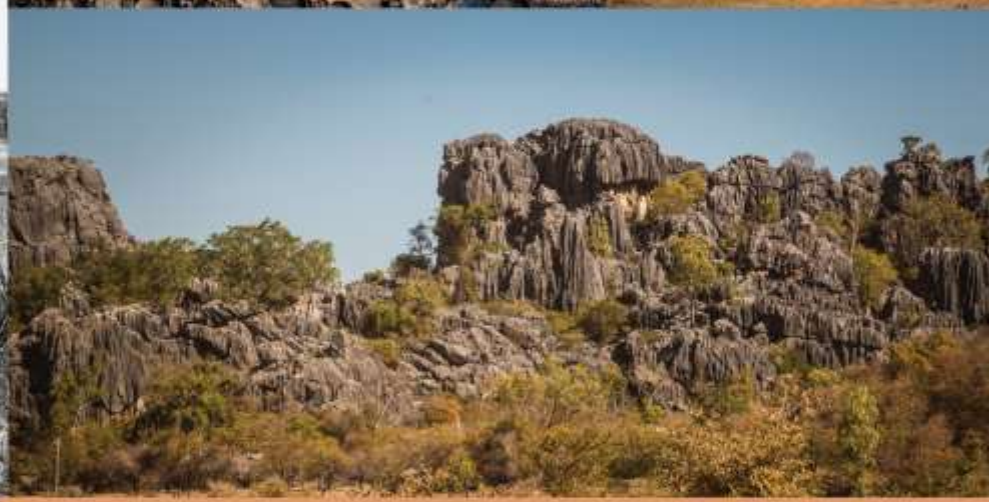

Northern Gulf

Grazing Lands Regional NRM Assessment

2015

Prepared by:

NRM Planning

@ Northern Gulf Resource Management Group Ltd

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Australian Government

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1. INTRODUCTION

1.1 THE NORTHERN GULF GRAZING LANDS REGION

Cattle grazing properties have existed in the Northern Gulf for more than a century and have played a significant part in the region's history and development.

There are approximately 160 grazing properties, covering an area of roughly 17m ha. These enterprises rely principally on native pastures to turn off about 200,000 cattle per year.

The communities of Northern Gulf grazing lands include:

The Etheridge Shire, which covers an area of 39,323 square kilometres and has existed as a local government entity since 1882. The Shire's population is 909, with 567 rateable properties. The shire is dominated by large broad hectare pastoral leases, which comprise of a combined estimated agricultural production value of $43.7m pa (Etheridge Shire Council, 2014).

Etheridge includes the four small townships of:

1. **Georgetown.** The Gulf Developmental Road passes through the town, linking Cairns - 412 km to the east - and Normanton - 301 km to the west. Georgetown is the administrative centre of the Etheridge Shire Council. At the 2006 census, Georgetown had a population of 254. Georgetown is situated on the Etheridge River, which was the site of a gold rush in the 1870s; the town was established on the site of the diggings. By 1900, grazing had replaced gold mining as the region's primary source of income, which continues to this day.
2. **Mount Surprise** is also located on the Gulf Developmental Road, 285 km west of Cairns. At the 2006 census, Mount Surprise and the surrounding area had a population of 162. While Mount Surprise is surrounded by grazing leases, the town economy benefits from tourism, with a weekly service from the passenger rail service, The Savannahlander, and close proximity to Undara Volcanic National Park and Forty Mile Scrub National Park, as well as nearby gem fossicking areas.
3. **Forsayth**, which is 415 km by road from Cairns. At the 2006 census, Forsayth had a population of 101. The town is the terminus of the Etheridge Railway. It is now serviced by a weekly, privately operated, tourist train, The Savannahlander. Forsayth is also very close to the tourist attraction of Cobbold Gorge, and is close to the site of a major prospective wind farm development.
4. **Einasleigh** is the smallest town in the Etheridge Shire, with a population of only 60. Einasleigh sits on the Eastern edge of the Newcastle Range, on the banks of the Copperfield River.

