposed to a moderate fire, therefore the woody carbon increased. Secondly, although the Karunjie land-system was still grazed at a 15% utilisation rate in the intensification option it did receive a biannual wet season spell and the cool fire would also have increased both the woody carbon and the carbon inputs into the soil. Thirdly, the Kennedy land-system was grazed at a higher utilisation rate than the baseline (20%), but the long rest periods (213 days) and the cool fire would have had a similar effect as occurred in the Karunjie land-system. Finally, grazing management was the same in the Pago land-system for both scenarios, however the intensification had a cool fire. Therefore, it is suggested that fire was the principal driver in determining the larger amount of carbon in the intensification scenario.

In summary, the projected change in carbon levels at MB highlighted a number of key findings which are specifically relevant to the lease, these include:

- the open woodland areas (Kennedy and Karunjie land-systems) can biosequester a larger amount of carbon compared to the spinifex hills and ranges (Buldiva and Pago land-systems);
- the potential to change the woody vegetation carbon far exceeds the potential to increase the soil carbon;
- a controlled savanna burning regime which involves igniting fires in May (early dry season) every four years can biosequester a large amount of woody vegetation carbon; and
- rest-based grazing and biennial wet season spelling in conjunction with controlled savanna burning can increase soil carbon above the baseline;

The nature of the MB results and implications for management are similar to that of RP. From strictly a carbon offset perspective, the results indicate that the full destock with a controlled savanna burning scenario (Scenario 5) would achieve the largest amount of carbon. However, adoption of this option may directly impinge on other important values of the land. Therefore, the specific implications of the management scenarios on the present financial, environmental and social/cultural profile of MB are examined in the remainder of this chapter.

Table 15: Projected carbon levels 2010 to 2040 at Mount Barnett

	Management Scenarios				
	Scenario 1 - Full destock	Scenario 2 – 'Best Practice' (baseline)	Scenario 3 - Intensification	Scenario 4 – Business-as-usual	Scenario 5 – Full destock with burning
1. Change in soil C (t CO_2-e ha^{-1} from 2010 - 2040)	0.04	-0.15	6.31	0.22	7.44
2. Change in woody C (t CO_2-e ha^{-1} from 2010 - 2040)	9.78	6.07	55.97	2.91	74.91
3. Difference in soil C to baseline (t CO_2-e ha^{-1} from 2010 - 2040)	0.19	0.00	6.46	0.37	7.59
4. Difference in woody C to baseline (t CO_2-e ha^{-1} from 2010 - 2040)	3.71	0.00	49.90	-3.16	68.84
5. Total change in soil C to baseline (t CO_2-e from 2010 - 2040)	23,874	0	809,103	46,822	951,390
6. Total change in woody C to baseline (t CO_2-e from 2010 - 2040)	464,834	0	6,252,261	-396,143	8,625,947
7. Total change in C to baseline (t CO_2-e from 2010 - 2040)	488,708	0	7,061,364	-349,322	9,577,337
8. Total gross carbon income (AUD) (2010 – 2040)	4,887,082	0	70,613,642	-3,493,216	95,773,373
9. Gross carbon income (AUD) yr^{-1}	162,903	0	2,353,788	-116,441	3,192,446
10. Gross carbon income (AUD) ha^{-1} yr^{-1}	1.38	0.00	19.98	-0.99	27.10

NB: Rounding error may occur

5.4 Greater change in soil carbon levels within smaller degraded areas

For the purpose of this study the potential for biosequestration was estimated at the pastoral lease scale (>150,000 ha). We considered that this approach may have diminished the magnitude of change that may occur at much smaller scales (<10,000 ha). The results from the previous section indicate that when estimates are made at a whole lease scale there are relatively modest increases in carbon levels over the 30 year assessment period. This is because the variation between sites within the same land-system is effectively homogenized and thereby limits the potential scope for increasing the baseline level.

Most of the land-systems that were surveyed included sites which had either very low or very high levels of carbon. The sites within the same land-system had similar soil and vegetation characteristics and therefore inherent variation can only partially explain the substantial differences in carbon levels between the sites. This study was unable to determine if the differences in carbon levels were the result of the most recent grazing and fire regimes, however, it is quite possible that the impacts of degradation occurred in the much earlier pastoral history.

The results from two individual sites are provided in order to highlight the substantial difference in soil carbon levels that occurred between sites (Figure 54). These two sites are both in the Cheela land-system (alluvial floodplain) and in the same paddock and were approximately 3 km apart. Furthermore, they are in a similar position in the landscape and share a similar relief. Despite these similarities, the results indicate that there is more than three times the amount of soil carbon at site CP18 compared to site CP9. There was insufficient evidence to definitively conclude what were the primary causes of this variation. However, it is likely that overgrazing in conjunction with below-average seasons has had an influence on the outcome. This inference is based on the fact that prior to the redesign of the infrastructure layout in the year 2000, Site CP10 was at a closer proximity to permanent watering points and was near the corner of the paddock. These factors may have led to the area surrounding the site to be disproportionately grazed. Results from a land cover change analysis (LCCA) of the two sites appear to support this inference (Figure 55) (refer to Appendix 5 for the methodology of a LCCA).

Site CP10. Soil carbon: 25.2 t CO_2-e ha^{-1}

Site CP18. Soil carbon: 86.5 t CO_2-e ha^{-1}

Figure 54: Difference in baseline soil carbon between sites in the same paddock in the Cheela land-system (alluvial floodplain) at Cheela Plains (NB: soil carbon values based on a profile depth of 30 cm)

Figure 55 illustrates that site CP10 had a much higher proportion of bare ground than site CP18 between 1989 and 2006. The index value used in the LCCA indicates the amount of bare ground at a site; a lower index value generally indicates an increase in total cover and potentially more soil carbon[26]. Both sites exhibit limited change in total cover until 2006, when they have a substantial increase in total cover which is most likely due to the above-average rainfall which occurred at that time. Therefore, the degradation which is evident at Site CP10 must have occurred prior to 1989. It is most likely that overgrazing for an extended period in conjunction with a series of below-average seasons caused the removal of tree and shrub patches and perennial grasses from the area surrounding Site CP10. The removal of ground covers combined with increased erosion most likely caused a reduction in soil carbon. This inference is important, because if management practices can substantially reduce soil carbon levels then it is plausible that management intervention could rebuild the existing very low baseline.

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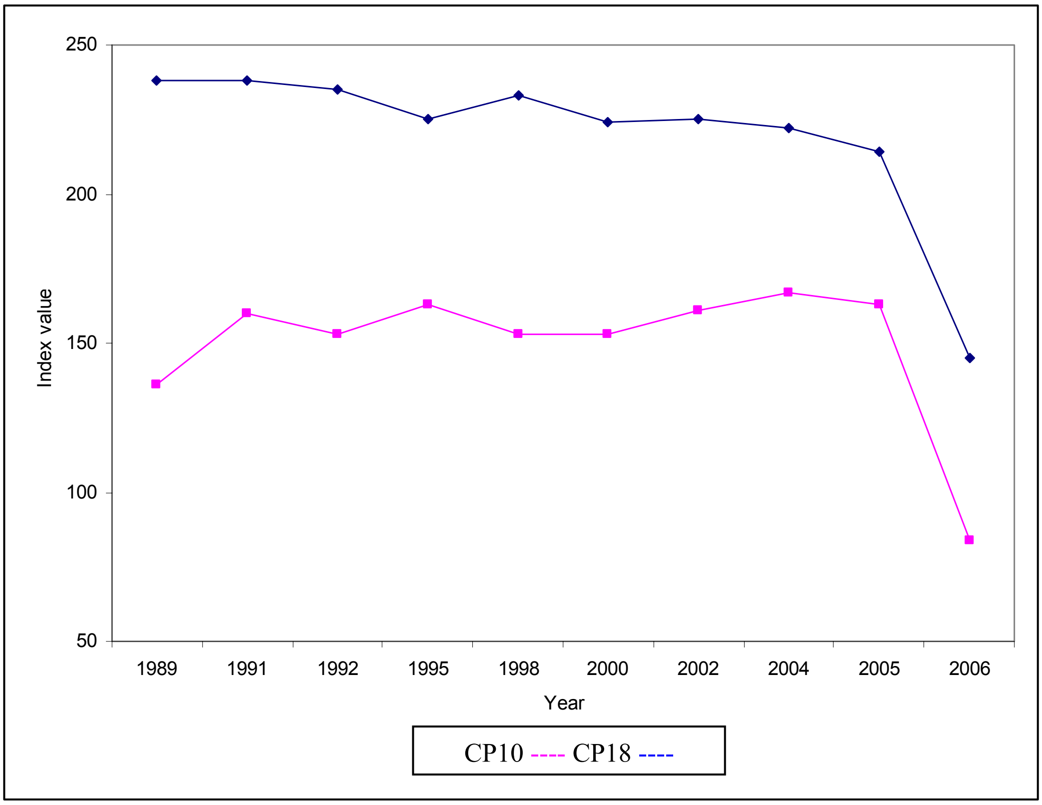

Figure 55: Estimated change in total cover for two sites at Cheela Plains based on LCCA Vegmachine™ output

In this context, if a landholder was seeking to maximise the opportunity for biosequestration then it is highly likely that they would be attracted to areas similar to CP10. Degraded areas will generally provide the greatest scope for biosequestration (and associated financial returns), although there are considerations about whether an area is too unstable to be cost-effectively rehabilitated.

[26]This is based on the fact that the results in section XX indicated a correlation between soil carbon and total ground cover in the Cheela land-system ($R^2 = 0.28$).

As an example, we assumed that a landholder has 1,000 ha which is similar to the degraded CP9 site and they decide to undertake a program to rehabilitate the area to a similar condition as the CP18 site and sell the offsets that arise from the project. The total potential return from the sale of the soil carbon would be \$613,000 and if we assume it takes the landholder 30 years to fully rehabilitate the area, then it would equate to a gross return of \$20.43 ha^{-1} yr^{-1} (see footnote for assumptions[27]). This potential return substantially exceeds those that were calculated at a whole lease scale for the three different scenarios at CP (the full destock scenario was -\$0.05 ha^{-1} yr^{-1} and intensification scenario was \$0.37 ha^{-1} yr^{-1}). It is also competitive when compared to the returns of cattle enterprises in the region. Furthermore, it is likely that a return of this magnitude would be able to be replicated for many of the other land-systems that were surveyed in this study. It is noteworthy that CP currently has 9,900 ha (or 5% of the lease) that is classified as degraded and could be suitable for a carbon offset project. Most pastoral leases in the WA rangelands would have similar sized areas (or larger) that would be suitable for rehabilitation and could yield reasonable financial returns.

The financial returns are likely to be made even more attractive by the fact that degraded areas typically contribute little to pastoral enterprises and are unlikely to have any residual value from a biodiversity perspective. The result suggests that it makes economic sense for offset project developers and landholders to focus their resources and management on areas which have the greatest scope for improvement. The size and distribution of such areas will vary between leases.

In summary, development of carbon offset projects on smaller, degraded areas, rather than across entire pastoral leases, is likely to yield higher returns on a per hectare basis and may require less complex management and monitoring programs.

5.5 Spatial barriers to practical implementation of savanna burning based projects

The previous section suggested that in order to achieve a greater increase in soil carbon, offsets projects could be developed on smaller, highly degraded areas as opposed to projects implemented at a whole lease scale. Although, this applies to projects where grazing, mechanical disturbance and/or reforestation are used to promote the regeneration, it does not apply to savanna burning based projects.

The West Arnhem Land Fire Abatement (WALFA) project provides the greatest practical insight into the issues of implementing a controlled savanna burning regime over extensive areas of Australian rangelands in order to achieve a climate change outcome. The WALFA project is a partnership between the Aboriginal Traditional Owners and indigenous ranger groups, Darwin Liquefied Natural Gas (DLNG), the Northern Territory Government and the Northern Land Council (Heckbert *et al.* 2009). Through this partnership indigenous ranger groups are implementing strategic fire management across 28,000 km^2 of Western Arnhem Land in the NT to offset some of the GHG emissions from the LNG plant at Wickham Point in Darwin. This fire management program has reduced GHG emissions (CH_4 and N_2O only) by approximately 100,000 t CO_2-e yr^{-1} and the indigenous community is paid \$1.1 million yr^{-1}

[27] Potential increase in soil carbon is based on the difference between degraded (CP9) and good condition (CP18) sites and is 61.3 t CO_2-e.
Potential returns = change in soil carbon (61.3 t CO_2-e) * price of carbon (\$10 per t CO_2-e) * area of offset project (1,000 ha).
Returns on per hectare basis over a 30 year period = (change in soil carbon (61.3 t CO_2-e) * price of carbon (\$10 per t CO_2-e)) / 30 year period.

by the resource company for the emission reductions and related environmental services (Heckbert *et al.* 2009).

Experience from the WALFA project has found that to effectively manipulate the existing fire regime an area of at least 20,000 km^2 may be required (Russell-Smith, *pers comm*. 2010). RP and MB are only 2,833 km^2 and 1,253 km^2 in size respectively. Consequently, it is unlikely that they would be able to achieve the increase in woody carbon arising from a full destock and a controlled savanna burning regime unless they were able to broker genuine cooperation with other land managers within the broader catchment. The risk of unmanaged fires from adjoining leases to RP and MB would be far too high and it could quite easily thwart any attempts they make to manipulate the burning regime within their lease boundaries. Recent experiences have shown that it is very difficult to achieve an agreement on a savanna burning management strategy across large areas in the Kimberley (Vigilente, *pers comm*. 2010). This is largely due to the multiple layers of tenure and governance and the number of stakeholders involved who either own, manage, use or have interests in the land.

This issue of spatial scale is a major barrier to the successful commercialisation of carbon credits that may be produced from either increased biosequestration or emission abatement from managed savanna burning in Northern Australia (Russell-Smith, *pers comm*. 2010). It is important to recognise this limitation, otherwise the significant increase in woody biomass that is predicted to occur at RP and MB as a result of controlled savanna burning may be misleading. The potential volume and value of offsets that may arise from controlled savanna burning on RP and MB are highly dependent on the implementation of a fire management program at a catchment scale (>2,000,000 ha).

5.6 Financial implications of the management scenarios

This section addresses two primary questions:

1. Which management scenario for each of the three pastoral businesses delivers the best financial result over the 30 year period?

2. What are the risk factors and assumptions that could alter the outcomes of the analysis?

5.6.1 Background to analysis

To examine the financial implication of the different management scenarios an economist from the DAFWA (Sam Harburg) undertook the analysis. The full suite of scenarios which was simulated in the previous section was not evaluated because there were relatively insignificant differences between some of them in terms of the estimated carbon income, overhead costs and/or gross cattle income (e.g. Best Practice *cf* Business-as-usual). It should be noted that the financial returns reported in this section were only intended to be indicative and are subject to significant variation due to changes in the underlying assumptions.

The analysis was conducted using discounted cash flow (DCF) and internal rate of return (IRR) methodologies. Both methodologies are widely used in determining the most profitable investment option for businesses and corporations (Ross *et al*. 2007).

A DCF analysis provides the net present value (NPV) of an investment option which represents the extra value that is created by an investment option. The NPV takes into account the opportunity costs on marginal project cashflows of forgone alternative investments[28]. The internal rate of return (IRR) is a rate of return used in capital budgeting to measure and compare the profitability of investments. The term 'internal' refers to the fact that its calculation does not incorporate factors which are external to the project. The IRR is the discount rate at which NPV equals zero and represents the smoothed, annualized rate of return provided by the project.

Investment projects should be accepted if the project NPV is greater than zero and the IRR is greater than the discount rate (10%) used to calculate the NPV.

The financial analyses were completed for the full 30 year simulation period of the management scenarios (2010 to 2040). Only the intensification (Scenario 2) and the Best Practice Scenario (Scenario 3 – baseline) were evaluated for CP. This was because the full destock scenario (Scenario 1) for the business resulted in a net carbon loss, hence there was no income from carbon credits. The three scenarios evaluated for both RP and MB included:

- 'Best Practice' (Scenario 2);
- intensification (Scenario 3); and
- full destock with controlled savanna burning (Scenario 5).

Scenario 2 acted as the 'baseline' scenario in which to calculate the NPV for both Scenarios 3 and 5 for RP and MB. Scenarios 1 (full destock only) and 4 (Business-as-usual) were not analysed because they biosequestered less total carbon than their closely affiliated scenarios (5 and 2 respectively).

Transitional changes to cattle herd structures were modelled using the Dynama program from the Breedcow suite of herd modelling programs (Holmes, 2005). Herd and business data used in the modelling was based on the benchmarking data compiled from the RCS Profit Probe™ process (see section XX for details).

General assumptions in the analysis included:

- A nominal discount rate of 10% was used to calculate NPV.
- Operating costs and capital expenditure were inflated at 3% per annum while cattle prices increased by 1.4% per annum, representing an annual 1.6% decline in real cattle prices. This level of decline in real prices was based on historical trends (ABARE, 2010).
- No account was made for potential productivity gains that may arise from new technology, practices or efficiency in the supply chain. In the most recent decade this has been estimated at 1.5% for the northern Australia beef industry (ABARE, 2010). Consequently, projected returns from the cattle enterprises may be higher than stated in this report.
- Exploratory modelling was undertaken to determine appropriate timeframes for implementation of the infrastructure development associated with the intensification

28 The opportunity cost of capital is the expected return forgone by bypassing of other potential investment activities for a given capital. It is a rate of return that investors could earn in financial markets (10%) through the investment in assets of similar risk.

scenarios. This was undertaken with reference to the opening and projected financial positions of each business.

- An interest rate of 10% was used on overdraft funds, an 8% interest rate was used for term debt and a 5% interest rate used for retained cash surpluses. These were used to project future financial positions of the businesses.
- A tax rate of 30% was employed.
- Carbon was initially traded at $10 per t CO_2-e increasing by 3% per annum.
- Carbon brokerage and insurance costs were 20% of the value of the saleable carbon credits.
- Under the intensification scenarios, 75% of the potential increase to the lease's carrying capacity was achieved upon completion of the development program. The remaining 25% was achieved 10 years after completion of the program.
- The percentage increase in stocking rate under the intensification scenarios were: 71% (CP); 42% (RP) and 103% (MB).
- The total cost of the infrastructure a part of the intensification scenarios were: $808,331 (CP); $6,964,636 (RP) and $2,319,500 (MB)[29]. These amounts represent the upper end of the scale of capital that could be expended on the intensification scenarios. Reduced expenditure could significantly affect the outcome of the analysis.
- Operating costs were adjusted for each scenario in response to changes in livestock numbers, enterprise and management practices.
- Land value appreciation was assumed to occur at 5% per annum. This was included to enable financial position projections. Land values were also adjusted in response to changes in potential carrying capacity arising through the implementation of these projects.
- Infrastructure maintenance was assumed to continue under the destock scenarios thereby assisting management of the carbon stores (e.g. homestead and sheds, access tracks, fire-breaks). This also maintained the capital value of the business.
- Although the intensification scenarios are likely to result in an increase in livestock productivity (weaning %, weight gain, mortality %), no accounting for potential gains were included in the analysis. This was due to the unreliability of any estimates and difficulties determining which gains are directly linked to the implementation of the intensification project and not achievable under the base scenario. Consequently, this may result in an underestimation of the returns of the intensification scenario.

Further assumptions specific to each business are described below:

Cheela Plains

- The development phase of the intensification scenario occurred over 15 years. A shorter implementation phase takes the equity of the business to an unacceptable level of risk due to excessive leverage. The 15 year development phase also produces an excessive degree of leverage over the initial phases of the project; however this does not significantly change the risk profile of the business from that projected under the base scenario.
- Agistment income is important for the business. 50% of the herd is livestock that are on agistment.

[29] CP – cost includes: 262 km fencing; 6.8 km poly pipe; 4 new watering points; 6 watering point upgrades.
RP – cost includes: 800 km fencing; 44.4 km poly pipe; 8 new watering points; 14 watering point upgrades.
MB – cost includes: 572 km fencing; 27 km new watering points.

Roebuck Plains

- The development phase of the intensification scenario occurred over 5 years. RP has the capacity to more rapidly implement the infrastructure development program because of its robust equity position.