The Croydon Shire, encompassing an area of 29,538 square kilometres, has a total Shire population of 312, most of which are located in the township of Croydon itself. The economy of the Shire remains based around the pastoral and services industries. Croydon was at the centre of the gold rush, and once boasted a population of around 7,000. With successful promotion its mining heritage, the tourism sector continues to grow with increasing numbers travelling the Savannah Way. Croydon's town water supply is from Lake Belmore, the largest freshwater impoundment in the Gulf region (Croydon Shire Council, 2015).

A large part of **Mareeba Shire** falls within the Northern Gulf NRM region. Most of the populated areas have been included in the Northern Tablelands assessment (Mt Molloy, Julatten, Dimbulah, Mutchilba and Irvinebank/Watsonville). Mareeba Shire also includes a large area of remote, broad hectare grazing country which has been included in the Grazing Lands section for the purposes of the NRM Plan. This area includes the townships of Almaden, Chillagoe and Mt Carbine.

1. **Almaden** is a small community located on the Burke Developmental road between Dimbulah and Chillagoe. It main landmark is the Railway Hotel and the rail station which is a stop on the weekly Gulf Savannahlander rail service.
2. **Chillagoe** was once a thriving mining town for a range of minerals, but is now reduced to a small zinc mine and some marble quarries. At the 2006 census, Chillagoe had a population of 227. Just out of town is the Chillagoe-Mungana Caves National Park containing limestone caves. There are between 600 and 1,000 caves in the Chillagoe-Mungana area. The caves, the spectacular karst landscape and the mining and smelting history are the main tourist attractions to the region. It has been claimed by a leading geologist that the Chillagoe region has the most diverse geology in the world.
3. **Mount Carbine** is a town which lies close to the Mount Carbine Tableland, and contains an active wolfram mine, which is a rare mineral used as a component in electronics. At the 2006 census, Mount Carbine had a population of 91.

The two main townships of the Carpentaria Shire are Normanton and Karumba, both of which have been included in the Gulf Coast section for the purposes of this assessment, however Carpentaria Shire also includes a large area of broad hectare grazing lands, which have been included in the Grazing Lands section.

The southern part of the Cook Shire also falls within the Northern Gulf NRM regional boundaries, mostly in the northern shed of the Mitchell catchment. No townships are included in this area.

FIGURE 1: THE GRAZING LANDS OF THE NORTHERN GULF NRM REGION. SOURCE: TREVOR PARKER, NGRMG, 2015

The grazing lands are mostly open woodland dominated by *Eucalyptus* and *Corymbia* species with a grassy understorey, but paperbark woodlands, lancewood open woodlands and bluegrass communities on open grasslands can also be found.

This reflects the region's diversity of landforms, geology, soil types, climatic variation and fire history. The grazing lands generally support native vegetation from pre-European times; however, these have been changed by cattle grazing; including introduction of exotic pasture grasses, woody weeds, as well as changed fire regimes. The understory and grass layer does not support the wildlife it once did, because of grazing impacts, weeds and feral animals. Furthermore, the long-term, continual growth trend of cattle numbers since the 1960's has resulted in a loss of desirable perennial grasses over some parts of the Northern Gulf.

It is recorded that the grazing lands provide habitat for 84 native mammal, 149 reptile, 33 amphibian and 377 bird species. However there may be many species still undocumented and the health of these species is unknown, due to the lack of field data in the Northern Gulf.

Concerns exist that the combined impacts of extensive grazing, changed fire regimes and pest animal species, possibly coupled with disease could have pushed many wild species to the brink of extinction throughout the region, with alarming declines of many small mammals and grain feeding birds.

Weeds also pose a serious threat to the natural resources across the Grazing lands and more than 300 invasive species are known to be introduced in our region. Although many of these weeds are only found in remote areas, there is a potential for them to spread with increased human traffic or changed climatic conditions. There are currently 56 weeds of concern to the region.

Pest animals which pose the most serious threats to our wildlife are the feral pig and the feral cat, however European rabbits, cane toads, wild dogs and horses are also found throughout the Northern Gulf. These species may prey on and compete with native fauna, and also degrade habitat by spreading weeds, cause erosion through trampling, host diseases and pathogens, and compete with cattle for native pastures. Control of pest species over large areas is problematic as it is often expensive and the results are not lasting, as pests will quickly recover if control is not regular. Targeted control or exclusion of pest animals appears to be the most cost effective option.