Mount Barnett

- Under the Best Practice and intensification scenarios; a financial grant was obtained from a relevant Indigenous Affairs Government Agency to purchase breeding stock so as to enable the business to reach its potential carrying capacity within five years.
- The development phase of the intensification scenario was modelled over a 10 year period. A more rapid delivery of the infrastructure development was not possible due to the relatively modest opening financial position of the business. Further livestock purchases occurred after year five when the business possessed sufficient capacity to finance the purchases via a mixture of accumulated cash surpluses and debt finance.

5.6.2 Results from economic and financial analysis of management scenarios

This section reports the results from the financial analysis and is followed by a discussion of the feasibility of the alternative scenarios for each business.

5.6.3 Net present value and internal rate of return

The projected NPV and IRR values that were calculated for the selected scenarios for the three businesses are presented in Table 16.

Table 16: Projected Net Present Value and Internal Rate of Return values for scenarios

	Cheela Plains	Roebuck Plains		Mt Barnett	
	Scenario 3 - Intensification	Scenario 3 - Intensification	Scenario 5 – Full destock with burning	Scenario 3 - Intensification	Scenario 5 – Full destock with burning
NPV	$64,084	($2,017,480)	$38,405,918	$12,517,781	$19,728,458
IRR	11.6%	5.9%	n/a*	298%	n/a*

Rounding errors may occur
***An internal rate of return cannot be calculated for Scenario 5 because there are no negative marginal cash flows in this scenario.**

The projected NPV and IRR for the intensification scenario at CP suggest that this option is financially feasible. The financial returns at CP may be higher if the business decided to continue to intensify their grazing management system. A return of 11.6% is relatively competitive compared to other on-farm and off-farm investment options. Consequently, the intensification scenario is financially attractive. However, there are potential risks related to the significant capital expenditure and the equity of the business which are discussed later in the next section.

The intensification scenario at RP is projected to result in an annual loss of $2,017,480 compared to if the business adopted the Best Practice Scenario. This is largely due to the high cost of infrastructure (relative to the marginal cashflow) that was included in the analysis. The predicted increase in stocking rate (42%) under the intensification was unable to compensate for the high capital costs of the infrastructure. If the capital expenditure for the infrastructure was able to be substantially reduced, without affecting the nature and size of the marginal benefits, then it is possible that the intensification scenario at RP could achieve a positive NPV (Harburg, *pers comm*. 2010). RP could still consider implementing the intensification scenario (albeit with reduced capital expenditure on infrastructure) if it resolved that it was unable to achieve a higher nominal return than 5.9% (the projected IRR) in an alternative investment. The strong emphasis that RP has on indigenous training and development may also influence the weighting that its management team places on the different priorities (i.e. financial, environmental, social and cultural). The projected returns from Scenario 5 (full destock with controlled savanna burning) at RP substantially outweigh those from Scenario 3. However, Scenario 5 is completely dependent on the opportunity to sell carbon credits in the voluntary market at a price of $10 t CO_2-e.

The projected returns from the intensification scenario at MB were positive compared to the Best Practice Scenario (base scenario). However, the returns from the intensification scenario are largely underpinned by the income from carbon credits. The low profitability of the existing business at MB resulted in a significant exaggeration of the returns generated by Scenarios 3 and 5 (i.e. very high NPVs and IRRs). Nonetheless, the amount of carbon biosequestered under Scenarios 3 and 5 at MB would most likely generate an acceptable NPV if they were analysed in comparison to a pastoral business displaying more ‘typical’ levels of profitability.

5.6.4 Real net worth Projections

5.6.4.1 Cheela Plains

Figure 56 presents the real net worth projections for Scenarios 2 and 5 at CP.

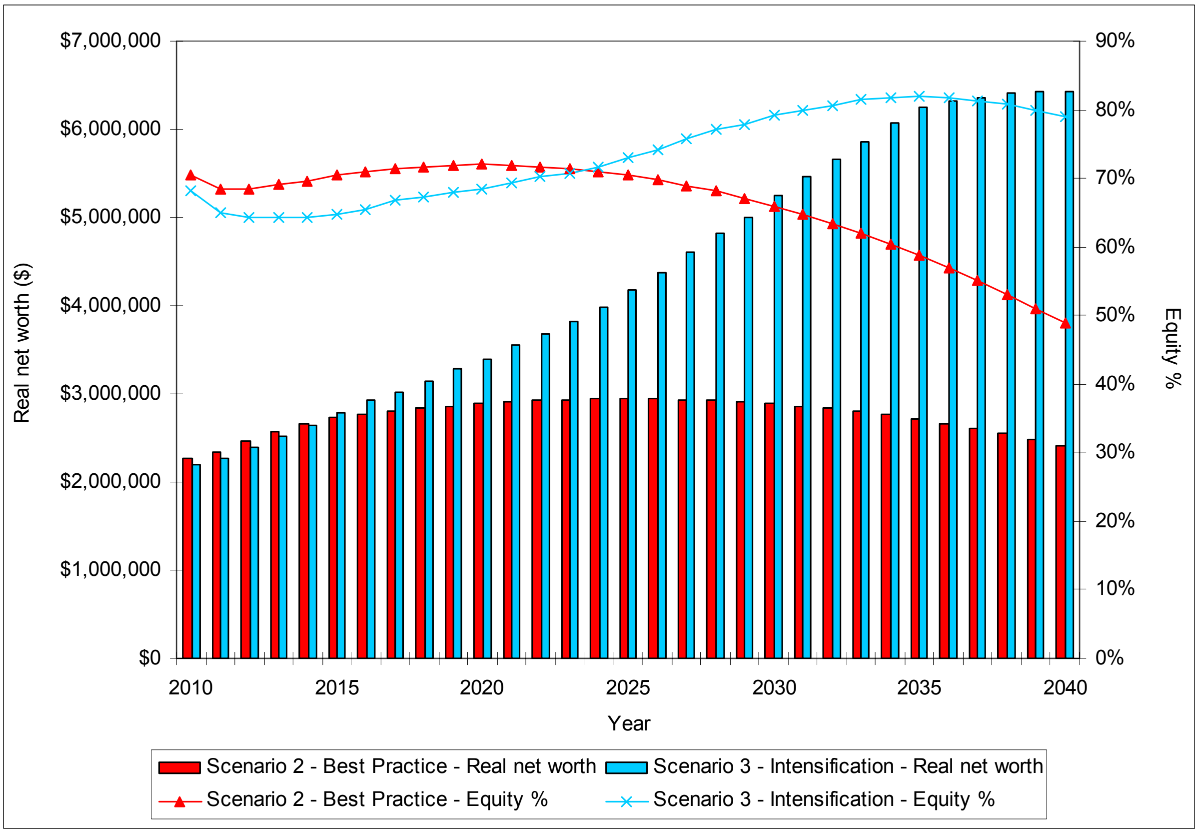

Figure 56: The impact of the management scenarios on the real financial position of Cheela Plains

Based on the analysis results from the intensification scenario, the equity of CP is projected to remain below 80% until 2031. During this period CP would be quite vulnerable to the adverse financial impacts of extended dry periods or catastrophic events such as a major flood event. The first ten years of the intensification scenario is the period that poses the highest risk to the business because it would need to undertake a significant outlay of capital, primarily funded by debt finance, whilst there would be a delay in the full realisation of the marginal benefits arising from the project (i.e. improvement in livestock carrying capacity). The length of the delay would largely be determined by the period between cycles of above-average seasonal conditions.

To reduce the exposure of the business to the impact of extended dry periods, CP could choose to undertake the infrastructure development program over a longer timeframe. However, whilst this would reduce the amount of debt the business is forced to accumulate over the medium term, this would actually reduce the NPV and IRR because the increase in the marginal cashflow would be deferred.

The financial position projections for the base scenario suggest that CP does need to invest in a major project in order to improve its existing financial resilience. However, investment in the intensification scenario does involve a high level of risk to the business which needs to be thoroughly considered.

The negative trajectory of real net worth and equity by the Best Practice Scenario is based on the assumption of declining terms of trade and no improvement in enterprise productivity.

Therefore, the trajectory of real net worth and equity could be made positive if CP was able to improve productivity and find efficiencies within the enterprise which reduced operating costs on an annual basis.

5.6.4.2 Roebuck Plains

Figure 57 presents the real net worth projections for Scenarios 2, 3 and 5 at RP.

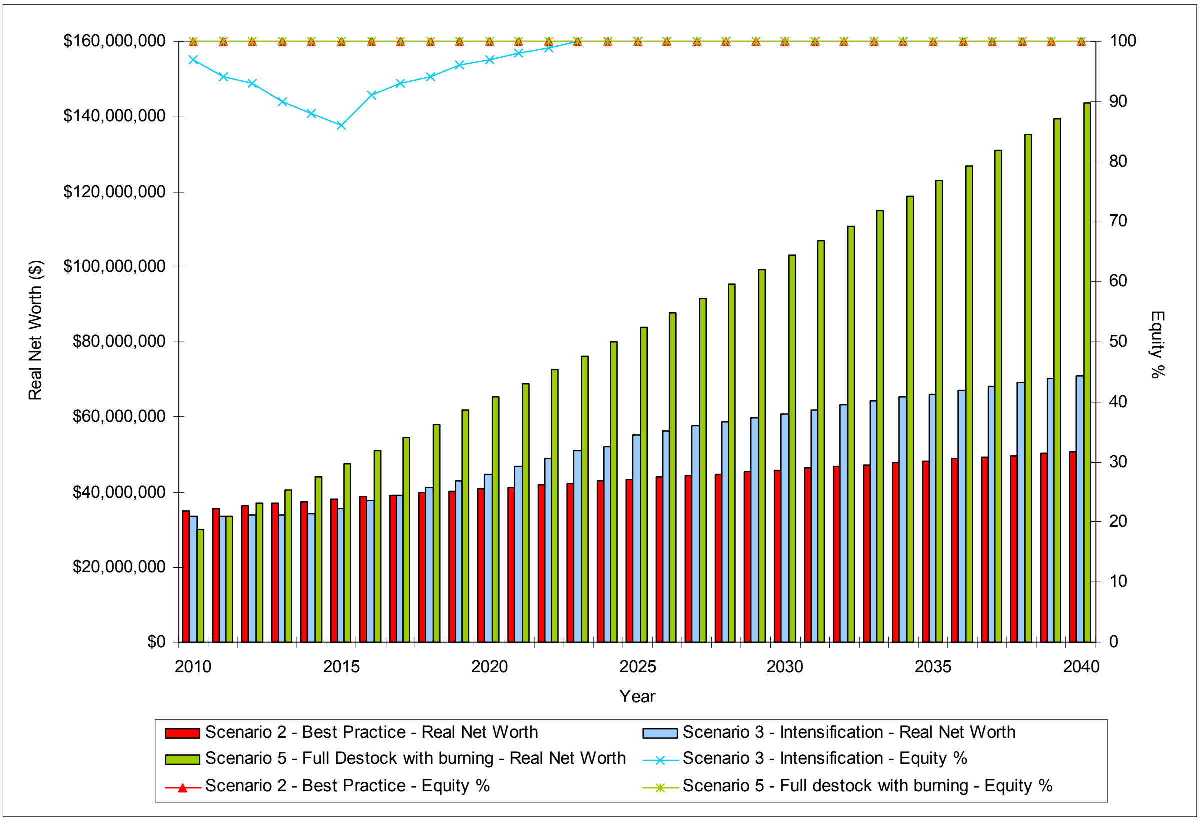

Figure 57: The impact of the management scenarios on the real financial position of Roebuck Plains

The robust financial position of RP (100% equity funded) provides it with the capacity to undertake a significant infrastructure development program requiring a substantial capital outlay. Figure 57 illustrates the decline in equity in the intensification scenario (lowest point is 88% in 2014) as a result of expenditure on infrastructure and livestock. The intensification enables an increase in stocking rate and as a result the equity of RP returns to 100% in 2023 (13 years since the start of the development) and real net worth steadily increases over time to a final position of $71,045,330 in 2040. The Best Practice Scenario had limited variation over the assessment period; equity remains at 100% and real net worth was projected to increase by $15,667,980 over the 30 year period.

There are clear financial benefits of adopting the full destock and controlled savanna burning scenario in comparison to Scenarios 2 and 3 at RP. The net worth of the business could increase by $113,323,059 between 2010 and 2040 (almost a fivefold increase). However, the business would be fully dependent on the carbon market and highly exposed to any changes in policy that may occur. The majority of the returns from carbon in Scenario 5 are derived from an increase in woody carbon and this type of carbon credit (Kyoto Protocol Article 3.4) would currently not be compliant with the Commonwealth Government's accounting rules. Consequently, the carbon would be limited to the voluntary market and therefore there may be greater volatility in the price of carbon. Consideration of whether the business can also manage fire across the lease will also affect the outcome. The sensitivity of the financial returns of the scenarios to the price of carbon is examined later in Section 5.6.6.

5.6.4.3 Mount Barnett

Figure 58 presents the real net worth projections for Scenarios 2, 3 and 5 at MB.

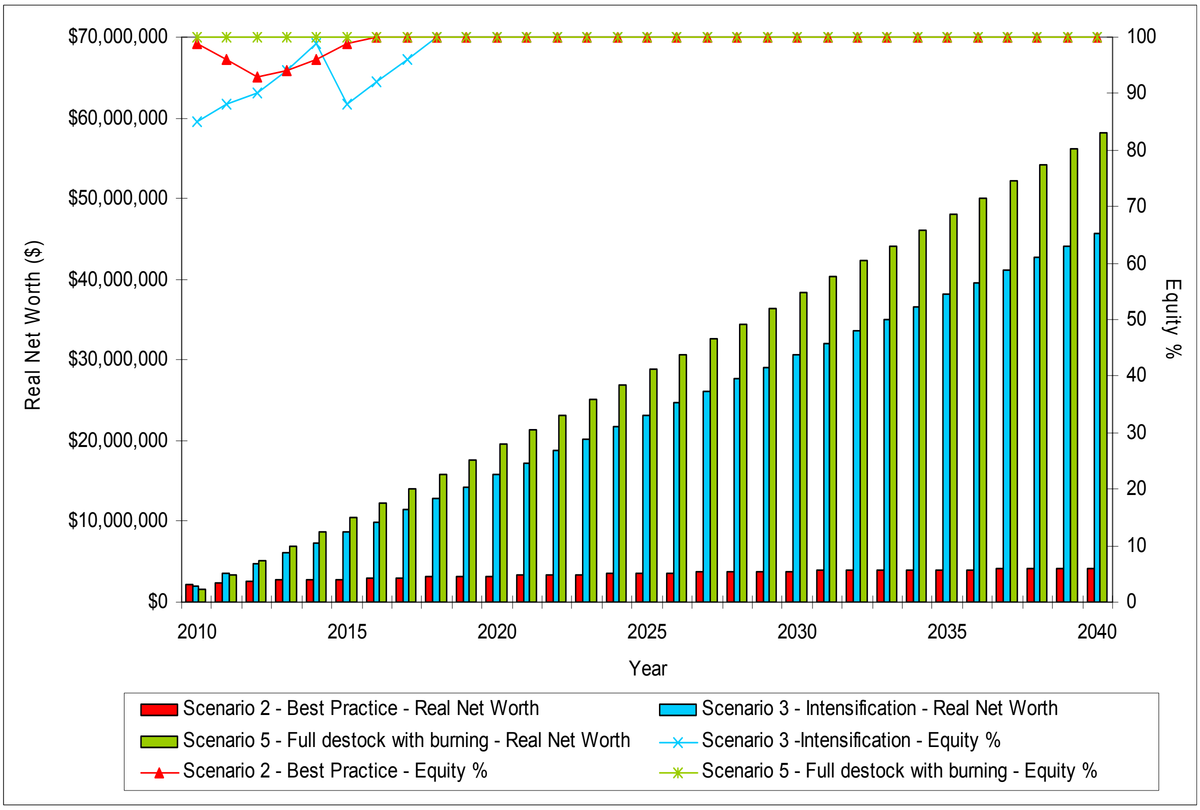

Figure 58: The impact of the management scenarios on the real financial position of Mount Barnett

The relative differences between the three scenarios at MB were similar to RP. The analysis found that Scenario 5 (full destock with controlled savanna burning) results in the strongest financial position for MB, followed by Scenario 3 (intensification) and Scenario 2 (Best Practice). Both Scenario 3 and 5 achieve very strong financial positions based on the set of assumptions used in the analysis. However, the feasibility of both scenarios is underpinned by the existence of a voluntary carbon market which will pay $10 t CO_2-e and the ability of MB to manage fire across the entire lease.

The relative returns of the intensification scenario at MB will be influenced by the capacity of the business to undertake the development program as described and modelled. This is a concern based on the low opening financial position and opening income earning capacity. If the infrastructure development program and associated increase in stocking rate is deferred or does not occur in its entirety then the NPV will be reduced. Furthermore, because the biosequestration income is a significant contributor to the intensification scenario, any significant changes to the projected biosequestration rates (positive or negative) will have a major impact on the profitability of the scenario.

The change in net worth for the Best Practice Scenario highlights that the financial returns solely from the cattle enterprise are fairly modest and involve limited risk to the business. The purchase of the additional cattle in this scenario only caused the equity to drop to 93% in 2012 before returning to 100% in 2016. Clearly, the returns from this scenario are dwarfed by the scenarios which involve income from the potential sale of carbon credits.

5.6.5 Projections of real operating cashflows

Figures 59, 60 and 61 provide projections of real operating cashflows. These projections only represent the cashflow from the sale of livestock and carbon credits[30]. The projections were derived through manual modelling of cattle herd structure adjustments; this created some volatility in year to year projections. However, this volatility is to be expected when undertaking such changes in herd size and structure within a pastoral business.

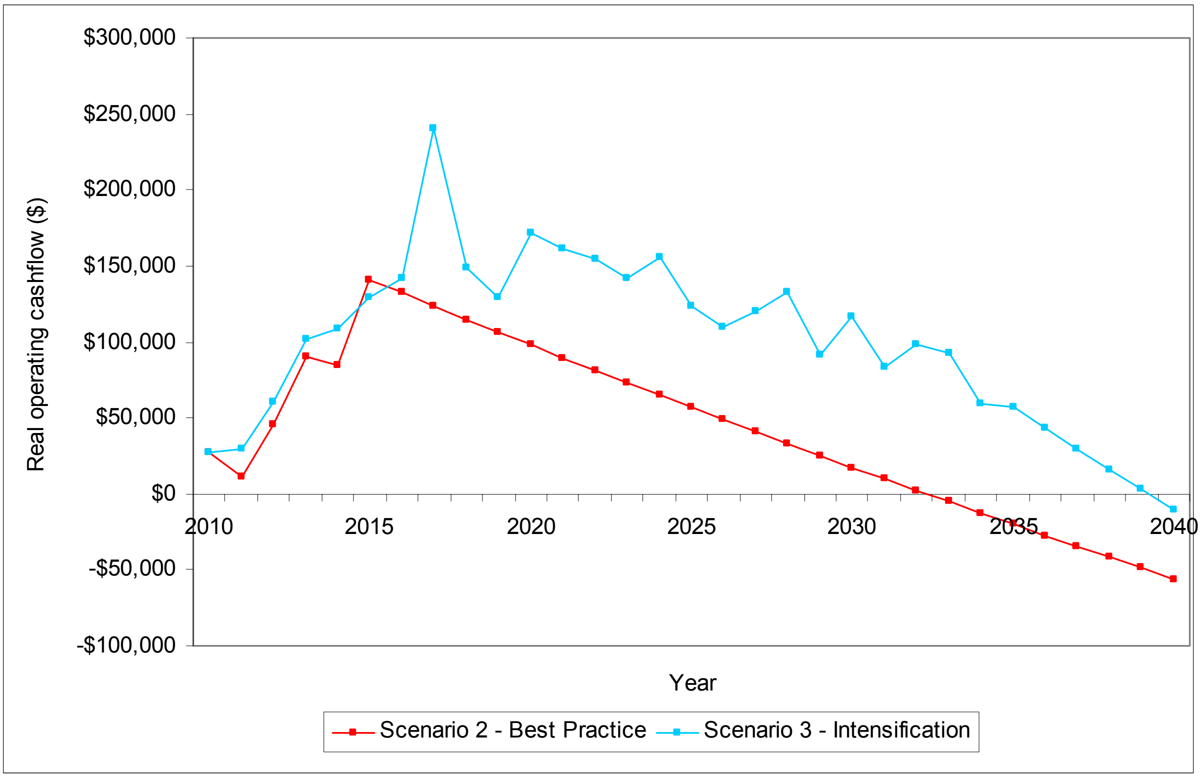

Figure 59: Projected real operating cashflow from scenarios at Cheela Plains

[30] As opposed to the cashflow that was generated from other investments. For example, the interest that was paid on the accumulated cash surplus of the businesses was not included in the results.

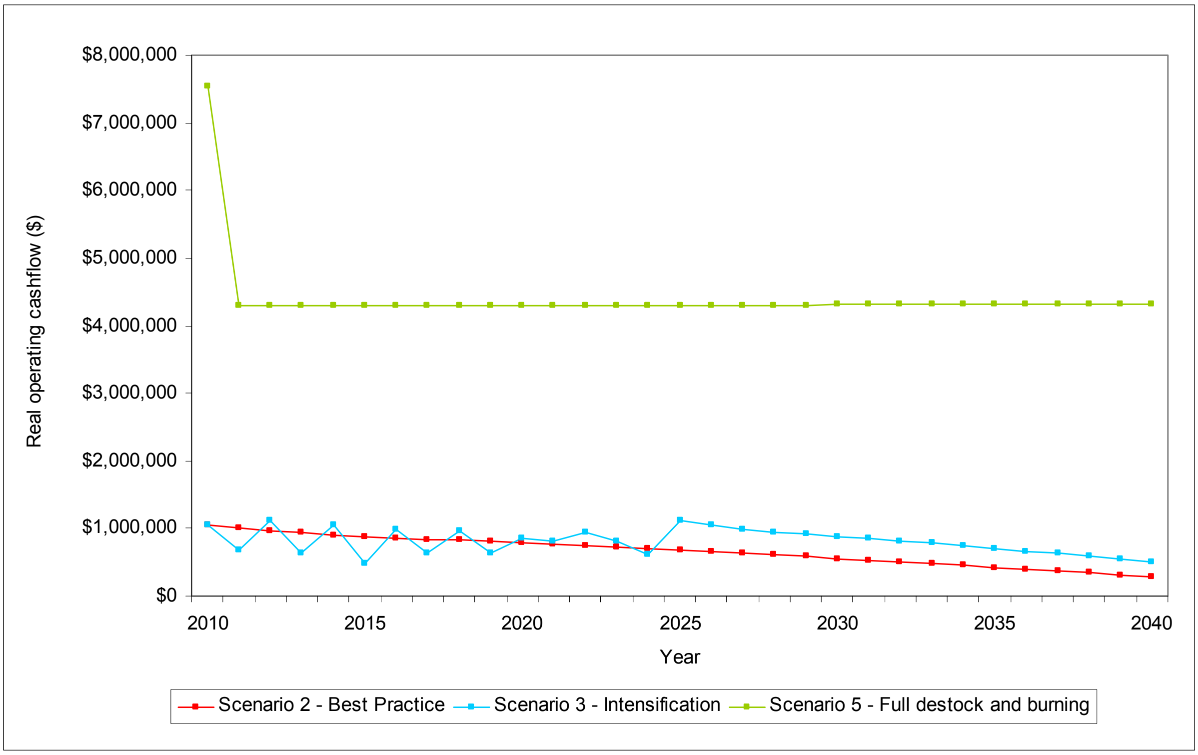

Figure 60: Projected real operating cashflow from scenarios at Roebuck Plains

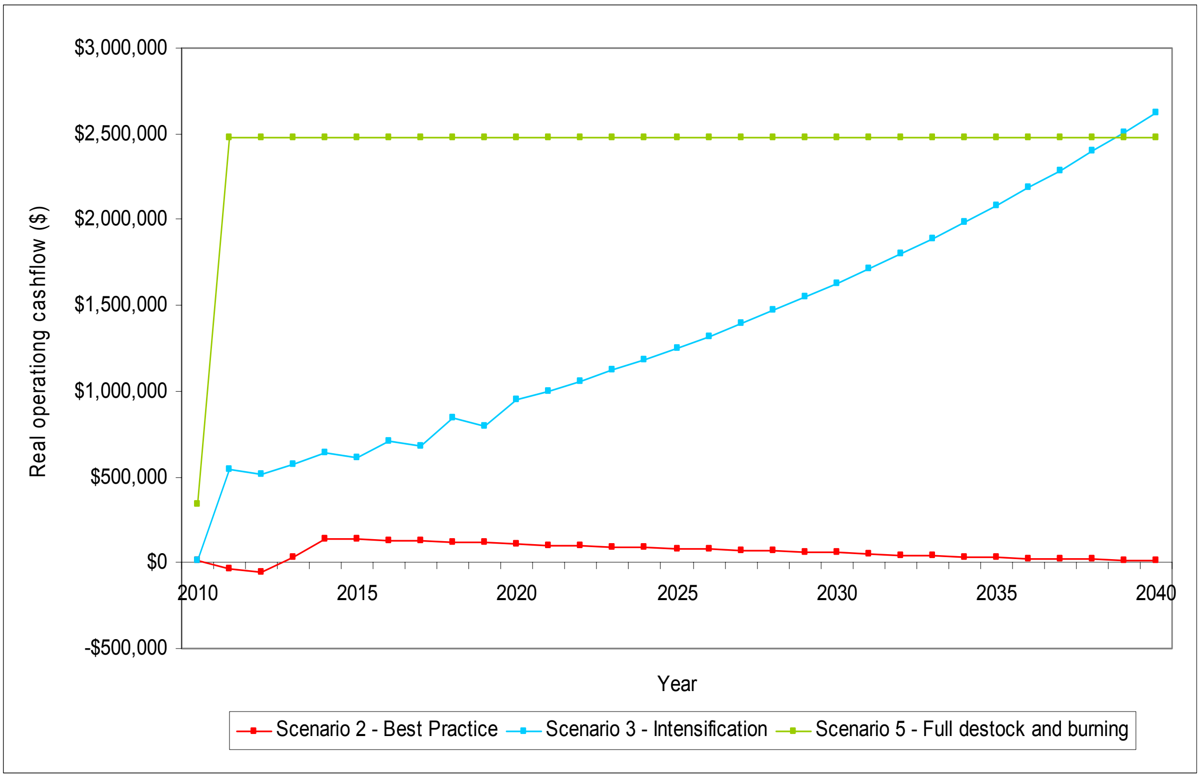

Figure 61: Projected real operating cashflow from scenarios at Mount Barnett

The salient feature of the results for the CP scenarios was the negative trajectory of the real operating cashflow beyond the year 2016. The initial increase in cashflow between 2010 and 2016 for both scenarios was caused by an increase in the number of livestock numbers. Once livestock numbers stabilised (2015 for Scenario 2 and 2035 for Scenario 3), the declining terms of trade progressively erodes the real operating cashflow. Furthermore, the income from the sale of carbon credits that was created as a function of the intensification scenario was insufficient to improve this negative trend. As stated earlier, the trajectory of real operating cashflow for both scenarios could be improved if CP was able to introduce productivity gains or improve the efficiency of the existing cattle enterprise.

The significant drop in cashflow of Scenario 5 at RP (full destock with controlled savanna burning) in 2011 is the result of the business selling off the entire herd in 2010. The cashflow from the sale of carbon credits does not commence until 2011. From 2011 to 2040, the cashflow for Scenario 5 plateaus as the business derives a regular real operating cashflow of $4.3 million per annum from the sale of carbon credits. The cashflow for Scenario 2 and 3 are on a negative trajectory due to the decline in terms of trade over the 30 year period. However, unlike CP, the larger economy of scale of the RP enterprise prevents it from producing a negative real operating cashflow within the analysis period.

The three management scenarios analysed at MB exhibit the highest degree of variation in the trajectories of real operating cashflow. The modest cashflow of Scenario 2 (Best Practice) over the 30 year period highlights that the business would need to undertake a development program if it intends to avoid the adverse impacts of declining terms of trade. The intensification scenario has a significant increase in cashflow in 2011, as income is derived from both a larger herd size and the sale of carbon credits. The real operating cashflow of the intensification scenario then steadily increases in almost a linear fashion as the full benefits of the increase in stocking rate and sale of carbon credits are realised. Scenario 5 (full destock with controlled savanna burning) has a significant increase in cashflow in 2011 as the income from the sale of the carbon credits commences. The cashflow for Scenario 5 then remains consistent until the year 2040, due the regular sale of carbon credits at a real price of $10 t CO_2-e.

5.6.6 Sensitivity of the financial returns of the scenarios to key assumptions

The results were tested to determine their sensitivity to a number of the key assumptions in the analysis. The sensitivity analysis involved manipulating real cattle prices and the contract price for carbon credits. A summary of the results of the sensitivity analysis is provided in Table 17.

Table 17: The sensitivity of net present value to the price of cattle and carbon credits

Scenario	Cheela Plains	Roebuck Plains		Mt Barnett	
	Scenario 3 - Intensification	Scenario 3 - Intensification	Scenario 5 – Full destock with burning	Scenario 3 - Intensification	Scenario 5 – Full destock with burning
Real cattle prices: -1.6% pa	$64,084	($2,017,480)	$38,405,918	$12,517,781	$19,728,458
Real cattle prices: +0% pa	$313,913	($1,113,763)	$35,016,914	$12,684,777	$19,465,899
Real cattle prices: +1% pa	$495,585	($363,067)	$32,444,486	$12,738,793	$19,267,289
No market for carbon	($151,555)	($3,280,931)	No income	($2,783,585)	No income
Carbon price: $5 per t CO_2-e	($36,994)	($2,648,569)	$18,756,146	$4,937,219	$9,434,560
Carbon price: $25 per t CO_2-e	$294,583	($66,094)	$97,355,233	$35,286,725	$50,610,153

An improvement in the price for cattle and carbon credits radically increases the NPV for the intensification scenario at CP and increase its attractiveness as an investment option. The results suggest that for CP to consider implementing the intensification scenario it would require cattle prices to be at least matching inflation and for carbon to be at least $10 t CO_2-e.

An increase in cattle prices still resulted in a negative NPV for the intensification scenario at RP when compared to the baseline (Scenario 2). As discussed earlier, this result is largely driven by the significant cost of the infrastructure relative to the marginal benefits provided by the project. RP could achieve a positive NPV for the intensification scenario, but it would require both a significant reduction in the amount of infrastructure that was included in this analysis and a substantial increase in livestock productivity. The reason the NPV of Scenario 5 at RP varies is because it is relative to the changing profitability of the base scenario (which does continue to derive an income from cattle sales). Therefore, as real cattle prices increase or stabilise over time the profitability of the base scenario improves and the marginal profitability provided by the full destock scenario is reduced. Clearly, if a carbon price of $25 t CO_2-e was able to be achieved then Scenario 5 at RP would become a very profitable proposition. The sheer volume of carbon credits at RP means that even at $5 per t CO_2-e an enterprise based solely on carbon could be profitable.

Cattle prices had less of an impact on the NPV of the intensification scenario at MB because carbon was the primary driver of the returns and the business has a small herd size which currently has low productivity. This is highlighted by the fact that if the business was unable to sell the carbon credits then investment in the scenario would not be feasible. The trends in Scenario 5 at MB are similar to those of Scenario 5 at RP.

5.6.7 Overall assessment of the financial feasibility of the management scenarios

The financial analyses undertaken as a part of this report represent a preliminary assessment of the profitability of the management scenarios for the three businesses. We recognised that there was a significant risk in making key assumptions concerning the different scenarios as these can heavily influence the outcome of the analysis. Obviously, more detailed analyses of the simultaneous interactions between key assumptions would further clarify the veracity of the results. Thorough sensitivity testing of key assumptions would also provide greater insight into the most suitable scenario or hybrid of scenarios.

The analysis highlights the marginal profitability of the pastoral businesses, particularly if real cattle prices continue to decline and the businesses do not (or are unable to) improve productivity and operating efficiencies. However, the potential sale of carbon credits may bolster the underlying profitability of the businesses. Carbon income, could be used to supplement existing cattle production income or replace cattle production as the sole enterprise for pastoral businesses. The analysis suggests that the adoption of an enterprise which is based solely on the sale of carbon credits is a highly feasible option for the pastoral businesses. However, it does expose the businesses to a high degree of risk, particularly since the carbon credits could only be sold in the voluntary market which has proven to be very volatile. Each business must also evaluate these results in the context of the other important values of the pastoral lease (environmental, social, culture and heritage).

5.7 Impact of methane and fossil fuel emissions on financial returns of carbon enterprises

The financial analysis suggests that all three businesses have the potential to biosequester carbon and generate an adequate financial return if they adopt certain management scenarios. However, the emissions from methane, fossil fuel usage and savanna burning that are associated with the scenarios were not taken into account in the analysis. This was a deliberate decision and is based on the fact that there is considerable uncertainty about the way in which a pastoral business may be accountable for these three sources of emissions.

Will the emissions from methane and fossil fuel need to be reported at the source (pastoral lease) or at the point of sale (e.g. a levy is paid per head that is exported or processed; fuel distributors charge an emissions levy)? It is also unclear if the concessions that the government may give to various sectors would alter the potential liability that pastoral businesses may incur if they participate in the carbon market (e.g. would a 1 t CO_2-e that is produced by cattle methane be the same value as 1 t CO_2-e that is biosequestered by trees or in the soil and sold as an offset?). Furthermore, the offset standard (e.g. VCS, NCOS, VER+) that a business owner decides to use to verify their offsets in the voluntary market will also determine the requirements of how methane and fossil fuel emissions are accounted for. For these reasons, the potential liability arising from these emissions were not included in the financial analyses. Nonetheless, it is important to evaluate their impact on the net biosequestration potential of the three case study businesses and hence they were calculated and the results are presented on a pastoral lease basis in Figures 62, 63 and 64.

The assumptions in these calculations included:

- Diesel and petrol consumption remains the same for all scenarios. Although we do expect consumption to vary between scenarios, we considered that there were too many variables which restricted an accurate estimation. Suffice to say that the intensification scenarios are likely to require the highest consumption and the full destock with no controlled savanna burning regime would have the lowest.
- The methane emissions for the Best Practice and Business-as-Usual Scenarios were the same and were estimated based on the average livestock numbers of the past five years. The methane emissions for the intensification scenario were based on the target potential carrying capacity.
- The emissions from savanna burning were the same for all scenarios except the option with full destock and controlled savanna burning (Scenario 5). The emissions were reduced by half for Scenario 5 in recognition of the fact that there is a substantial reduction in the intensity of the fire and this may cause less consumption of the biomass (the savanna burning emission calculations were completed using the same methodology as described in Section 2.14). It is probable that there will be differences between the other scenarios, however the large number of variables and their interactions would have made a simple estimate very difficult.
- The price of $10 per t CO_2-e was used in calculating the potential financial liabilities of the emissions.

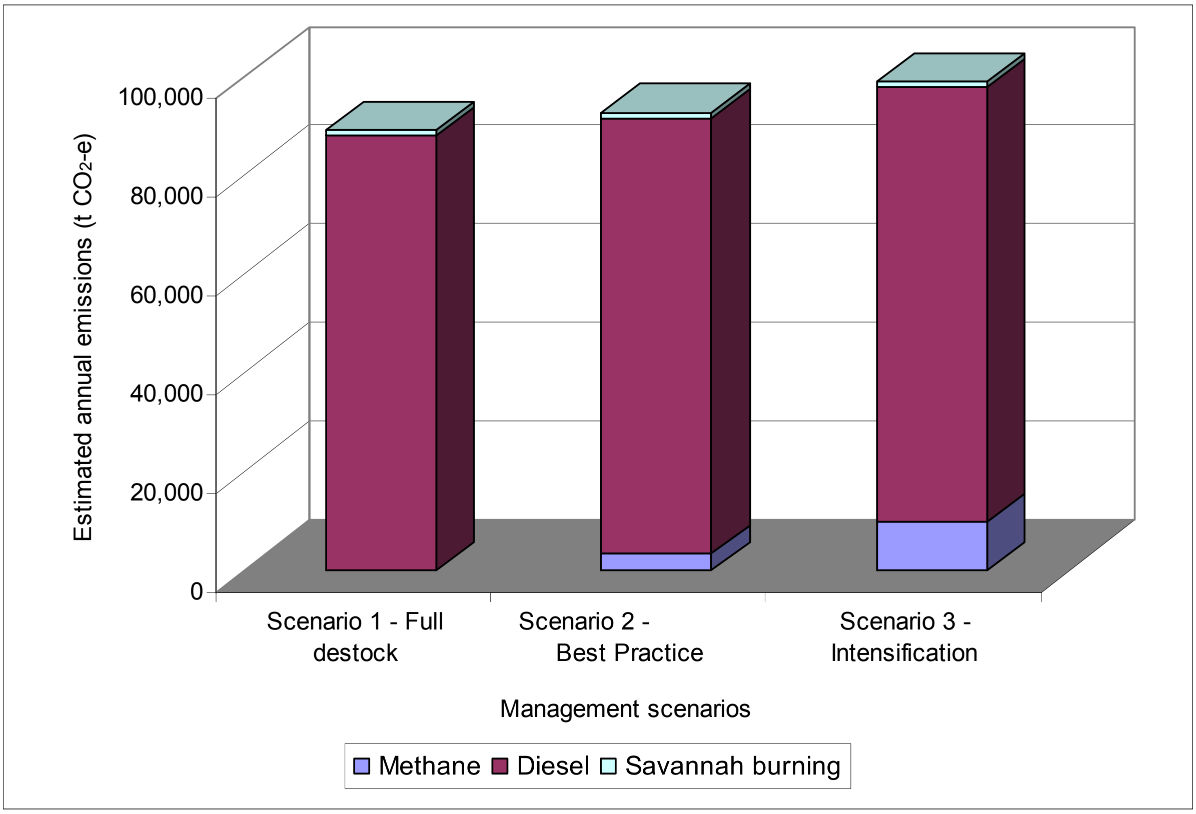

Figure 62: Estimated annual emissions from alternative management scenarios of Cheela Plains

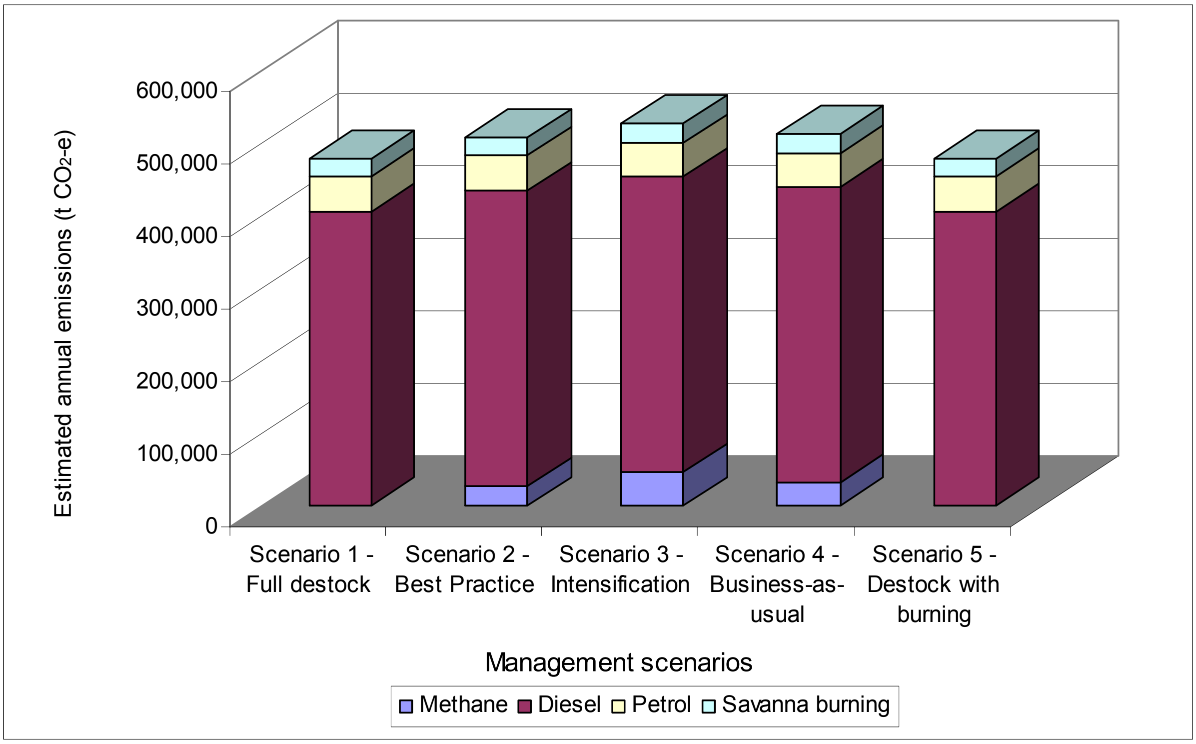

Figure 63: Estimated annual emissions from alternative management scenarios of Roebuck Plains