Poorly managed grazing lands can lead to the loss of ground cover, cause erosion, foul water supplies, compact soil and disperse weeds. Cattle also impact on native wildlife by causing a reduction in food resources and by opening up the understory which leaves some species prone to predation. These impacts can be managed by good grazing practices such as the spelling of pasture in the wet season and maintaining long-term safe stocking rates that are adjusted in response to that year's weather.

Fire in the Northern Gulf grazing lands is infrequent as intensive grazing practices reduce the fuel load and many graziers prefer not to proceed with fire management strategies. In this way they preserve pasture for cattle, however a lack of burning can contribute to woodland thickening and create higher fuel loads for wildfires, both of which can impact on grazing enterprises. These fires can kill many native tree and fauna species. In fact wildfires across the Northern Gulf have caused in the past widespread environmental destruction and loss of productivity to the grazing industry.

While the Northern Gulf region covers 8% of the land area of Queensland – an area three times the size of Tasmania – it only accounts for less than half a percent of the state's total population. The people of this remote region are few, but they are resourceful, self-reliant and hard working. They readily volunteer their time to help others, as shown by the rates of volunteering in the Northern Gulf which are some of the highest in Australia. Community cohesion and networks are strong, and providing the human asset of this region which gives strength and resilience to overcome adversity.

It is a resilience and work ethic which has seen this community through many hard times, with the last decade including many catastrophic events such as the 2009 floods which resulted in an area the size of Germany and France combined being inundated for 8 weeks, followed by Cyclone Yasi, a ban on the live export trade, uncontrolled bushfires over 750,000 ha of Etheridge Shire in 2012 followed by a failed wet season and water supply shortages across the region.

If the climate predications are correct, Northern Australia should prepare for more of the same. Current trends and future projections indicate our region may experience:

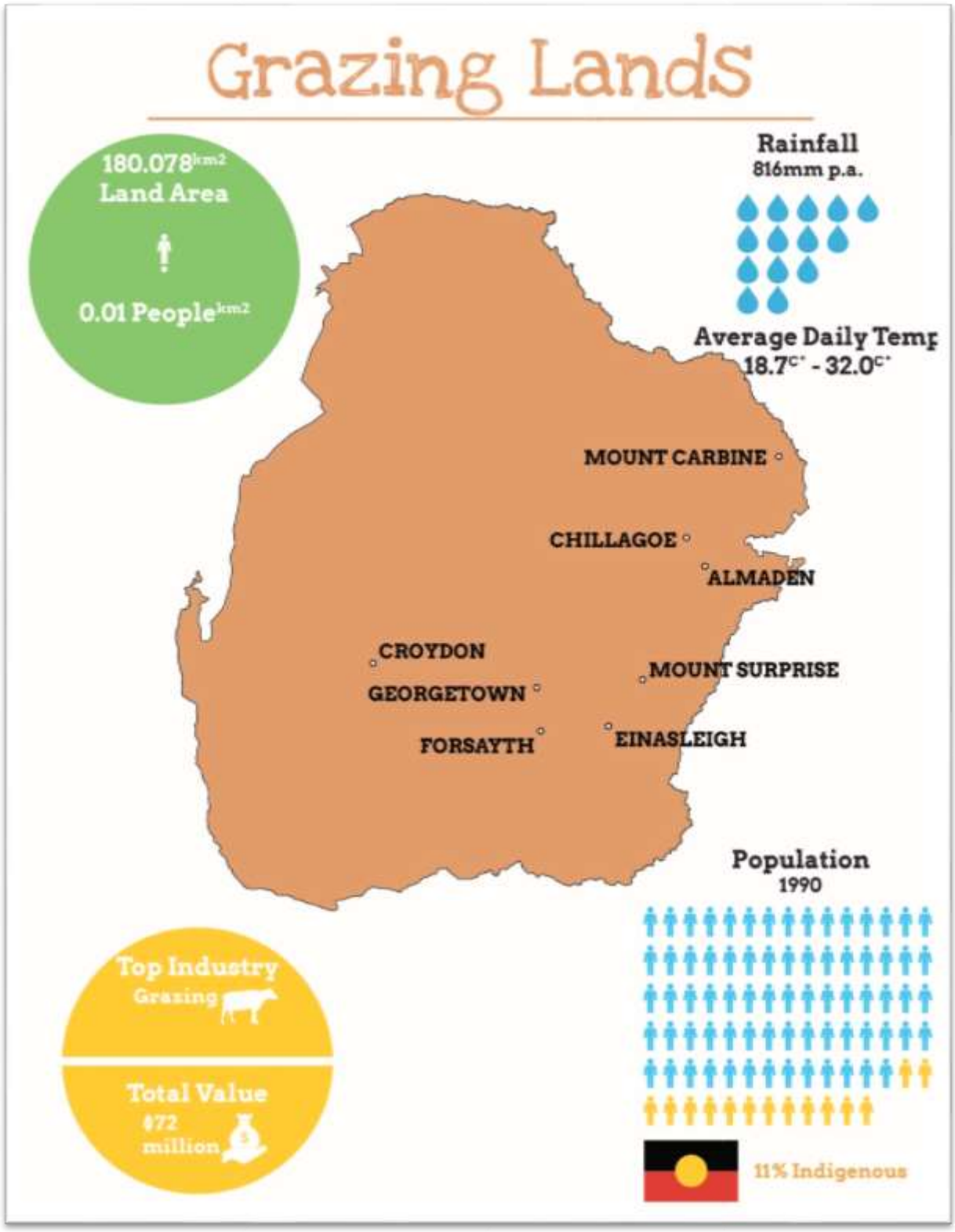
1. Increased incidence of destructive wild fires
2. Increased intensity of high rainfall events (flood and cyclones)
3. Longer dry seasons
4. Continued warming of temperature, including more hot days (Moise et al, 2014).