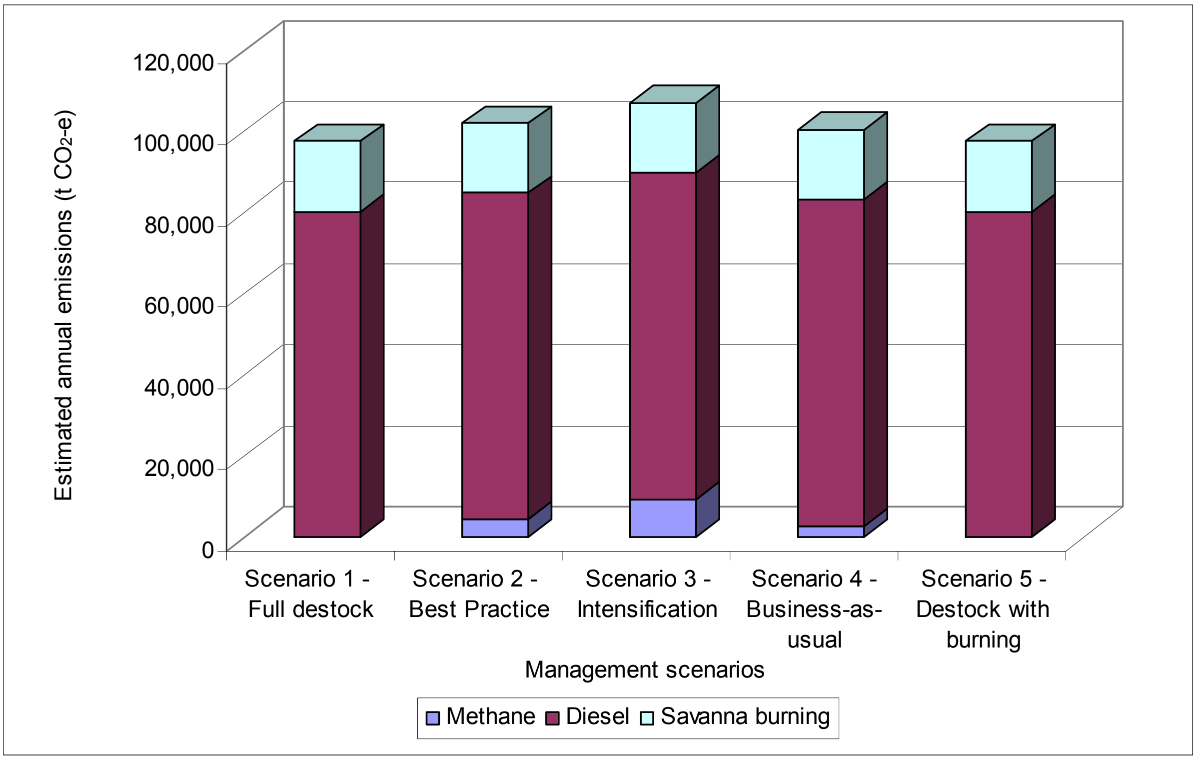

Figure 64: Estimated annual emissions from alternative management scenarios of Mount Barnett

The important finding from these estimates is that emissions produced by methane, fossil fuels and savanna burning are significant factors in the GHG profiles of the businesses. If these emissions had to be fully accounted for and priced at \$10 t CO_2-e, then the minimum amount that CP, RP and MB could be liable for on an annual basis would be \$891,406; \$4,783,891 and \$976,212 respectively.

The intensification scenario produced the highest amount of GHG emissions for all businesses. RP could be required to pay in excess of \$5 million per annum if they pursued the intensification option and emissions from methane, fossil fuel and savanna burning had to be included in their GHG accounts. The cost of paying for the emissions exceeds the income generated from the sale of carbon offsets for most of the management scenarios. The only scenarios which resulted in a positive net balance were:

- RP Scenario 5 - full destock with controlled savanna burning (\$1,349,298 per annum)
- MB Scenario 3 – intensification (\$1,282,709 per annum)
- MB Scenario 5 – full destock with controlled savanna burning (\$2,216,234 per annum)

(Values quoted are the gross incomes from the potential sale of carbon offsets after the cost of the total emissions have been subtracted).

Clearly, there are substantial reductions in the potential incomes that could be achieved from the sale of carbon offsets if the full cost of the GHG emissions needed to be paid. It highlights the implications of policy guidelines which determine how emissions from pastoral businesses are accounted for. If pastoral businesses are required to take full account of their total emissions in their offset projects then the results from this study suggest that there may be only a limited number of management options which can generate a satisfactory financial return.

The greatest reductions in GHG emissions on the three leases can be made by finding efficiencies in the use of fossil fuel. Research and extension efforts should be targeted at this area in order to assist pastoral businesses integrate technologies (e.g. telemetry, solar power vehicles) and management practices which require minimal use of fossil fuels.

5.8 Implications of the management scenarios for landscape function and environmental assets

It is important to have an understanding of the potential impacts that the alternative management scenarios may have on landscape function and the important environmental assets of the pastoral leases. Landscape function in this study is defined as the capacity for an ecosystem to attract water and nutrients and produce a ‘pulse’ of growth which provides biological feedback. The environmental assets are defined as the biophysical components of the landscape that are unique to the area (e.g. endemic flora and fauna species, wetlands). The primary environmental assets on the three leases were reported in Section 2.10. The following section details the potential environmental impacts of the management scenarios.

5.8.1 Cheela Plains

The three management scenarios (full destock, best practice and intensification) are unlikely to have any major detrimental effects on landscape function and the environmental assets of CP. Perhaps one of the most controversial scenarios from a land-use perspective is the full destock option. There are strong divergent opinions concerning the impact that fully destocking an ecosystem will have on landscape function, particularly when it has been disturbed by grazing for more than a century (Dean *et al*. 2009). There is some evidence to support the view that completely destocking can have a positive impact on landscape function (Brandis, 2008). However, other evidence suggests that once rangeland ecosystems are disturbed and in most cases degraded, they will require some form of ongoing management in order to assist their ecological restoration (Sayre, 2001). Reconciliation of these contrasting views has been the focus of substantial research, however a general conclusion is still not forthcoming. We suggest that fully destocking CP may have mixed impacts on the different land-systems within the lease.

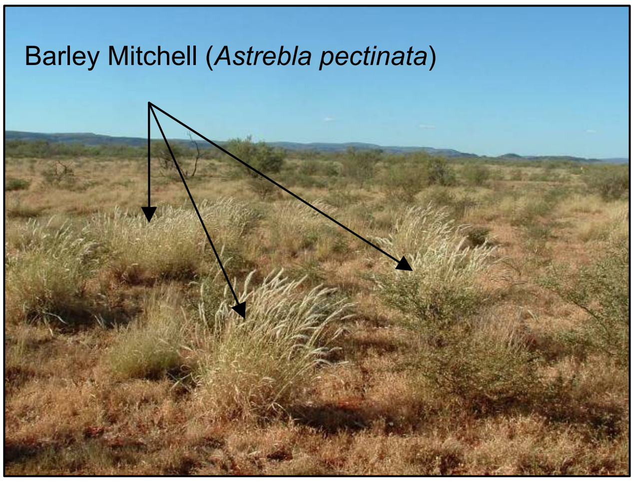

Figure 65: Increasing density and distribution of decreaser perennial grass species in grazed paddocks at CP
(Note the woody 'islands of fertility in the background)

A government land survey in 1978 classified the rangeland condition of the CP lease as 8% good, 26% fair and 66% poor condition[31]. In contrast, a pastoral lease inspection in 2008 classified the rangeland condition as 46% good, 43% fair and 11% poor condition (Dray and Stockdale, 2008). The managers of CP attribute this significant improvement in rangeland condition to a combination of the rest-based grazing system which was implemented in 2000, the colonisation by buffel grass (*Cenchrus ciliaris*) and a sequence of above-average seasons. This suggests that livestock do not need to be fully removed in order to achieve a substantial improvement in landscape function. However, would the ecological regeneration at CP have occurred more rapidly or over a much broader area at CP in the absence of grazing?

We cannot provide a categorical response to this question as there are very few areas in the productive land-systems on CP that have remained ungrazed. However, it is probable that in the absence of total grazing (livestock and kangaroos) the ecosystem would respond in a similar trajectory of regeneration. Specifically, apart from areas which are actively eroding, woody increaser species (*viz*. *A. victoriae*; *A. xiphophylla*, *A. tetragonophylla*) are likely to initially colonise areas and provide refuges for herbaceous species (*viz*. buffel grass, Roebourne Plains grass - *Eragrostis xerophila*). These 'islands of fertility' will effectively act as filters which trap soil that would have previously been transported and lost from the area

[31] Rangeland condition is a term which integrates an assessment of the relative distribution, density and diversity of perennial vegetation and condition of the soil surface conditions. It is often used as a surrogate for landscape function.

via the Hardy River. As ground cover increases and soil conditions become increasingly favourable (*viz.* low bulk density, available nutrients, stable temperature) then we would expect to see expanding distributions of decreaser perennial plant species (e.g. *Astrebla* spp., *Dicanthium sericium*, *Themeda triandra*, *Eulalia aurea*) (see Figure 64 as an example).

The full destock scenario may have adverse impacts on landscape function if management placed a strong emphasis on encouraging woody plant thickening. 55% of the carbon at CP was stored in the woody vegetation and the related coarse woody debris. If carbon was the only source of income for the business then there would be a strong financial incentive for management to investigate ways which would increase the woody component of the ecosystem on the lease. Functional landscapes require healthy stands of both woody shrubs and trees and herbaceous plants in order to maintain efficient water and nutrient cycles and energy flow. Distortion of the natural balance between woody plants and herbaceous shrubs and grasses is likely to have a mid to long-term detrimental impact on landscape function. Increased woody thickening has also proven to adversely impact biodiversity and may affect the recharge of the natural sources of water on Cheela (*viz*. Cheela spring and Woongarri pool). This issue is a significant risk because the artificial watering points would most likely be turned off under the full destock scenario. Therefore, existing native fauna would be dependent on these key sources of water.

It is unlikely that there would be any major impacts (positive or negative) on landscape function as a result of adopting the 'Best Practice' scenario (set-stocking with a 15% utilisation rate). The relatively low level of pasture utilisation is unlikely to compromise the active succession process which is currently underway at CP. The only significant risk that this scenario poses to landscape function is if a sequence of well below-average seasons occurs and management delays the adjustment of stocking rates. Failure to align stocking rate with the seasonal carrying capacity may reduce the existing robust stands of Roebourne Plains grass and buffel grass and this would leave the soil surface vulnerable to erosion.

The third scenario of intensification at CP is an extension of the management practices that have been implemented on the lease since 2000. Therefore, there is evidence to suggest that this scenario does have the potential to generally improve landscape processes across the lease. It is clear that some areas will respond more rapidly than others. For example, Figure 65 highlights that within the area under the rest-based grazing system at CP, some paddocks have had an improvement in total cover between 1989 and 2006 whilst others have generally remained unchanged.

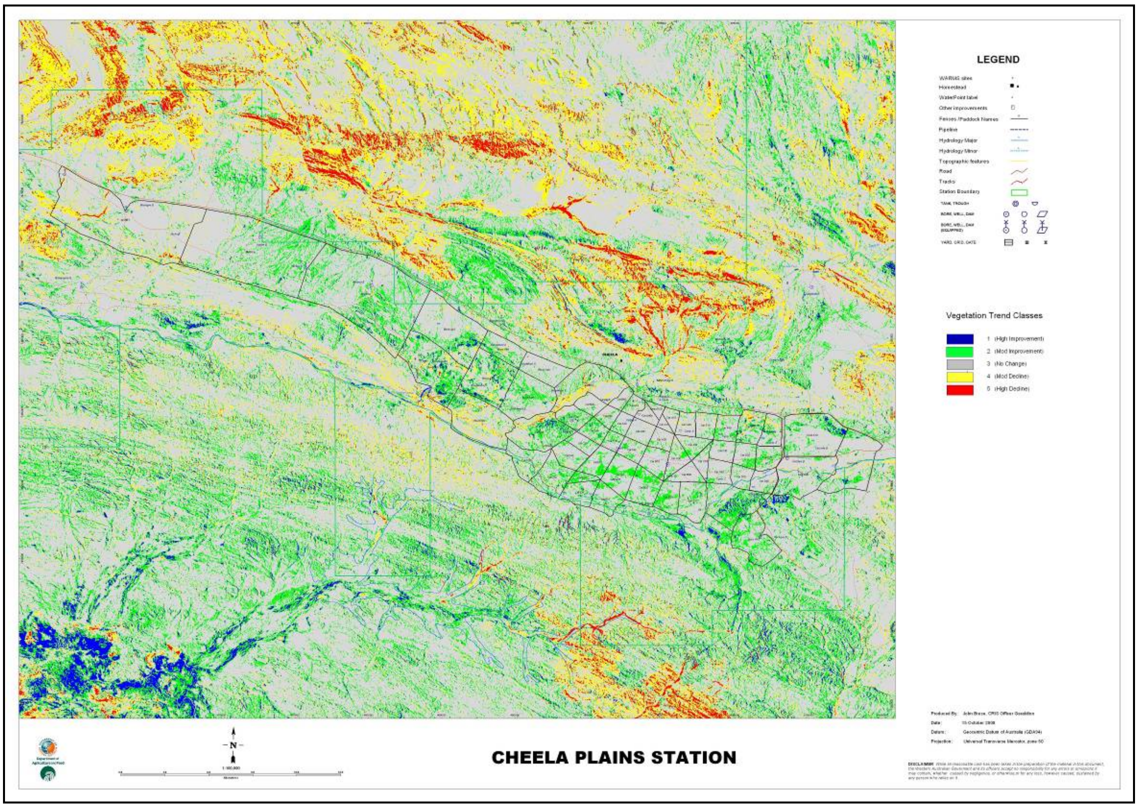

Figure 66: Estimated change in total cover between 1989 and 2006 at CP based on LCCA Vegmachine™ output

It is noteworthy that the managers of CP consider that the regeneration of the large, previously degraded floodplain would not have occurred without the disturbance of livestock grazing (Pensini, *pers comm*. 2009). This is based on their observations that the degraded area had remained virtually unchanged until the rest-based grazing system was introduced in 2000. There had been a sequence of above-average seasons (1973 to 1985) prior to the implementation of the rest-based grazing system which was relatively equivalent to the one that occurred between 1998 and 2004 which assisted the ecological regeneration. Therefore, above-average rainfall may not have been solely responsible for the improvement. Buffel grass was also likely to have been only a contributing factor. Buffel grass was first spread on CP by hand in 1963 in the headwaters of the Beasley River (Pensini, *pers comm*. 2010). By 1976, buffel grass was still largely confined to the Beasley River and along the Hardy River. There is evidence to suggest that the intensification of the grazing system conditioned the landscape in a manner that enabled it to capitalise on the benefits of the sequence of above-average seasons (1998 to 2004) and the colonisation of buffel grass of areas outside the main river channels (Tongway *pers comm*. 2008).

In summary, the specific impacts that the five management scenarios may have on landscape processes and the environmental values of CP include:

- Full destocking may maintain the existing trajectory of ecological regeneration and therefore management could expect an increase in decreaser shrub and grass species and improved soil surface conditions (this would clearly have biodiversity benefits). There was no clear evidence to suggest that the rate of regeneration would occur more rapidly compared to the intensification scenario. Consideration should be made regarding potential impacts on landscape processes and water recharge if the destock scenario demonstrates a propensity to woody weed thickening.

- Set-stocking with a 15% utilisation rate is likely to maintain the existing functional landscape processes provided management proactively adjusts stocking rate to the seasonal carrying capacity. This will be particularly important during sequences of below-average seasons when most of the acute damage is usually caused.
- The intensification scenario is likely to continue to have a positive impact on landscape processes provided stocking rate is adjusted appropriately and the additional infrastructure is installed in a 'ecologically aware' manner (e.g. minimum amount of clearing for fence lines; grade access tracks to conform with the natural contours; locate waters in resilient areas).

5.8.2 Roebuck Plains

Many of the impacts of the five simulated management scenarios for RP are similar to those discussed for CP. However, because fire plays a much greater role in the ecosystem at RP, it may result in some additional impacts (positive or negative). Specifically, the major considerations pertinent to RP include:

- changes in the density of wood plants in the large tracts of *Acacia* sandplain due to the burning regime;
- changes in herbaceous ground cover and soil surface conditions as a result of grazing disturbance, particularly on the marine floodplain;
- down-stream impacts that may effect the integrity of the Ramsar listed Roebuck Bay;
- minimisation of disturbance to the three large lagoons that are used by over 45 species of migratory birds;
- impacts of fire on flora and fauna diversity across the lease (Woinarski *et al*. 2005); and
- infrastructure development needs to have minimal impact on the landscape.

The full destock without controlled savanna burning scenario (Scenario 1) results in a significant increase in woody carbon. This increase is primarily a function of an increased availability of nitrogen. It is possible that an increase in woody plants will reduce landscape function because a reduced understorey will limit the capacity of the landscape to capture transported water and nutrients. However, in this instance the woody weed thickening will occur in the *Acacia* sandplains (Yeeda and Wanganut land-systems) and these areas are renowned for their deep sandy profiles. Consequently, even if the herbaceous understorey was significantly reduced it is unlikely that there would be a significant loss of water and nutrients from the area. Full destocking of the floodplain is likely to result in a gradual increase in ground cover as areas which have previously been overgrazed begin to be re-colonised by perennial grasses (viz *Sporobolus virginicus*). Scenario 1 is unlikely to have any detrimental impacts on the Ramsar listed Roebuck Bay or the lagoons. The full destock with controlled savanna burning scenario (Scenario 5) would have similar impacts to Scenario 1. However, the effects of woody plant thickening are likely to be accentuated in Scenario 5 as it was predicted that it would biosequester at least three times more woody carbon than Scenario 1.

The Best Practice scenario (Scenario 2) for RP represents a reduction in the present pasture utilisation rate that is currently applied across the lease (i.e. reduced from 30% to 15%). Consequently, it may result in an improvement in landscape processes, particularly on the marine floodplain, as ground cover may increase and the physical properties of the soil are enhanced. Indeed, the model results suggest that set-stocking at 15% utilisation resulted in the highest increase in soil carbon compared to all the other scenarios. An improvement in ground cover and soil surface conditions may have a positive impact on Roebuck Bay if the deposition of excessive sediments becomes an issue. Provided the lagoons remain fenced off and are only episodically grazed then it is unlikely that this scenario would have any adverse impacts on the integrity of these areas or interfere with the behaviour of the migratory birds.

The intensification scenario (Scenario 3) requires a substantial financial investment and consequently the business would seek to achieve a reciprocal increase in the number of cattle that are managed on the lease. It is possible that if grazing pressure is not effectively managed within the system then the adverse impacts of overgrazing will be magnified, particularly during below-average seasons. Furthermore, the smaller paddocks, shorter graze periods and higher livestock densities may result in more uniform utilisation and if the rest periods are not suitably managed, then vulnerable decreaser plant species may be adversely affected (e.g. native millet – *Panicum decompositum*). However, if grazing pressure is managed appropriately it is quite possible that substantial improvements in landscape function and related pastoral potential can occur on RP as a result of the intensification scenario. The rapidity of the potential improvement will be largely influenced by seasonal conditions. The infrastructure development associated with the intensification scenario needs to be designed and installed in an 'ecologically aware' manner.

Figure 67: Evidence of localised patch grazing on the Roebuck floodplain

The Business-as-usual scenario (Scenario 4) at RP is likely to have a fairly benign impact on landscape processes when compared to the other scenarios. This inference is based on the results from the CENTURY simulation which predicted that the scenario would result in a fairly modest increase in soil carbon across the lease (<3.33 t CO_2-e increase between 2010 and 2040). It is possible that the level of grazing involved in this scenario could cause degradation in localised areas because the CENTURY model assumed that the utilisation rate was moderated at approximately 30% across the lease. In reality, patch grazing is a common occurrence in large paddocks which are set-stocked (Figure 67). Earlier reconnaissance surveys of RP found evidence to support this statement (*viz*. bare soil surface near watering points and reduced densities of perennial grasses in some fertile run-on areas). However, unless these localised areas of degradation coalesce at a landscape scale, they are unlikely to have any overriding biophysical impact.

In summary, the specific impacts that the five management scenarios may have on landscape function and the environmental values of RP include:

- The increase in the density of woody plants in the *Acacia* sandplains as a result of Scenarios 1, 3 and 5 may adversely affect the herbaceous understory through the competition for water, nutrients and light. Management should seek to achieve a suitable balance between the two components in the ecosystem. We expect that this will be largely determined by financial implications. For example, would a landholder who has fully destocked and is solely reliant on income from carbon credits reduce the density of woody plants simply to achieve a biodiversity outcome for no monetary gain?)
- All of the management scenarios resulted in an increase in ground cover and improvement in soil surface conditions, albeit some scenarios were far better than others.
- None of the scenarios are likely to cause any adverse impacts on the lagoons or the Ramsar listed Roebuck Bay. In fact, most of the scenarios may improve the integrity of the Bay through a reduction in sediment deposition.
- More frequent fires in the full destock scenarios (1 and 5) may compromise the vigour of some fire intolerant perennial plant species.

5.8.3 Mount Barnett

The impacts of the five management scenarios on landscape function and the environmental assets of MB are relatively similar to those outlined for RP. Therefore, a summary of specific impacts include:

- The CENTURY results indicated that the intensification scenario (Scenario 3) and the full destock with controlled savanna burning scenario (Scenario 5) biosequestered the greatest amount of soil carbon compared to the others. This is largely the result of reduced fire intensity and, in the case of the intensification option, improved control over grazing pressure. Increased levels of soil carbon indicate that these scenarios may improve landscape processes on the lease, particularly in the fertile, open woodland areas (Kennedy land-system).
- Increased densities of woody plants may affect the water recharge and the environmental flows of the Barnett and Hardy Rivers. Woody plant thickening may also reduce the productive capacity of the open woodland areas of the Barnett and Police Valleys.
- There are a number of unique geological and environmental assets on MB that are of high value from a tourism perspective (e.g. Spider impact crater, Manning Gorge, Galvins Gorge). None of the scenarios are likely to have a major detrimental impact on any of these assets.

5.9 Implications of the management scenarios on social and cultural values

A change in management strategy or land-use usually has ramifications for the social and cultural facets of a business and the region in which it operates. A detailed evaluation of the social and cultural impacts of the management scenarios was not the focus of this study. However, in recognition of their importance in the decision making process, the following is a list of potential implications that should be considered:

- Fully destocking and simply managing the landscape for carbon offsets may require less labour (particularly if no fire management is required). If this change in land-use occurred across a region then there may be a significant reduction in the number and the quality of support services as well as the size and vibrancy of the local community. Alternatively, evidence from the West Arnhem Land Fire Abatement Project indicates that the opposite may hold true for remote indigenous communities, because it provides employment for local people to 'manage their country' and be paid for it.
- If entire regions were fully destocked for an extended period then both the internal and external pastoral infrastructure would inevitably deteriorate and the 'corporate knowledge' of the industry and its service providers would decline over time[32]. This would be a major issue if the region needed to be returned to cattle production. It would require significant capital investment and involve a considerable lag time as the industry and its service providers become reskilled.
- For some leaseholders who currently do not run a commercial pastoral business the opportunity to derive an income from managing the landscape for carbon offsets may be attractive. The stakeholder groups that may be interested include: Indigenous communities, people who have purchased leases for lifestyle or philanthropic purposes and conservation based State Government agencies or non-government organisations. There could be many follow-on benefits, particularly for some remote indigenous communities as it maybe an opportunity for them to become a part of the mainstream economy (e.g. genuine employment, utilisation of their traditional knowledge to manage country, improved self-worth, health and general wellbeing).
- Intensification of the existing management system is likely to pose many legitimate concerns by pastoralists. Intensification requires a strong commitment and keen sense of purpose as it will require a high level of management and pastoralists will be required to develop new skills and be challenged on a regular basis.
- The infrastructure development program will require significant capital investment and this may intensify the financial pressure. Pastoralists may need to become involved in a support group of like-minded people to maintain motivation and drive innovation. Pastoralists would need to determine if the potential 'costs' of intensification (time, money and energy) are commensurate with the returns (financial, environmental and social). They may also need to evaluate whether the intense management system is compatible with their personal qualities and life goals.
- The social implications of either adopting the Best Practice Scenario or continuing with the Business-as-usual Scenario are fairly benign. To adopt the Best Practice scenario both RP and MB simply need to make moderate reductions in their stocking rates. These decisions are made on a regular basis and would require no radical social readjustment and would have no cultural implications. CP is continuing to manage according to the intensification scenario, therefore a transition back to a set-stocking

[32] Internal infrastructure refers to that which is managed by an individual pastoral business (e.g. watering points, fences), whilst external infrastructure refers to that which is used by the industry as an aggregate (e.g. export holding yards and facilities, feedlots, road train depots).

system may increase anxiety levels because management has less control over grazing pressure.

5.10 Overall assessment of the different management scenarios

No two properties in the Kimberley-Pilbara region are the same, in the same way that no two land managers are the same. Land use and management regimes are usually determined by a complex web of interrelated climatic, economic, environmental, social and cultural factors. Consequently, there is never only one management strategy or land use which is exclusively suited to all areas and can be universally applied to every circumstance. The purpose of this study was not to recommend which management scenario each business should adopt, rather it sought to obtain objective information which could be used to assist in the decision making process. Clarification of the specific goals of a business will determine the most compatible management scenario (or a hybrid of the management scenarios).

In this context, we attempted to synthesis all of the information which has been presented in the previous sections into a simplified qualitative assessment which evaluated each of the scenarios against five core criterion (refer to Table 18). The scoring for each criterion is based on a simple ranking of:

- good (the management scenario is likely to deliver positive benefits related to the specific criterion);
- fair (the management scenario is likely to have a relatively benign effect on the specific criterion); and
- poor (the management scenario is likely to have an adverse impact on the specific criterion).

The ranking is based on the outcomes of a transition from the existing enterprise and circumstance of the business to the alternative scenario. Consequently, the same management scenarios may have different rankings for separate businesses. It should be recognised that the scoring of each management scenario may vary depending on the manner and the scale at which the scenario is undertaken. Based on their specific circumstances, businesses will need to determine what relative weightings they apply to the five criterion. For example, is the financial imperative the most important factor or is landscape recovery and community engagement? Where are the trade-offs in their personal situations? Finally, we emphasis that the assessment in Table 18 pertains only to the case study business and there is limited scope to extrapolate these results over a much larger geographical area.

Table 18: Qualitative assessment of the different management scenarios for the case study businesses

Business	Management Scenario	Climatic – capacity for sequestration or emissions abatement	Economic – financial returns of enterprise	Environmental – impact on land condition and biodiversity	Social – community engagement and employment	Cultural – preserving heritage and indigenous knowledge
CP	Scenario 1 - Full destock	Poor	Poor	Good	Poor	Fair
	Scenario 2 – 'Best Practice' (baseline)	Fair	Fair	Fair	Fair	Fair
	Scenario 3 – Intensification	Good	Good	Good	Fair	Fair
RP	Scenario 1 - Full destock	Good	Good	Good	Poor	Good
	Scenario 2 – 'Best Practice' (baseline)	Fair	Fair	Good	Fair	Fair
	Scenario 3 – Intensification	Good	Good	Good	Fair	Fair
	Scenario 4 – Business-as-usual	Poor	Fair	Fair	Fair	Fair
	Scenario 5 – Full destock with controlled burning	Good	Good	Good	Poor	Good
MB	Scenario 1 - Full destock	Fair	Fair	Fair	Fair	Good
	Scenario 2 – 'Best Practice' (baseline)	Fair	Fair	Fair	Fair	Good
	Scenario 3 – Intensification	Good	Good	Good	Good	Good
	Scenario 4 – Business-as-usual	Poor	Fair	Fair	Fair	Fair
	Scenario 5 – Full destock with controlled burning	Good	Good	Fair	Fair	Good

5.11 Conclusion

The rangelands have considerable potential to significantly reduce the legacy load of greenhouse gas emissions through biosequestration and can reduce future emissions through innovative technologies and practices (Garnaut, 2008; CSIRO, 2009). The results from this study found that businesses in the Kimberley-Pilbara do have the capacity to biosequester carbon and some of these management strategies can achieve satisfactory financial returns. Some of the management strategies complement existing enterprises whilst others may displace the present land use (e.g. full destocking). Many of the management scenarios are able to deliver a number of other environmental, social and cultural co-benefits. However, some may directly compromise the infrastructure and social fabric that support the existing pastoral industry[33].

At a whole lease scale CP has the potential to biosequester an estimated 81,329 t CO_2-e over the 30 year simulation period which could be valued at \$813,294 (or \$0.37 ha^{-1} yr^{-1}). This increase in baseline carbon levels was achieved through the intensification scenario (i.e. rest-based grazing). The results indicate that at CP the intensification scenario can achieve the highest financial return. This was because it biosequestered higher levels of carbon and cattle income increased proportionally with the increase in the potential livestock carrying capacity. Much greater changes to the baseline carbon level could be achieved if CP developed an offset project on a smaller scale (<10,000 ha) within areas which are severely degraded. The greatest change in baseline carbon levels at CP is likely to occur in the river floodplain (River land-system).

The results suggest that RP has significant potential to biosequester carbon due to its large spatial size, relatively reliable rainfall and productive land-systems. At a whole lease scale RP has the potential to biosequester an estimated 18,399,567 t CO_2-e over the 30 year simulation period which could be valued at \$183,995,666 (or \$21.66 ha^{-1} yr^{-1}). This represents an attractive financial proposition to RP when compared to the returns from the existing cattle enterprise. In contrast to CP, this increase in baseline carbon level was achieved through the full destocking and controlled savanna burning scenario. All of the simulated scenarios had an increase in soil carbon; whilst only the two destock scenarios (1 and 5) resulted in an increase in woody plant carbon. The results indicate that RP could capitalise on the financial opportunity to trade in offsets and continue to manage a cattle enterprise, however it would need to intensify its existing operations. The results indicate that early dry season burning (May) can result in a significant increase in the baseline levels of woody biomass in the extensive *Acacia* sandplain areas of the lease. None of the management scenarios is likely to have any significant detrimental impacts on the Ramsar listed Roebuck Bay or the lagoons on RP which are important habitat for 45 species of migratory birds.

Compared to the other two businesses, MB has considerable scope to adjust its present management system. This is because it currently has a limited amount of infrastructure and this restricts their capacity to exercise control over grazing pressure across the lease. At a whole lease scale MB has the potential to biosequester an estimated 9,577,337 t CO_2-e over the 30 year simulation period which could be valued at \$95,773,373 (or \$42.98 ha^{-1} yr^{-1}). This increase in the baseline carbon level was achieved through the simulated full destock and

[33] In this context social fabric is defined as the level of community engagement; the number of employment opportunities; a strong sense of community identity and purpose; and the level of innovation and support that occurs when a critical mass of like-minded individuals participate in the same industry.

controlled savanna burning scenario. The potential gross income from this scenario was by far the highest on a per hectare basis compared to any of the other businesses.

For the majority of the land-systems which were modelled, the woody plant carbon represented a much higher proportion of the total compared to the soil carbon. Therefore, there may be a financial incentive for landholders who derive an income from carbon offsets to increase the density of woody plants on their lease. This may distort the natural balance between the woody plants and the understorey and if applied across a large area it could have adverse impacts on landscape function, biodiversity, stream flow and water recharge.

The way in which emissions from methane, fossil fuel and savanna burning are accounted for and covered will have a significant effect on the financial prospects for carbon offsets in the rangelands. Consequently, in the event that all sources of emissions were fully covered on a pastoral lease, the potential annual liability would erode quite considerably any income from carbon offsets. It is noteworthy, that contrary to popular opinion this study found that methane made a relatively minor contribution to the total of GHG emissions produced by a pastoral business (<10% of the total). Instead, fossil fuel consumption was responsible for the vast majority of emissions. A greater research focus on technologies and management practices which are less reliant on fossil fuels could radically alter the GHG profile of pastoral businesses. Carbon brokerage may also be a considerable cost to an offset project[34].

In conclusion, this study found evidence to suggest that a change in management practice on the case study businesses in the Kimberley-Pilbara region may increase the baseline levels of soil and woody plant carbon. It demonstrated that biosequestering carbon and livestock grazing are not mutually exclusive and that pastoralists in the Kimberley-Pilbara region may have an opportunity to reduce GHG emissions and improve landscape function whilst continuing to produce high quality beef for both the export and domestic markets. The potential financial returns that may arise from carbon offset based enterprises will be heavily dependent on the voluntary carbon market and climate change policy settings of the Commonwealth and State Governments.

[34] The financial analyses within this study used a carbon brokerage rate of 20% of the total value of the offsets (Carbonlink, 2009).

CHAPTER VI: THE NEXT PHASE IN THE DEVELOPMENT OF THE WA RANGELANDS CARBON INDUSTRY

> "Climate change policies have the potential to result in fundamental changes in Australian agriculture, especially over the longer term. It is arguable that the impact of climate change policies could be greater than the impact of climate change itself, especially in the short to medium term" (Keogh, 2007, p. 11).

In 1883 the Governor of Western Australia, Sir Frederick Broome, along with the other administrators of the fledging WA colony were faced with a difficult decision. They had received a promising report from John Forrest about the economic prospects for a vibrant pastoral industry in the Kimberley region. However, there were many genuine risks and barriers which had to be overcome in order to realise this opportunity. Therefore, John Forrest recommended the government provide the "easiest terms and conditions" to encourage the development. The government took this advice and as a consequence the pastoral industry played a critical role in the socio-economic development of a region which today has one of the fastest growing populations and economies in Australia. The WA State Government has a similar challenge today in respect to the nascent carbon industry.

Politicians, industry, Traditional Owners, investors and the relevant administrators in WA are generally aware of the potential opportunities for carbon offset based enterprises in the State's rangeland regions. However, many are largely unclear about the specific pathway that needs to be taken in order to commercialise carbon offsets and realise the benefits that it may deliver to a business or a region. Consequently, this Chapter provides some recommendations for government and industry concerning how to progress the development of the carbon based industry in the WA Rangelands. Specifically it sought to address four key questions:

- Why should the State Government and other service providers support the development of a carbon based industry in the WA Rangelands?
- Who are the primary stakeholders in the rangeland carbon opportunities and what is their role?
- Where should we target the resources in order to commercialise carbon in the WA Rangelands?
- What are the specific actions that need to occur in order to commercialise the opportunities in the WA rangelands?

We wish to highlight that whilst the focus of this study was primarily focussed on carbon offsets, reference to 'carbon opportunities' in this final chapter includes other potential carbon asset classes in the rangelands (e.g. controlled savanna burning, biofuel production, methane mitigation from livestock or non-domestic grazers, reforestation, afforestation). In addition, the horticultural precincts and intensive agricultural areas which lie within the WA Rangelands region (e.g. Carnarvon Basin, Ord Irrigation Area) are included in our reference to the 'WA rangelands carbon industry'.

6.1 Potential benefits to Western Australia

A carbon-based industry in the WA Rangelands has the potential to make a significant contribution towards a number of the socio-economic and environmental priorities of the WA State and Federal Governments. The State Government has a long-term focus on regional development throughout Western Australia. The Royalties for Regions (RFR) program is an agreement that highlights the priority that the WA Government has placed on growing vibrant, sustainable regional communities[35]. Sustainable communities require a robust economic base and carbon based enterprises in the WA Rangelands have the potential to attract significant amounts of capital into the regions and compliment existing industries. Commercialisation of carbon in the WA could provide opportunities for employment, build local capacity, improve services and retain many of the environmental benefits in the immediate region.

Development of a carbon industry in the WA Rangelands could contribute to the fulfilment of Recommendations 4, 5 and 8 of the Northern Australia Land and Water Taskforce (Commonwealth Government, 2009, p. 4). The taskforce recommended that the Australian government "should act to improve the condition and resilience of the natural estate of northern Australia through the provision of market based incentives to reward good stewardship on privately held and indigenous owned lands" (Commonwealth Government, 2009, p. 4). Carbon has proven to be an effective market based instrument which can catalyse a shift in management practices and promote ecologically sustainable development.

The specific benefits of a carbon based industry in the WA Rangelands may include:

- a carbon industry in Australia's rangelands could generate more than $1.64 billion per year for a period of at least 30 years and WA could capture a significant share of this income[36];
- a significant proportion of the State's land estate is presently degraded and the restoration of this is well beyond the capacity of land managers and taxpayer funded natural resource management (NRM) programs. Carbon based enterprises have the potential to improve the condition of the natural estate at minimal cost to the community;
- improved land condition and restoration of habitat will conserve the integrity of the State's unique biodiversity;
- carbon based enterprises can compliment existing pastoral businesses and thereby strengthen their financial resilience;
- rangeland carbon enterprises can provide significant employment opportunities, particularly in remote areas where participation in the mainstream economy is typically very low and there is a strong culture of welfare-dependency; and
- a carbon industry in Australia's rangelands could offset approximately 25% of Australia's total annual emissions and thereby mitigate the adverse consequences of climate change[37].

35 The RFR program involves the equivalent of 25% of Western Australia's mining and onshore petroleum royalties being returned to the State's regional areas. The money is in addition to regular Budget programs and in 2009-10 it will provide an additional $619 million for regional communities.

36 Based on the biosequestration/mitigation estimates made by CSIRO (2009 p. 17) and a carbon price of $10 t CO_2-e.

37 Based on Australia's annual emissions in 2007 of 596 Mt CO_2-e (inclusive of emissions from LULUCF) (DCC, 2009) and the estimated biosequestration potentials (CSIRO, 2009)

The WA Government will need to discern whether these potential benefits to the State overshadow the issues of risk and liability that are related to the genesis of any new industry. In addition, it will also need to determine whether the investment that will be required to establish the appropriate institutional framework to support a carbon industry in the WA Rangelands will yield a higher socio-economic dividend to the State compared to other competing opportunities and priorities.

6.2 Key stakeholders and their role in the development of a WA Rangelands carbon industry

This study held a workshop in February 2010 in order to clarify the immediate pathway for the commercialisation of carbon in the WA Rangelands. The workshop involved representatives from research organisations, private carbon consulting and brokering groups, producer lobby groups and government (Agknowledge, unpublished). The participants came to a general consensus that their vision was "to encourage sustainable industry and community development and improved environmental benefits through commercialising rangelands carbon" (Agknowledge, unpublished, p. 1). To achieve this vision the workshop participants identified six key issues that need to be progressed, these include:

1. **Research –** limited data on most WA rangeland land-systems.

2. **Measurement –** which voluntary standard (if any) is appropriate for carbon credits created in the WA Rangelands. Investors want confidence in the carbon estimates.

3. **Land tenure –** existing pastoral lease conditions in the WA rangelands are perceived to be restrictive.

4. **Security and liability** – consideration of any ongoing liability for the State of potential changes in baseline carbon levels in the rangelands.

5. **Information exchange –** sharing and dissemination across State agencies, landholders, traditional owners, service providers and investors.

6. **Market uncertainty –** at present the carbon industry is heavily reliant on the voluntary carbon market and it is susceptible to change due to future State and Federal Government climate change policies.

Table 19 provides a summary of the major stakeholders and their proposed interests and role in the emerging WA carbon industry.