New irrigated agriculture may bring new wealth and prosperity to the grazing lands, but its environmental impacts will need to be managed carefully. However, increasing income from various forms of ecosystem service delivery, particularly on lands that are marginal for grazing, would be a boon to both pastoral enterprises and the environment.

Central to all this change are the pastoralists themselves. With all that is required from them and all the stresses and strains they already have to bear, many will be in no position to take up improved practices, let alone participate in the conservation economy. Pathways out of debt must be found before resilience in the face of change can be achieved, and pastoralists must be supported in the adoption of new practices, rather than have it mandated.

In this context, we plan for the future. To be prepared for upheaval and increasing uncertainty, all stakeholders in the region will rely and build on existing community capital and manage natural capital sustainably to ensure the Northern Gulf region will continue to adapt, grow and prosper.

2. DEMOGRAPHICS



1.3 Social Assessment

The Grazing lands communities are classed as "very remote" in the Accessibility and Remoteness Index Assessment (Government 2014)(Queensland government, 2014). Croydon, Cook and Carpentaria Shires all fall within the top 10% of the most disadvantaged LGAs in Queensland (Socio-Economic Indexes for Areas; 2006 census).

Communities in the Gulf region are generally characterized by welfare reliance, low skill levels, low education, low income and low levels of home ownership (CSRM 2008; Development 2009)(Centre for Social Responsibility in Mining; 2008/ Gulf Savannah Development; 2009).

The Indigenous population of the Grazing lands is 11%, which is far lower than the neighbouring coastal region, of 59% Indigenous population. Communities with the largest Indigenous populations are Croydon which is 30% Indigenous, and Chillagoe, which is around 20%.

While the region suffers from relative isolation, limited economic and education opportunities and highly dispersed population, Northern Gulf's grazing communities continue to have strong and distinct cultural integrity around key locations and industries.

1.3.1 Income

Most of the population is low income: one third of the population earns less than $400 per week, indicating poor financial capacity to adapt to change. This may mean that many residents in the region are living below the poverty line, which is $234 per week.

The median total family income in the Northern Gulf in 2011 was $55,410, with 19.2% of families earning less than $31,200 per year (Queensland government, 2014). Some 40.3% of individuals earn less than $400 per week and 32.2% of individuals earn between $400- $999 per week (OESR 2014). Around 20% of the Queensland population is in the most disadvantaged quintile, however in the Northern Gulf region, some 44.2% of the population are considered to be in the most disadvantaged quintile.