Table 19: Key stakeholders in the emerging WA Rangelands carbon industry

Stakeholder group	Specific interests in the carbon industry	Role in the development of the carbon industry
Traditional owners	Preservation of cultural and natural heritage and employment opportunities for the local community	Assist in the development of carbon projects which are both culturally sensitive and advance the rights of indigenous people. Communities may also partake in the employment opportunities created by the projects.
Landholders (indigenous communities, pastoralists, NGOs, resource companies)	Enhance the financial stability/resilience of existing businesses. Improve land condition and biodiversity. Build socio-economic capacity within the regions.	Develop innovative business plans to realise the opportunities in the region. Lobby government for the approval to diversify their business into carbon based enterprises. This group is the primary financial beneficiaries of carbon projects.
Mining and resource companies	The majority have significant GHG emission liabilities and a commitment to deliver broader socio-economic benefits to the regional community.	Provide investment capital to purchase voluntary carbon credits from rangeland carbon projects. Existing company corporate structures and physical infrastructure could be used to support carbon projects.
Offset project developers, carbon brokers, private investors and equity firms	Potential financial returns and interests in mitigating the effect of climate change and improving land condition and biodiversity.	Delivering the rangelands carbon credits to the market. Involved in the commercial development of projects.
Research bodies and universities	Fostering and building the scientific basis of GHG mitigation and abatement	Delivering focussed research programs which address specific questions of the rangeland carbon industry.
Department of Agriculture and Food WA	Sustainable industry development	Facilitating industry and research partners in realising the opportunity through the development of commercial scale carbon projects.
Department of Regional Development and Lands	Greater socio-economic and environmental outcomes for regional WA. Require confidence in its potential feasibility.	Management of land tenure and security of title issues. Consideration of the liability of carbon projects on leasehold land to the State
Department of Environment and Conservation	Improved conservation outcomes, potential income generation from management of existing reserves	Potential development of commercial scale carbon projects within the conservation reserve system
WA Office of Climate Change	Development of robust technologies and management practices that cost-effectively reduce GHG emissions in WA	Assist in the development of verification protocols applicable for rangeland carbon projects.
Commonwealth Government	Achieve GHG emission reductions in the most cost-effective manner	Provide leadership in the development of both the voluntary and mandatory markets in Australia.

6.3 Priority areas of investment to commercialise carbon offsets in the WA Rangelands

The WA Government currently invests in market development for a range of industries. Therefore, the government needs to resolve what and how it will invest in building knowledge, information and facilitate landholders and service providers in order to realise the benefits of the trade of rangeland carbon for WA. We consider that there is adequate information to justify the commercialisation of carbon in the WA Rangelands. The challenge now is to scope how a number of defined case studies can be progressed through to commercialisation.

There is a range of carbon asset classes which differ in their potential volume, monetary value and ease to market. Therefore, to facilitate the development of the industry in the region, it is important that further research and investment capital is directed to the carbon asset classes which have the following characteristics:

- high ‘bankability’ and marketability (i.e. robust accounting and verification process is currently available for the asset class; comparatively easy to implement change in practice or land use; immediate recognition of the benefits of the asset class by corporate buyer’s; and the attractiveness of the asset class to customers and consumers).
- capacity to yield attractive financial returns with minimal delay in real operating cashflow;
- high fungibility (i.e. capacity to be traded in a range of carbon markets both within Australia and internationally);
- low transaction costs in the measurement and verification of the asset; and
- limits the exposure of industry players to risk and liability.

CSIRO completed a qualitative assessment of the ‘bankability’ of the range of carbon asset classes that can be created on rural land in Australia (CSIRO, 2009). Asset classes which involve regrowth or plantation enterprises were regarded as having a higher bankability and marketability due to the much greater research base and the commercial maturity of the forestry sector (Figure 68). This has been demonstrated by the fact that the majority of Australian carbon offset developers and brokers servicing the voluntary market are principally involved with carbon credits from woody vegetation (Broad, K. *pers comm*. 2010). Carbon credits from woody vegetation are also highly fungible because they are a recognised asset class under Article 3.3 of the Kyoto Protocol.

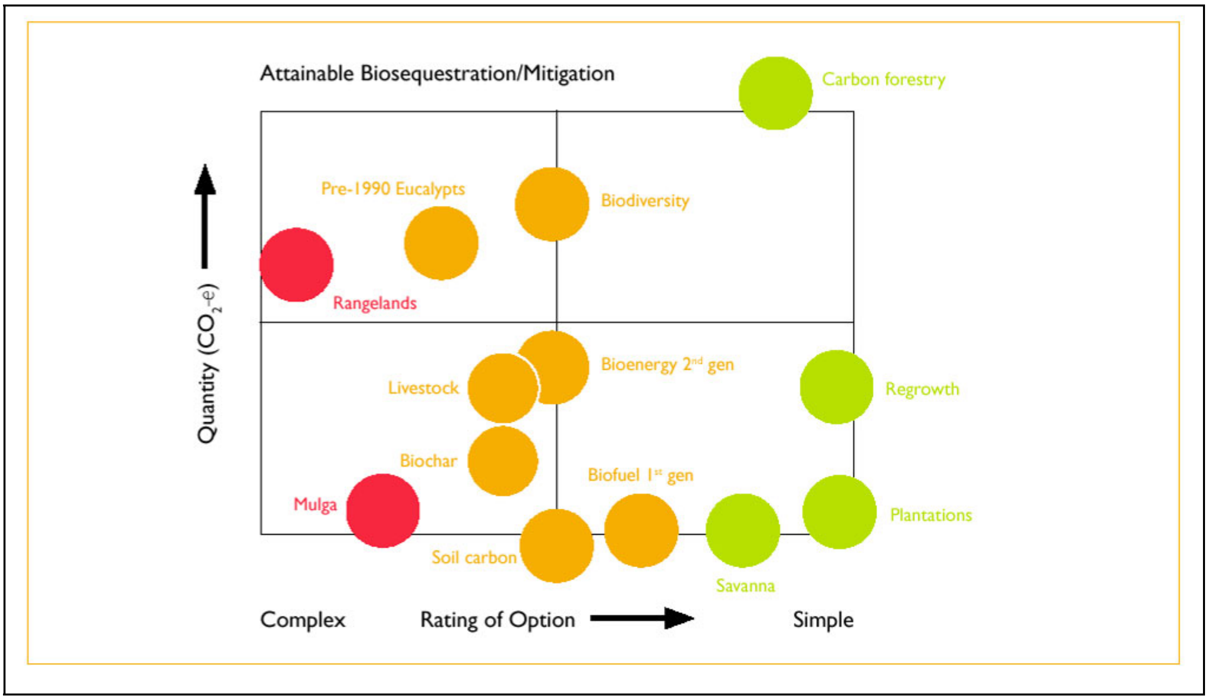

Figure 68: Qualitative assessment of the 'bankability' of different carbon asset classes based on the attainable GHG biosequestered/mitigated and complexity of implementation of each asset class (Reproduced from CSIRO, 2009)
(The colour of the balls indicates the relative difficulty of implementation. Red being the most difficult and green the least difficult to implement).

The CSIRO study was conducted with a specific focus on Queensland, however the findings of the report still have significant application to the WA Rangelands. Consequently, we adapted the information contained within this report and prepared a similar assessment which identifies the 'most bankable' carbon asset classes as they relate specifically to the WA Rangelands (Table 20). The rankings of the different factors in the assessment are based on a simple shading scale, where green equates to 'good', orange equates to 'fair' and red equates to 'poor'. The assessment is arbitrary, but we consider that it highlights the relative merit of the different asset classes in the region based on the existing policy and commercial environment.

Table 20: Qualitative assessment of the relative commercialisation prospects for different carbon asset classes in the WA rangelands

Carbon asset class	Maturity of science and technology	Potential volume and value	Ease of implementation	Fungibility	Level of risk and liability	Level of other socio-economic and environmental co-benefits	Applicable WA Rangeland region
Plantation forestry*				Article 3.3 Sinks Kyoto, CPRS and NCOS compliant			Kimberley-Pilbara
Regrowth of native vegetation*				Article 3.3 Sinks Kyoto, CPRS and NCOS compliant			Limited areas within the existing intensive agriculture and horticultural precincts
Savanna burning				Kyoto compliant gases only (N_20 and CH_4)			Kimberley
Biofuel 1st generation				Article 3.1 – compliant with Kyoto, CPRS and NCOS			Kimberley-Pilbara Gascoyne-Murchison Goldfields
Bioenergy 2nd generation				Article 3.1 – compliant with Kyoto, CPRS and NCOS			Kimberley-Pilbara Gascoyne-Murchison Goldfields
Biodiversity plantings*				Article 3.3 Sinks Kyoto, CPRS and NCOS compliant			Pilbara Gascoyne-Murchison Goldfields-Nullarbor
Biochar				Article 3.4 not included in CPRS, voluntary market only			Restricted mainly to the intensive agriculture and horticultural precincts (Ord and Carnarvon basin)
Mitigation of GHG from livestock and other grazers (e.g. camels)				Article 3.1 – compliant with Kyoto, CPRS and NCOS			Entire WA Rangelands region
Reforestation and afforestation*				Article 3.3 Sinks Kyoto, CPRS and NCOS compliant			Gascoyne-Murchison Goldfields-Nullarbor
Reforestation and afforestation**				Article 3.4 not included in CPRS, voluntary market only			Gascoyne-Murchison Goldfields-Nullarbor Kimberley-Pilbara
Soil carbon (resulting from revegetation projects)				Article 3.4 not included in CPRS, voluntary market only			Gascoyne-Murchison Goldfields-Nullarbor Kimberley-Pilbara

***Asset class meets current Kyoto requirements of canopy cover > 20% and > 2 m height and patches > 0.2 m. **Asset class fails to meet Kyoto requirements for a 'forest'. (Information in table is adapted from CSIRO, 2009). See footnote 5 (page 29) for the definition of reforestation and afforestation.**

The assessment indicates that the immediate opportunity for carbon in the WA Rangelands is related to plantation based projects. However, plantation based projects which involve a monoculture of exotic tree species may be difficult to implement due to quarantine restrictions and conservation policies. Furthermore, there have been very few commercial scale plantations in the WA Rangelands and hence the local knowledge and practices may need to be developed. Despite the extensive land area of the WA Rangelands, studies have shown that in some parts of the region there are relatively limited sources of underground water (particularly in some areas of the Murchison and the Goldfields where water quality can be quite poor) (Johnson and Commander, 2006; Johnson *et al*. 1999). Consequently, this will restrict plantation based projects to areas where the enterprise can achieve sustainable water use and not compromise the natural hydrology.

Competition with mining companies for water may also restrict the scope for plantations in the WA Rangelands particularly since the value of mineral commodities currently dwarfs the potential income from carbon credits. However, there may be potential synergies with mining companies where they have issues with excessive water (e.g. dewatering large mine pits, waste water from mine camps). In the context of these potential barriers, a feasibility study should be conducted to identify the areas which are highly suited to plantation developments in the WA Rangelands and the WA government could provide favourable lease conditions in order to attract significant corporate investment.

Unlike Queensland there are few areas throughout the WA Rangelands which have been extensively cleared prior to 1990. Therefore, there is limited scope for carbon projects based on woody vegetation regrowth. Consequently, we suggest that this asset class is of significantly less interest to the State compared to the other classes.

Controlled savanna burning is an attractive asset class given the potential for it to deliver a range of associated co-benefits, particularly for remote indigenous communities. A precedent for this asset class has been set by the success of the WALFA project in the West Arnhem Land region in the NT. The Kimberley region has an opportunity to replicate the success of this project, however it will require further investment to realise the opportunity. Extensive research of fire ecology and management has been completed and it is considered that the majority of this research is applicable to the North Kimberley (Russell-Smith, J. *pers comm*. 2010). Therefore, we suggest that the investment should be primarily targeted at resolving the policy issues specific to WA and the development of a business plan (e.g. industry cooperative) which can effectively serve the diverse interest of project participants.

The Kimberley is a mosaic of different land tenures. Consequently, one of the greatest barriers to the implementation of an effective a controlled savanna burning project is likely to be regional cooperation and coordination. Resolving these social issues may require significantly more investment than what was required to develop a robust scientific base for the ecological and atmospheric benefits of controlled savanna burning. For the immediate future, development of a controlled savanna burning project on large areas in the Kimberley which are primarily managed by the State Government (e.g. Prince Regent and Drysdale National Parks) could serve to establish a precedent and build local technical and managerial capacity in WA.

Biofuel 1st generation and bioenergy 2nd generation have significant scope in WA given the State's large mining and resource sector and its associated high demand for energy. The DAFWA in partnership with resource companies have been investigating the opportunity for biofuels in the region as a part of its *Growing the North* Industry Development Program (Lewis *et al*. 2009; Pracilio, G. 2009; Brockman *et al*. 2009). This work has involved trials with selected plant species (*viz*. *Pongamia pinnata* and *Moringa oleifera*) in the North-east Goldfields, Upper Gascoyne, the Pilbara and the East Kimberley. They have demonstrated their adaptability to the region and have the potential to provide large volumes of biodiesel. Resource companies have shown strong interest in this opportunity as it can be vertically integrated into their existing supply chain and achieve significant GHG reductions and may mitigate their potential obligations of a future mandatory carbon market.

We consider that biochar as an asset class in the WA Rangelands has limited scope for commercialisation. This assessment is primarily based on the fact that the region presently has very limited areas suitable for intensive agriculture and horticulture. Therefore, crops, pastures and tropical forestry plants that are grown must generate a financial return commensurate with the high value of the land and higher operating costs. It is unlikely that an enterprise based on biochar would be competitive with options currently available to growers in the region. We suggest that the development of this asset class should receive much less resources compared to the others.

Management practices and technologies which can either directly or indirectly reduce GHG emissions from livestock and other non-domestic grazers are of significant interest for the WA Rangelands. Although this study found that the contribution made by livestock methane to the overall GHG profile of an individual pastoral business is quite small compared to fossil fuel use, at an aggregate scale it does represent 10% of Australia's total emissions. The CSIRO, QDPI and MLA have made a significant investment into the development of technologies and the management practices which can reduce livestock emissions (Charley *et al*. 2008).

The immediate opportunity for the WA Rangelands in respect to this asset class is to identify the specific ways in which findings from the latest research can be integrated into the livestock production systems. This may require embedding this activity into existing research and development projects or creating targeted initiatives which have a strong extension focus to build the capacity and awareness of the WA pastoral industry. There is also a commercial opportunity to achieve significant GHG reductions through the control of other non-domestic grazers in the WA Rangelands (Moore, 2009). Commercialisation of this opportunity will require further investigation in terms of the feasibility and the data underlying the models.

Arguably, the asset class which has the greatest commercial scope in the WA Rangelands is the reforestation and afforestation of lands that have been historically degraded by overgrazing and disturbance from mining. Extensive work in the North-East Goldfields has demonstrated the potential for reforestation projects in the semiarid regions of WA (Yamada *et al*. 1999). Whilst this dataset is comprehensive, it is limited in the extent to which it can be extrapolated across the broader region. Therefore, we recommend an investment be made into targeted carbon accounting surveys across the WA Rangelands in order to improve the accuracy of baseline estimates (both aboveground and belowground pools). Specifically, we suggest that the existing dataset of the Western Australian Regional Monitoring System (WARMS) could be calibrated for carbon levels.

The existing WARMS system includes a network of 1,617 sites which have detailed vegetation measurements and soil surface condition assessments dating back to 1994. We suggest that with adequate destructive sampling the WARMS dataset could provide a retrospective record of the changes in carbon levels. If management history, seasonal conditions and other site specific data were analysed then this could provide one of the most comprehensive analyses of the change in carbon levels ever conducted in the WA Rangelands. It would also provide a robust regional model which could make more accurate predictions of the change in carbon levels. A second phase of this research project would be to calibrate the on-ground measurements with an appropriate remote sensing tool.

The estimated potential to reforest or rehabilitate the degraded semiarid rangelands was specifically highlighted in the final report from Garnaut (2008). Presently, whilst ongoing research into the technical aspects of reforestation of semiarid land is required, the primary barrier to the successful commercialisation of the opportunity is related to the tenure and policy arrangements. The WA Department of Regional Development and Lands (DRDL) have indicated that they are interested in supporting the development of carbon based enterprises in the WA Rangelands provided they can meet the relevant requirements concerning Native Title Rights, environmental guidelines and satisfy any liability risks to the State. The right to trade carbon on a WA pastoral lease is separate to the right incumbent pastoral lessees have to use the land for pastoral purposes (Eckert and McKeller, 2008). At the time of writing, there has been no formal application made to the DRDL for the carbon rights on a pastoral lease. Therefore, the immediate focus to commercialise this opportunity should be on the development of specific offset projects on defined areas of land in the WA Rangelands. Government could have a role in facilitating the DRDL process whereby the necessary technical and policy knowledge is provided to ensure the best outcome for the applicant, the regional economy and the environment is achieved, whilst avoiding any risk to the State.

In summary, we recommend that the WA State Government in conjunction with research organisations, commercial partners and non-government organisations (NGOs) undertake the following actions in the short to mid-term:

1. Conduct a desk-top feasibility study to identify areas that would be suitable for plantation based carbon projects (Kyoto Protocol Article 3.3) in the WA Rangelands (with consideration of: tenure arrangements, water supply, agronomic issues, local employment and skills capacity, environment and conservation, indigenous heritage, synergies with other industries).

2. Develop a controlled savanna burning project in the North Kimberley, initially on lands held by the Department of Environment and Conservation (DEC), and then develop similar projects in areas which involve more complex tenure arrangements and cross-jurisdictional borders (i.e. partnerships across Northern Australia). This could be integrated with the current activities undertaken by the North Australian Indigenous Land and Sea Management Alliance (NAILSMA) and the Kimberley Land Council (KLC). Savanna burning projects aim to reduce fire frequency in order to reduce greenhouse gas emissions and increase the existing amount of woody vegetation.

3. Develop effective business plans for specific controlled savanna burning projects which are applicable for the Kimberley Region and mutually satisfy the diverse interests of project participants.

4. Develop the existing partnerships with resource companies which are investigating the opportunities for Biofuel 1st generation and Bioenergy 2nd generation with the view of having a commercial scale project in operation within five years.

5. Identify management practices and technologies that reduce livestock GHG emissions and are applicable to the WA pastoral industry. This may require a targeted project or could be embedded in existing DAFWA rangeland extension projects (e.g. the co-funded Meat and Livestock Australia and DAFWA Northern Grazing Systems project).

6. Provide institutional and technical support for commercial operators who may seek to commercialise the emission reductions from the removal of non-domestic grazers (e.g. emission reductions from the culling of feral camels).

7. Undertake further carbon accounting field surveys in order to improve the accuracy of estimates of carbon stores in the WA Rangelands with a specific focus on areas which have the greatest capacity for change. These surveys should be undertaken in a way which will enhance the utility of remote sensing tools and other simulation modelling currently used for national carbon accounting purposes.

8. Develop carbon project methodologies for reforestation and afforestation asset classes in the most deforested areas of the State (e.g. more than 30% of the Gascoyne-Murchison region is degraded and therefore it is likely to have a very low carbon baseline). Provide technical and policy advice in order to secure the necessary carbon rights over the land of these projects;

9. Develop and implement technologies and practices which improve the efficiency of fossil fuel consumption on pastoral businesses in the WA Rangelands such as (e.g. telemetry, solar power, electric powered vehicles, redesign of paddock configuration and low stress stock handling).

10. Clarify the legal requirements necessary to trade carbon that is biosequestered in the native vegetation and the soil on leasehold land in the WA Rangelands. Identify any relevant changes that could be made to the Land Administration Act as a part of the DRDL Land Tenure Review process.

11. Assist the WA Valuer General in determining the appropriate value of carbon credits that may be created under different carbon projects on leasehold land to facilitate the application process for Carbon Rights on WA leasehold land.

The Office of Climate Change (OCC) currently has a coordinating role within the WA Government to ensure all Departments are making a positive contribution to the government's response to climate change. Therefore, the OCC may be the appropriate WA body to catalyse the necessary resources and partners in order to achieve the proposed actions. However, given the complex nature of the issues associated with the rangelands carbon industry it may be necessary for government to appoint a specialised task force either within the OCC or DRDL in order to progress the issues. Alternatively, there is an opportunity for the DAFWA to take a lead role in the commercialisation of the opportunities by establishing a Rangelands Carbon Program which could be a part of the portfolio of programs within the *Growing the North* Program. There are a number of reviews currently underway within the WA government which are examining alternative tenure arrangements and conditions of pastoral leases in WA. There is an opportunity for the information from this report to assist the relevant committees in determining how rangelands carbon should be managed within the State's natural estate.