1.3.2 Employment

In 2008-9 some 94.5% of businesses in the Northern Gulf were small businesses. Small businesses in the region generally have a lower per capita than the Qld average. Some 46% have a turnover range of less than $100K, 35.5% turnover between $100K≤$500K, 9% turnover between $500K ≤ $1M, and 8.9% turnover ≥$1M (OESR 2012).

While most enterprises have offset cost increases by reducing their labour costs, this is not an option for the top 25% of businesses, which are already operating at a high level of input efficiency. This explains the closing of the gap between the best performing and average businesses. Corporation-run businesses are the least flexible in their cost structure, so can be outperformed by well-run family businesses (McLean et al. 2014). However this trend also means that employment opportunities in the grazing industry are declining.

The region's relatively stable population provides a good opportunity for building economic knowledge and awareness. The combined unemployment rate in the Carpentaria Shire, Croydon Shire and Etheridge Shire local government areas (LGA) was 15.2% in November 2012, compared with 5% across Queensland (OESR 2012; QTT 2012). Underemployment is not well reflected in the figures and youth employment remains overly high. In primary industries, employment is strongly affected by natural disaster and debt. Although unemployment in the region is generally high, there are significant opportunities in the emerging industries of tourism, environmental management, cropping and horticulture sectors (GRPAC 2000).

There is a broad shortage of "most professionals" in regional and remote areas of Queensland, particularly non-coastal areas (Economics 2011)(BTIRE 2006). Skilled workers must be brought into the region to complete work and rarely reside in the Gulf region beyond the scope of their employment. There is poor re-skilling of industries or labour forces to adapt to other business models or business enterprises or cope with changed resource conditions. There is a need to re-skill and provide assistance to develop business plans to help cope with change and build business resilience.

TABLE 1. EMPLOYMENT BY INDUSTRY, 2011 CENSUS, EMPLOYED PERSONS 15 YEARS AND OVER, USUAL RESIDENTS

SA1 by Main Statistical Area Structure (Main ASGS) (UR)	Grazing Lands	Percentage
INDP - 1 Digit Level		
Agriculture, Forestry and Fishing	464	47.1%
Mining	49	5.0%
Manufacturing	12	1.2%
Electricity, Gas, Water and Waste Services	5	0.5%
Construction	44	4.5%
Wholesale Trade	12	1.2%
Retail Trade	23	2.3%
Accommodation and Food Services	71	7.2%
Transport, Postal and Warehousing	30	3.0%
Information Media and Telecommunications	0	0.0%
Financial and Insurance Services	0	0.0%
Rental, Hiring and Real Estate Services	0	0.0%
Professional, Scientific and Technical Services	12	1.2%
Administrative and Support Services	19	1.9%
Public Administration and Safety	100	10.2%
Education and Training	43	4.4%
Health Care and Social Assistance	30	3.0%
Arts and Recreation Services	6	0.6%
Other Services	13	1.3%
Inadequately described	19	1.9%
Not stated	33	3.4%
Total	985	100.0%

Source: ABS 2011 Census, Tablebuilder

1.3.3 HEALTH AND WELLBEING

The average age of owners/managers of cattle properties across Northern Australia is close to 50 years old and there has been very little change in this statistic over the last 30 years (ABARES 2014). Farmers have higher rates of injury, disease, accident and suicide than do their metropolitan counterparts (Kõlves et al. 2012a; Kõlves et al. 2012b). Indeed, while suicide rates have decreased in cities, they have increased in regional and remote areas. Pastoralists in Northern Australia are currently under significant financial and emotional stress. Of pastoralists who participated in the Gulf Cattlemen's Association survey in 2014, 71% expressed the need for financial planning advice, 45% for Department of Human Services assistance and 54% for counselling for depression and mental health issues (ABARES 2014b). Financial counselling services are available, and have recently survived the threat of being closed down. Many pastoralists feel shamed by the failure of their businesses and are afraid to ask for assistance.