6.4 Conclusion

Rural Australia faces pressures for structural change from both climate change and its mitigation (Gaurnat, 2008). Parts of the WA Rangelands continue to maintain a negative trajectory characterised by low financial returns, declining land condition and loss of social capital. The realisation of a substantial part of the biosequestration and mitigation potential of the WA Rangelands could favourably transform the socio-economic prospects of the region. Full utilisation of the biosequestration potential could play a significant role in the global mitigation effort. The WA Government needs to determine how it will seek to support the development of the emerging rangelands carbon industry. The immediate opportunity is to develop the methodologies for a number of the most 'bankable' carbon asset classes within the region and work towards the implementation of a number of case study projects. This process will involve securing the legal rights to trade the carbon rights on specified areas on leasehold land within WA.

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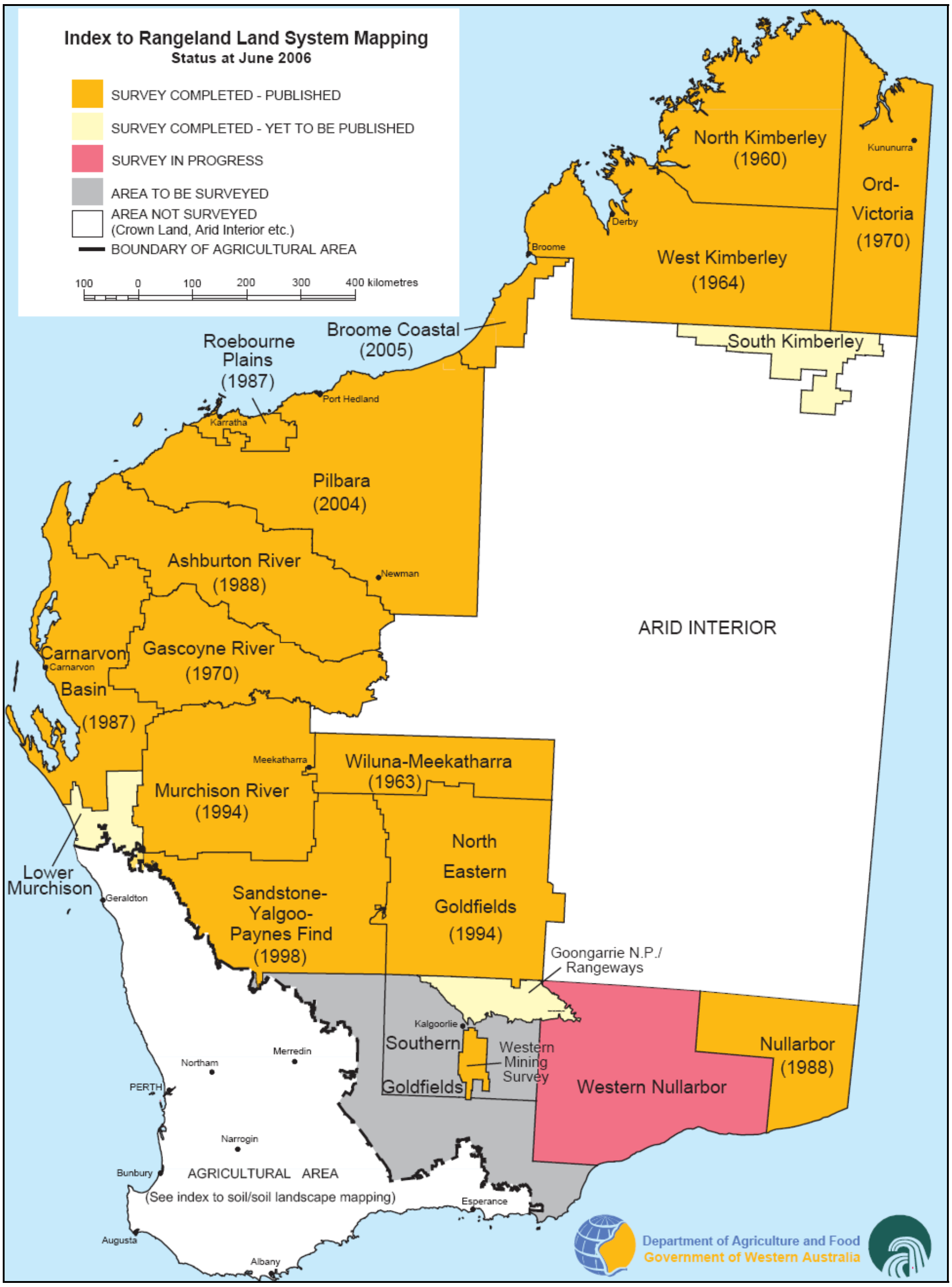
State of the Voluntary Carbon Market 2007 – Picking Up Steam
h**ttp://www.carbon.sref.info/an-example/market-news**

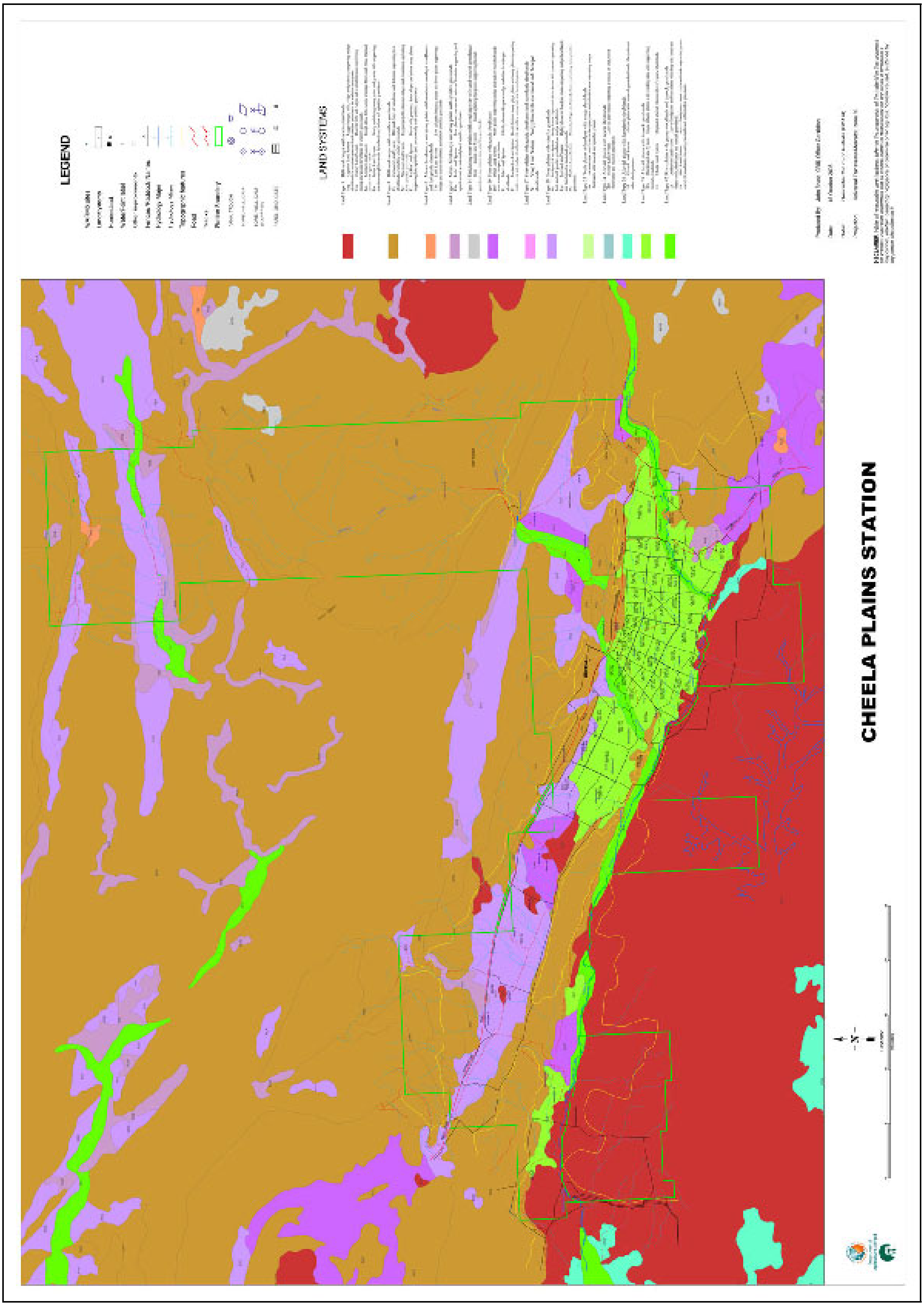
8.0 APPENDICES

8.1 Appendix 1: Rangeland resource survey areas of Western Australia

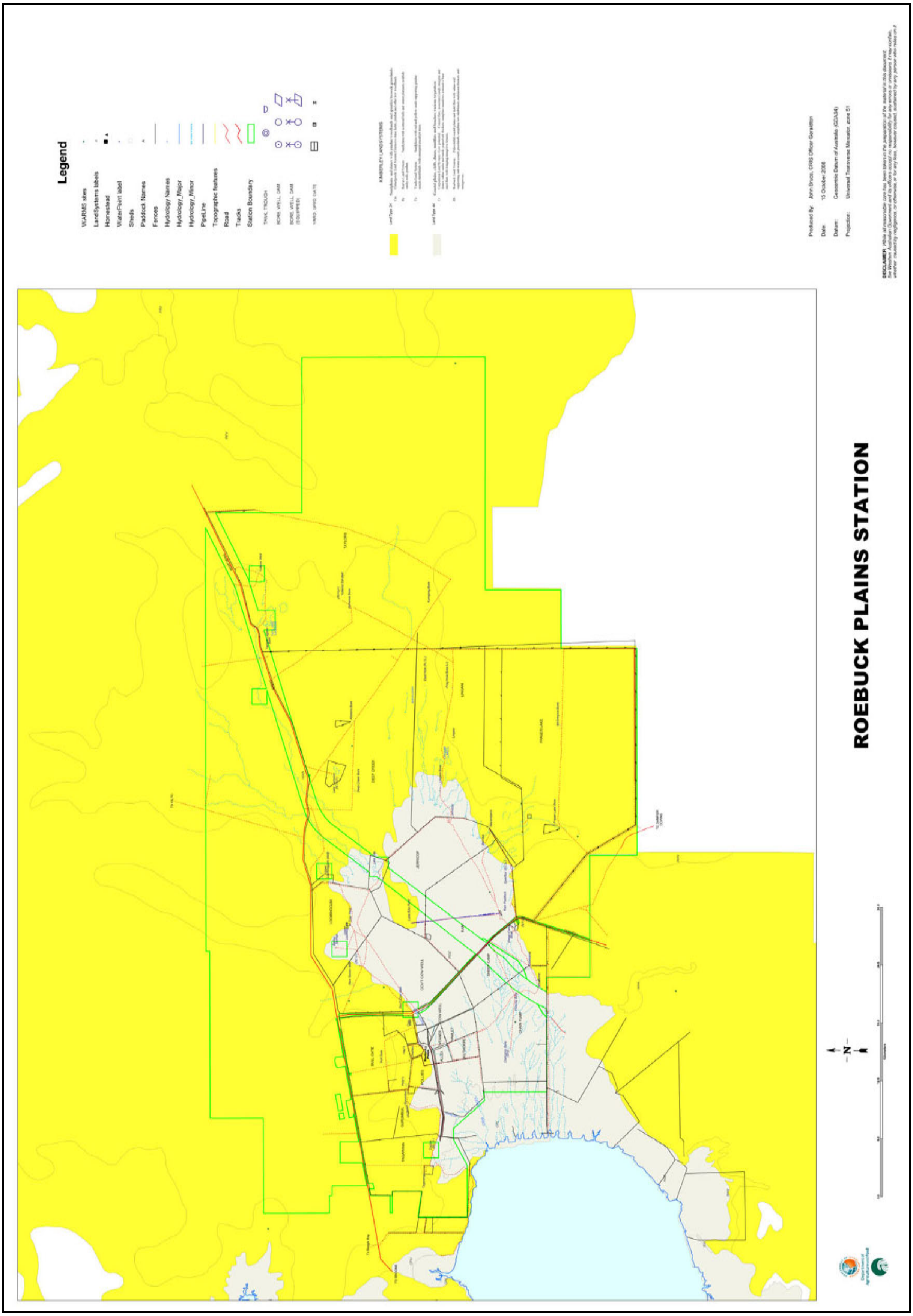


*Survey not illustrated is the recent Ord Valley Technical Bulletin (Schoknecht *et al*. 2009)

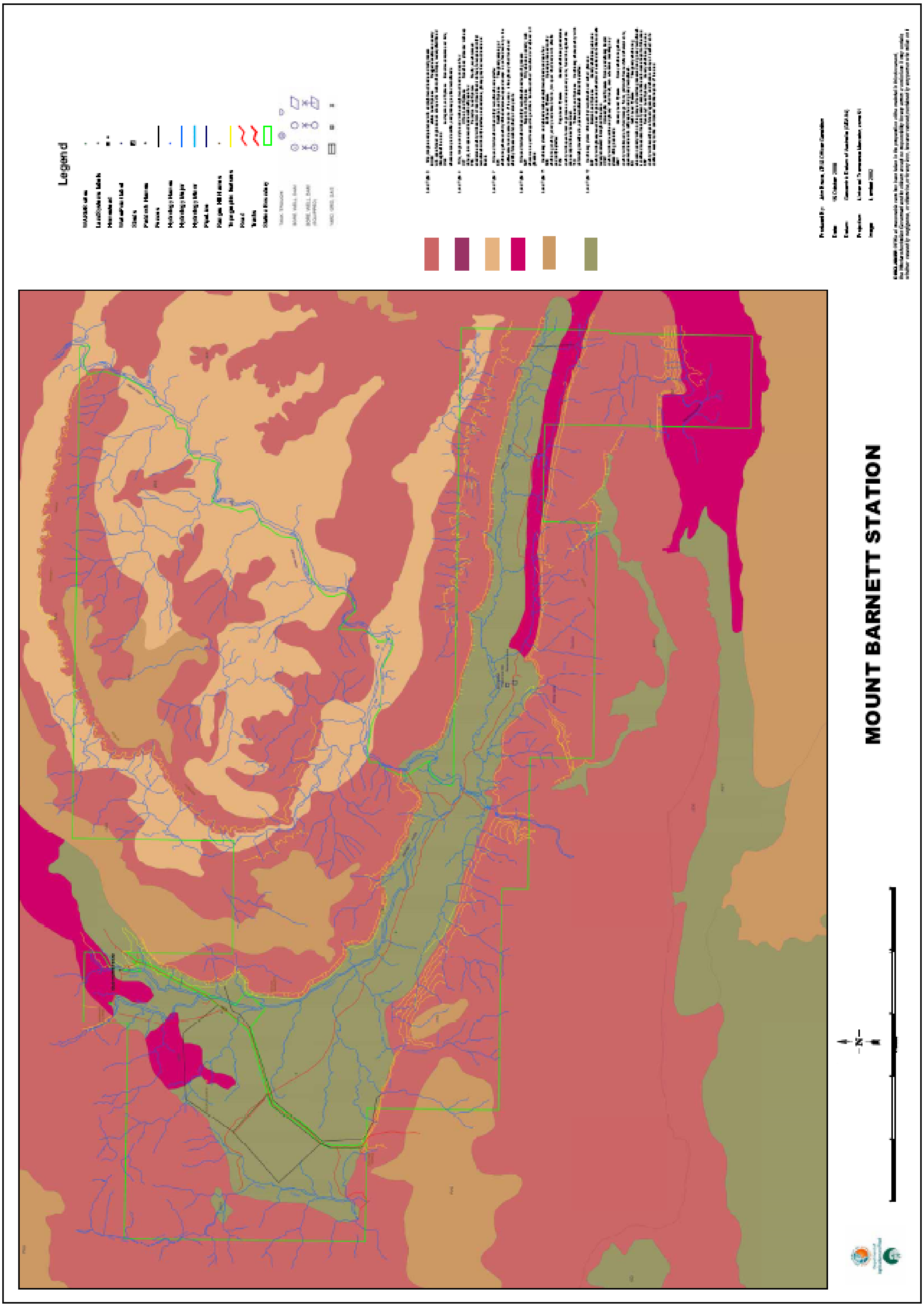
8.2 Appendix 2 – Cheela Plains land-system and infrastructure map



8.3 Appendix 3 – Roebuck Plains land-system and infrastructure map



8.4 Appendix 4 – Mount Barnett land-system and infrastructure map



8.5 Appendix 5: A guide to land cover change analysis images

The Vegmachine™ land cover change analysis (LCCA) approach recommends a series of steps for summarizing land cover changes related to condition, including:

- careful selection of dates based on regional knowledge;
- derivation/checking of spectral index/indices for different land types; and
- production of 'trend images' on a land system basis (i.e. stratified) with some reference to ground knowledge

This context provides a framework for interpretation of different relative changes, and for targeting ground work to test or refine those interpretations.

Compromises here are considerable and include:

(a) dates used are those in AGO NCAS archive – for the Kimberley region these are quite early in the dry season;

(b) there was no capacity to test/develop indices with these images; we have used indices which have proved effective elsewhere. But the b2+b3 index which was used in the east Kimberley was developed and tested using late dry season imagery – the interpretation (and indeed whether this index is appropriate) with these earlier images and varying greenness is unclear; and

(c) there was no capacity here to stratify the trend displays for different land types, or to 'set' the colour displays based on known reference sites or areas of good condition; in some cases alternative displays are provided

What are trends and what do the colours and filenames mean?

VegMachine™ displays images (pre-prepared) and temporal plots from multi-date index files (pre-prepared). A temporal plot of a spectral index (y) vs time (x) records the historical response of a pixel (or area). It may be stable (a flat line), or more complicated. Here we have images one or more years apart, the point values on a temporal plot may be joined by line segments. Trend plots for different areas are easily compared to see when different changes have occurred.

'Trends' are statistical summaries of these temporal plots (i.e. index (Y) over time(X)) calculated for each pixel. These summaries are numbers, which can be displayed as images which we call 'trend images' – these images reveal patterns of 'change'.