Farming is a stressful occupation that often involves financial insecurity and isolation, both of which are exacerbated by climatic events such as drought (Drought Policy Review Expert Social Panel 2008). The worst outcome of this stress includes suicide. In Queensland, agricultural works have one of the highest suicides rates of any occupational grouping . Suicides of males in rural Queensland are most frequent within 12 months of a work- or income-related stress (such as a business failure or income reduction), when a mental health illness has been diagnosed, or when moral support from family and friends is lacking (Kõlves et al. 2012a; Kõlves et al. 2012b). While statistical evidence for drought or natural disasters causing an increase in suicide rates is lacking (McKay et al. 2012), pastoralists report drought as causing significant financial and emotional stresses. The financial difficulties facing the pastoral industry described above, and the need to make substantial changes to their businesses (which are likely to beyond their financial capacity) just to stay afloat, are additional stresses that are likely to see increasing number of pastoralists needing support for mental health issues.

1.3.4 Education

Some 47.5% of the region's residents have a post-school qualification, compared to 50.4% for the whole of Queensland (OESR, 2012). There are currently few opportunities or facilities within the region for residents to expand their skill-base, with most having to travel to other regions particularly to gain higher education.

Many children rely on the internet for distance education. Certain barriers to access are found in the region, for example currently 5GB of data at a speed of 1,056kpbs is available for $92 per month compared to $20 per month at higher speeds of 2-3MBs in metropolitan areas (Development 2014)(GSD, 2014).

Some towns in the region do not have primary schools and there are limited support services throughout the region (GRPAC 2000). There are five schools in the Grazing lands (Forsayth, Mt Surprise, Georgetown, Croydon and Chillagoe) and none of them offer secondary education. Departure of children from the region to access secondary education is a major problem for many families, with the transition to Year 7 as the first year of high school in line with other states of Australia causing extra emotional and financial stress on many families. While there has been some growth in programs for education and knowledge building in the Northern Gulf developing and in place (TSCRC 2006), many high school students from remote areas attend boarding school in urban or more developed coastal areas or rely on School of the Air for their education (Stokes et al. 1999).

There is significant skills shortage in the Northern Gulf caused largely by the lack of education or training facilities (NGRMG 2008). There is a lack of tertiary or vocational education facilities in which to up-skill the region's population in association with enterprise level adjustment. There is also a significant migration of the region's youth towards larger cities seeking greater education and employment opportunities than the Northern Gulf can offer them (NGRMG, 2008).

1.3.5 Housing

There is currently a surplus of housing stock in Georgetown. Croydon has less housing available, however the Council does own a significant amount of houses which they are able to provide to employees and visiting professionals. Smaller remote centres struggle to provide additional housing, and the costs of building in remote areas can be prohibitive, due to freight costs and having to bring in skilled labour from outside the region.

1.3.6 Social Services

Much of the region's population and businesses are reliant on larger settlements outside the Northern Gulf, including Atherton, Mareeba and Cairns for various essential and non-essential services.

Many small communities rely on monthly or weekly "clinic" days (frequency of visits depends on the size of community), provided by service providers such as the Royal Flying Doctor's Service. The reductions in funding to health services such as Medicare Local and Frontier Services/Savannah Regional Health Service are a blow to the remote populations, the latter of which had to close down their regional office in 2014.

1.4 Indigenous Cultural Values

1.4.1 Indigenous people and Natural Resource Management - the national context

Australia has endorsed the *United Nations Declaration on the Rights of Indigenous Peoples*, which asserts, "Indigenous peoples have the right of self-determination. By virtue of that right they freely determine their political status and freely pursue their economic, social and cultural development". The declaration is non-binding, but Australia's endorsement indicates a commitment to its principles.

As discussed in the introductory chapters of this report, Australian Indigenous leaders consider self-determination to be their highest priority, which means being able to choose whether to use their lands for conservation or other purposes, and whether to be employed as rangers or in other professions (Brennan 2001; DAFF 2011; NTNRMB 2010). Many Indigenous Australians do wish to fulfil their own obligations to land and culture, and to gain at least part of their livelihoods from undertaking cultural and natural resource management (Holmes 2014; Martin et al. 2007; Wensing 2014). Evidence of this is the number of active Indigenous ranger groups and the number of Indigenous Protected Areas that have been established in the last decade.