See Vegetation product documentation on www.landmonitor.wa.gov.au for more info

CMIS software calculates six standard summaries:

1. Mean (mean of index value over all dates)
2. Linear slope over time [scaled] - +ve indicates an overall upward trend over the period (in a regression sense); zero would be a flat (overall) trend
3. Quadratic curvature (estimated independent of slope); positive curvature would mean the trend curves below then back up relative to the fitted linear
4. Standard deviation about mean – sometimes an indicator of dysfunction
5. 'residual' Standard dev about line
6. 'residual' Standard dev about quadratic

Trend displays

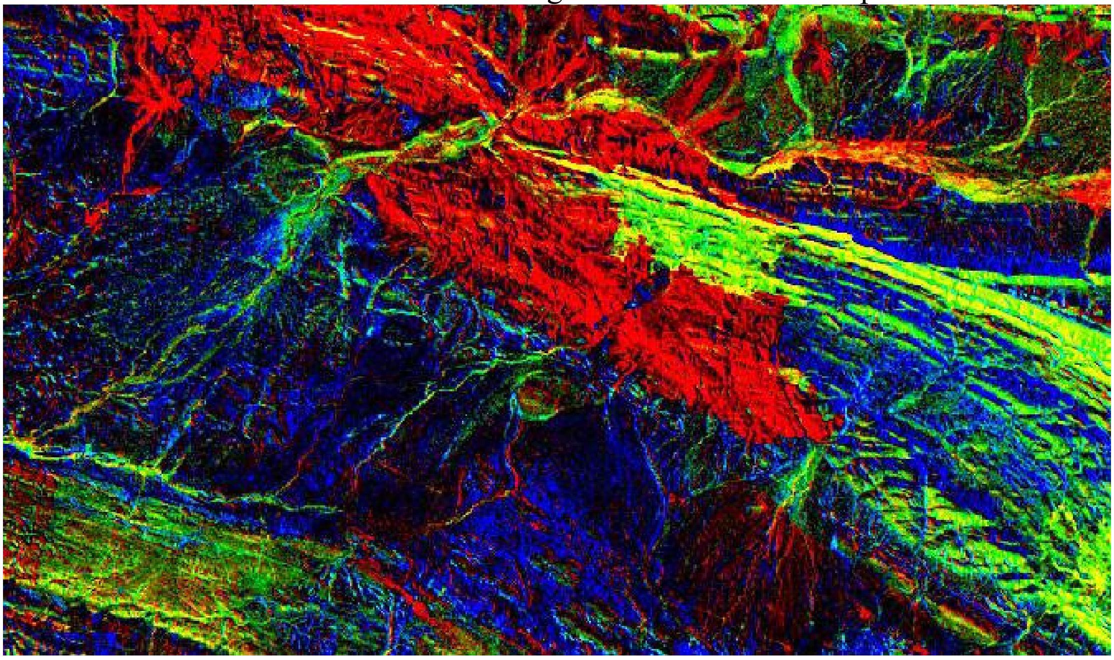
Colour images can display 3 ‘components’ at the same time in red green and blue colour guns. The six ‘trends’ above can be displayed in numerous ways. A couple of ‘semi-standards have been set for trend display:
Based on:
Linear trend ***Positive*** and Linear trend ***Negative*** are usually of greatest first interest;
These are combined with a quadratic (usually the negative quadratic only) in green
Useful displays are:

Positive (increasing) linear cover trends displayed in BLUE, negative in RED
Quadratic (neg) in GREEN
Shorthand in names RGB == ‘L,Q,L’

An alternative is to display:

Positive (increasing) linear cover trends displayed in BLUE, negative in RED
Mean in GREEN

Green & red mix to create Yellow or Orange as shown in the example below



Detail from ‘LQL’ trend image of Cheela: Black areas are relatively stable; red suggested decline; blue increase in cover; Green – not a strong linear trend but a curve; yellow (RED+GREEN).

TEMPORAL plots using Vegmachine^{TM} reveal these patterns for real units of land.

8.6 Appendix 6: Definitions of key performance indicators used in the Profit Probe™ analysis

Profitability (economics)	
ROA - Return on assets (%)	• EBIT as a percentage of total closing assets
- Land ROA	• Return to the land business if you removed your production business and leased the land out
- Production ROA	• Return to the production business if you leased the land it was run on as compared to owning it
EBIT – Earnings before interest and tax ($/ha)	• The profit from the production business (gross product less direct, overhead costs, depreciation, unpaid labour)
Asset turnover ratio (%)	• Gross product as a percentage of total closing assets.
Gross margin ratio (%)	• Gross margin as a percentage of gross product
Overhead ratio (%)	• Overheads as a percentage of gross product
Productivity	
Cattle	
Meat produced (kg/ha)	• Kg of liveweight beef/meat produced per hectare of land allocated to all cattle enterprises
Break even costs ($/kg)	• The total cost (direct + overheads + crop transfers in but excl. finance, tax and development) to produce a kilogram of beef
Meat Price ($/kg)	• Gross value of sales divided by kilograms of beef sold.
Cost / DSE or LSU ($)	• The total cost (direct + overheads) per livestock unit
Meat Gross margin ($/ha)	• Gross margin (gross product less livestock direct costs) per hectare of land allocated to all cattle enterprises
Cattle - Feedlot	
Average daily Gain (kg/head)	• Total kilograms produced divided by the (total head * number of days in feedlot)
Feed Conversion Ratio (Feed kg/kg Gain)	• Total feed input per animal compared to average kilograms gained
Break even costs ($/kg)	• The total cost (direct + overheads + crop transfers in but excluding finance, tax and development) to produce a kilogram of beef
Meat Price ($/kg)	• Gross value of sales divided by kilograms of beef sold
Cost / DSE or LSU ($)	• The total cost (direct + overheads) per livestock unit
Meat Gross margin ($/LSU)	• Gross margin (gross product less livestock direct costs) per LSU managed
Sheep - Wool	
Clean wool produced (kg/ha)	• Clean wool produced per hectare of land allocated to wool enterprise
Break even costs ($/kg)	• The total cost (direct + overheads + crop transfers in - animal trade balance [but excluding finance, tax and development]) to produce a kilogram of wool
Wool price ($/kg clean)	• Gross value of wool sales divided by kilograms of clean wool sold.
Wool cost / DSE ($)	• The total cost (direct + overheads) per livestock unit for the sheep wool enterprise
Wool gross margin ($/ha)	• Gross margin (gross product less livestock direct costs) per hectare of land allocated to all sheep wool enterprises

Sheep - Meat Meat produced (kg/ha)	• Meat produced per hectare of land allocated to meat enterprise
Break even costs ($/kg)	• The total cost (direct + overheads + crop transfers in – animal trade ballance [but excluding finance, tax and development]) to produce a kilogram of meat
Meat price ($/kg)	• Gross value of meat sales divided by the kilograms of meat sold.
Meat costs / DSE ($)	• The total cost (direct + overheads) per livestock unit for the sheep meat enterprise
Meat gross margin ($/ha)	• Gross margin (gross product less livestock direct costs) per hectare of land allocated to all sheep meat enterprises
Cropping Crop yield ($/unit)	• Yield for each crop based on a per production unit
Total crop costs ($/unit)	• The total cost (direct, overheads but excl. finance) to produce a unit of crop.
Price received ($/unit)	• Price received excluding currency gains/losses
Gross margin ($/ha)	• Gross margin (Gross product less direct costs and depreciation) per hectare of land allocated to enterprise
People	
Gross product ($/FTE)	• The amount of gross product (income) produced per FTE
Yield (units/FTE)	• The amount of crop produced per FTE
Area managed (ha/FTE)	• The total area cropped divided by the number of FTEs employed
Holidays and training (wks/FTE)	• Weeks spent on holidays and training per FTE
Pecuniary (finance)	
Finance ratio	• Interest and leases paid as a % of gross product
Expense ratio	• Direct, overhead and finance cash expenses as a % of gross product
Property	
Area cropped	• Total area of crop planted for this property
SDH or DDH/100mm of rainfall.	• The number of stock days or DSE days grazed per hectare of useable land per 100mm of rainfall received in the year
Average LSU or DSE managed	• The average of the opening and closing number of large stock units or dry sheep equivalents managed in the year.
Energy costs	• This adds all energy related costs for overheads and direct costs and divides this by $ '000 of gross income.

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8.7 Appendix 7: Example of woody carbon belt transect recording sheet

WOODY CARBON BELT TRANSECT RECORDING SHEET									
Site No:		CP5				**Transect No:** 3/3			
Date:		20/05/2009				**Recording sheet no:** 1/2			
Waypoint:		488586.5 E 7463432 N							
Assessors:		PJ/GW							
					Tree/shrub specifications				
Transect distance (cm)		Patch/interpatch type 1. bareground 2. grass/litter 3. shrub/tree patch	Tree/shrub species	Basal width (cm)	DBH ~1.4 m (cm)	Canopy width (cm)	Status 1. Alive 2. dead	% crown visibility	
Start	End								
0	206	1							
206	208	3	snnoli	2		53	1	30	
208	250	1							
250	270	2							
270	580	1							
580	590	3	snnoli	10		143	1	55	
590	715	2							
715	930	1							
930	935	3	snnoli	5		163	1	45	
935	1070	2							
1070	1072	3	snnoli	2		138	1	15	
1072	1130	2							
1130	1144	3	acavic	14	13	211	1	55	
1144	1220	1							
1220	1260	2							
1260	1263	3	acavic	3	7	105	1	30	
1263	1340	2							

8.8 Appendix 8: Example of coarse woody debris recording sheet

COARSE WOODY DEBRI (CWD) RECORDING SHEET				
Site No:		CP101	**Date:**	22/05/2009
Assessors:		BM/KR	**Recording sheet no.**	1/1
Method used (1 or 2):		1	CWD sample specifications	
Sample No. (must be >25 mm)	Length (cm) (NB: longest side)	Diameter (cm)	Status (1. sound or 2. rotten)	Internal diameter (cm) (if applicable)
1	49	2.5	1	
2	39	3.5	1	
3	23	4.5	1	
4	26	4.5	1	
5	135	27	2	
6	27	4	1	
7	99	3.5	1	
8	36	3	2	
9	103	2.5	1	
10	53	3	1	

8.9 Appendix 9: Summary of projected carbon levels under different management scenarios

The following tables provide a summary of the projected change in carbon levels under the different management scenarios for the three pastoral leases. To assist in the interpretation of the tables, definitions of the terms used are provided:

1. **Projected change in soil carbon** – the predicted change in soil carbon per hectare between 2010 and 2040 based on a three year moving average.
2. **Projected change in woody carbon** - the predicted change in woody carbon per hectare between 2010 and 2040 based on a three year moving average.
3. **Difference in soil carbon to baseline** – the difference in the change in soil carbon levels of a particular scenario compared to the change in soil carbon levels of the business-as-usual scenario. The business-as-usual scenario acts as the baseline level of carbon and because it is not a static number, any changes in soil carbon (positive or negative) due to the alternative scenarios need to be compared to it.
4. **Difference in woody carbon to baseline** – the same as 3 except it applies to the woody carbon pool.
5. **Projected total change in soil carbon** – the change in soil carbon compared to the baseline multiplied by the total area of the land-system on the pastoral lease. It effectively represents the total volume of soil carbon credits that could be available for trading purposes. Areas based on information presented in Section XX.
6. **Projected total change in woody carbon** – the same as 5 except it applies to the woody carbon pool.
7. **Projected total change in soil and woody carbon** – simply the sum total of 5 and 6. It represents the total volume of carbon credits (soil and woody) that could be available for trading purposes.

Projected carbon levels between 2010 and 2040 at Cheela Plains

Table 1: Scenario 1 - Full destock

OPTION 1: FULL DESTOCK	Land-system			
	Boolgeeda	Capricorn	Cheela	River
1. Change in soil C (t CO_2-e ha^{-1} from 2010 - 2040)	2.60	-0.15	2.03	6.06
2. Change in woody C (t CO_2-e ha^{-1} from 2010 - 2040)	13.89	1.38	-1.33	25.28
3. Difference in soil C to baseline (t CO_2-e ha^{-1} from 2010 - 2040)	0.58	0	5.15	0.49
4. Difference in woody C to baseline (t CO_2-e ha^{-1} from 2010 - 2040)	-5.82	0	1.04	-5.84
5. Total change in soil C to baseline (t CO_2-e from 2010 - 2040)	11,669	0	107,092	3,253
6. Total change in woody C to baseline (t CO_2-e from 2010 - 2040)	-116,458	0	21,610	-38,513
7. Total change in C to baseline (t CO_2-e from 2010 - 2040)	-104,789	0	128,702	-35,260

Table 2: Scenario 2 – Business-as-usual (baseline)

OPTION 2: BUSINESS-AS-USUAL	Land-system			
	Boolgeeda	Capricorn	Cheela	River
1. Change in soil C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	2.02	-0.15	-3.12	5.57
2. Change in woody C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	19.71	1.38	-2.37	31.12

Table 3: Scenario 3 – Intensification

OPTION 3: INTENSIFICATION	Land-system			
	Boolgeeda	Capricorn	Cheela	River
1. Change in soil C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	1.94	-0.15	1.09	5.37
2. Change in woody C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	19.96	1.38	-2.34	29.78
3. Difference in soil C to baseline ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	-0.08	0	4.21	-0.20
4. Difference in woody C to baseline ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	0.25	0	0.03	-1.34
5. Total change in soil C to baseline ($t\ CO_2$-e from 2010 - 2040)	-1,513	0	87,507	-1,337
6. Total change in woody C to baseline ($t\ CO_2$-e from 2010 - 2040)	4,977	0	559	-8,863
7. Total change in C to baseline ($t\ CO_2$-e from 2010 - 2040)	3,464	0	88,066	-10,201

Projected carbon levels between 2010 to 2040 at Roebuck Plains

Table 4: Scenario 1 – Full destock

OPTION 1: FULL DESTOCK	Land-system			
	Carpentaria	Roebuck	Wanganut	Yeeda
1. Change in soil C (t CO_2-e ha^{-1} from 2010 - 2040)	2.81	4.26	2.47	2.50
2. Change in woody C (t CO_2-e ha^{-1} from 2010 - 2040)	0	0	7.28	14.03
3. Difference in soil C to baseline (t CO_2-e ha^{-1} from 2010 - 2040)	-2.58	-3.47	-0.65	-0.70
4. Difference in woody C to baseline (t CO_2-e ha^{-1} from 2010 - 2040)	0	0	13.49	21.09
5. Total change in soil C to baseline (t CO_2-e from 2010 - 2040)	-4,119	-147,423	-62,822	-99,898
6. Total change in woody C to baseline (t CO_2-e from 2010 - 2040)	0	0	1,312,647	2,990,148
7. Total change in C to baseline (t CO_2-e from 2010 - 2040)	-4,119	-147,423	1,249,825	2,890,250

Table 5: Scenario 2 – Recommended best practice (baseline)

OPTION 2: RECOMMENDED BEST PRACTICE	Land-system			
	Carpentaria	Roebuck	Wanganut	Yeeda
1. Change in soil C (t CO_2-e ha^{-1} from 2010 - 2040)	5.39	7.72	3.12	3.21
2. Change in woody C (t CO_2-e ha^{-1} from 2010 - 2040)	0	0	-6.22	-7.06

Table 6: Scenario 3 – Intensification

OPTION 3: INTENSIFICATION	Land-system			
	Carpentaria	Roebuck	Wanganut	Yeeda
1. Change in soil C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	1.93	3.19	3.13	3.33
2. Change in woody C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	0	0	-4.49	-3.29
3. Difference in soil C to baseline ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	-3.46	-4.53	0.01	0.13
4. Difference in woody C to baseline ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	0.00	0.00	1.73	3.77
5. Total change in soil C to baseline ($t\ CO_2$-e from 2010 - 2040)	-5,530	-192,693	614	17,987
6. Total change in woody C to baseline ($t\ CO_2$-e from 2010 - 2040)	0	0	168,310	533,927
7. Total change in C to baseline ($t\ CO_2$-e from 2010 - 2040)	-5,530	-192,693	168,923	551,914

Table 7: Scenario 4 – Business-as-usual

OPTION 4: BUSINESS-AS-USUAL	Land-system			
	Carpentaria	Roebuck	Wanganut	Yeeda
1. Change in soil C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	1.82	1.99	1.16	1.29
2. Change in woody C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	0	0	-5.69	-8.54
3. Difference in soil C to baseline ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	-3.57	-5.73	-1.96	-1.91
4. Difference in woody C to baseline ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	0.00	0.00	0.53	-1.48
5. Total change in soil C to baseline ($t\ CO_2$-e from 2010 - 2040)	-5,708	-243,736	-190,568	-271,250
6. Total change in woody C to baseline ($t\ CO_2$-e from 2010 - 2040)	0	0	51,830	-209,950
7. Total change in C to baseline ($t\ CO_2$-e from 2010 - 2040)	-5,708	-243,736	-138,738	-481,200

Table 8: Scenario 5 – Full destock with controlled savanna burning

OPTION 5: FULL DESTOCK WITH BURNING	Land-system			
	Carpentaria	Roebuck	Wanganut	Yeeda
1. Change in soil C (t CO_2-e ha^{-1} from 2010 - 2040)	5.15	6.60	9.79	10.24
2. Change in woody C (t CO_2-e ha^{-1} from 2010 - 2040)	0	0	61.00	65.33
3. Difference in soil C to baseline (t CO_2-e ha^{-1} from 2010 - 2040)	-0.24	-1.12	6.68	7.04
4. Difference in woody C to baseline (t CO_2-e ha^{-1} from 2010 - 2040)	0.00	0.00	67.22	72.39
5. Total change in soil C to baseline (t CO_2-e from 2010 - 2040)	-387	-47,809	649,382	997,386
6. Total change in woody C to baseline (t CO_2-e from 2010 - 2040)	0	0	6,539,058	10,261,938
7. Total change in C to baseline (t CO_2-e from 2010 - 2040)	-387	-47,809	7,188,439	11,259,324

Projected carbon levels between 2010 to 2040 at Mount Barnett

Table 9: Scenario 1 – Full destock

OPTION 1: FULL DESTOCK	Land-system			
	Buldiva	Karunjie	Kennedy	Pago
1. Change in soil C (t CO_2-e ha^{-1} from 2010 - 2040)	0.3	1.0	-1.3	0.8
2. Change in woody C (t CO_2-e ha^{-1} from 2010 - 2040)	3.2	17.1	22.7	6.8
3. Difference in soil C to baseline (t CO_2-e ha^{-1} from 2010 - 2040)	0	0.6	0.1	0.8
4. Difference in woody C to baseline (t CO_2-e ha^{-1} from 2010 - 2040)	0	7.9	6.9	10.0
5. Total change in soil C to baseline (t CO_2-e from 2010 - 2040)	0	10,622	3,824	9,428
6. Total change in woody C to baseline (t CO_2-e from 2010 - 2040)	0	139,452	199,983	125,399
7. Total change in C to baseline (t CO_2-e from 2010 - 2040)	0	150,074	203,807	134,827

Table 10: Scenario 2 – Recommended best practice (baseline)

OPTION 2: RECOMMENDED BEST PRACTICE	Land-system			
	Buldiva	Karunjie	Kennedy	Pago
1. Change in soil C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	0.3	0.4	-1.4	0.1
2. Change in woody C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	3.2	9.2	15.8	-3.2

Table 11: Scenario 3 – Intensification

OPTION 3: INTENSIFICATION	Land-system			
	Buldiva	Karunjie	Kennedy	Pago
1. Change in soil C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	7.7	5.1	5.9	6.1
2. Change in woody C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	73.3	53.0	42.3	43.6
3. Difference in soil C to baseline ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	7.5	4.7	7.3	6.1
4. Difference in woody C to baseline ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	70.2	43.8	26.5	46.8
5. Total change in soil C to baseline ($t\ CO_2$-e from 2010 - 2040)	440,479	82,675	210,096	75,853
6. Total change in woody C to baseline ($t\ CO_2$-e from 2010 - 2040)	4,132,795	767,867	764,875	586,724
7. Total change in C to baseline ($t\ CO_2$-e from 2010 - 2040)	4,573,274	850,542	974,971	662,577

Table 12: Scenario 4 – Business-as-usual

OPTION 4: BUSINESS-AS-USUAL	Land-system			
	Buldiva	Karunjie	Kennedy	Pago
1. Change in soil C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	0.3	0.1	0.3	0.1
2. Change in woody C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	3.2	6.7	3.5	-3.2
3. Difference in soil C to baseline ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	0	-0.2	1.8	0
4. Difference in woody C to baseline ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	0	-2.4	-12.3	0
5. Total change in soil C to baseline ($t\ CO_2$-e from 2010 - 2040)	0	-3,766	50,588	0
6. Total change in woody C to baseline ($t\ CO_2$-e from 2010 - 2040)	0	-42,810	-353,333	0
7. Total change in C to baseline ($t\ CO_2$-e from 2010 - 2040)	0	-46,576	-302,745	0

Table 13: Scenario 5 – Full destock with controlled savanna burning

OPTION 5: FULL DESTOCK WITH BURNING	Land-system			
	Buldiva	Karunjie	Kennedy	Pago
1. Change in soil C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	7.7	9.5	7.2	8.3
2. Change in woody C ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	73.3	88.7	93.7	64.8
3. Difference in soil C to baseline ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	7.5	9.1	8.6	8.2
4. Difference in woody C to baseline ($t\ CO_2$-e ha^{-1} from 2010 - 2040)	70.2	79.5	77.9	68.0
5. Total change in soil C to baseline ($t\ CO_2$-e from 2010 - 2040)	440,479	159,618	248,031	103,261
6. Total change in woody C to baseline ($t\ CO_2$-e from 2010 - 2040)	4,132,795	1,395,389	2,245,611	852,152
7. Total change in C to baseline ($t\ CO_2$-e from 2010 - 2040)	4,573,274	1,555,007	2,493,642	955,414