In contrast to prioritisation of biodiversity and cultural heritage values, investments in Indigenous development are difficult to prioritise spatially, especially if it is Indigenous people themselves who are to determine how their communities and lands are to be developed. However, the greatest concentration of Indigenous-held lands in the Monsoonal North is in the Kimberley and the Top End, which is also where most non-urban Indigenous people live (Figure 2). This coincides with the areas of most intact landscapes and highest concentration of recognised biodiversity and cultural heritage values described above. These areas are therefore most likely to attract funding for Indigenous cultural and natural resource management.

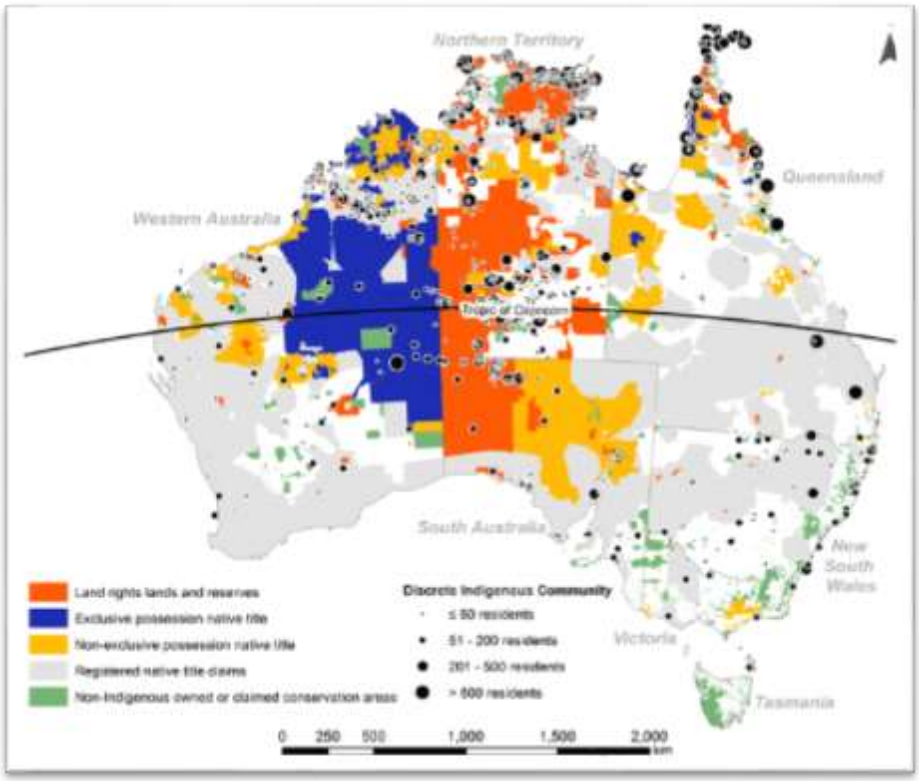


FIGURE 2. INDIGENOUS ESTATE AND DISCRETE INDIGENOUS COMMUNITIES, 2010

SOURCE: ALTMAN (2014), UNEP (1992)

1.4.2 Indigenous pastoralism

Indigenous people have a long association with the northern beef industry, with many Aboriginal stockmen providing low-wage labour on cattle stations until the equal pay decision of 1967 (May 1994; Skyring 2012). Indigenous pastoralism is a significant and growing part of the northern beef industry. Efforts to develop Indigenous pastoralism have taken a vertical integration model that spans resource development; education and training; cattle breeding, fattening, processing and live export through to tourism, and is likely to benefit the rest of the industry (ILC 2013a, 2013b, 2013c, 2013d; McClelland Rural Services Pty Ltd 2014). Along with increasing the number of properties in Indigenous hands and employment opportunities for Indigenous people, Indigenous-owned lands offer the opportunity to increase the size of the Northern Australian cattle herd. Indigenous owned or managed cattle stations in the Northern Gulf include Delta Downs (on the coast), Bonny Glen, Bulleringa, Powis and Oriners.

Not all pastoral properties purchased on behalf of Indigenous communities will remain as pastoral operations. For example, Tallaroo Station (315 km^2) located on the Einasliegh river between Mt Surprise and Georgetown, was purchased to establish an Indigenous Protected Area (ILC 2013).

1.4.3 Native Title

Most pastoral leases coexist with Native Title (Stevenson 1997). Those that are not can be sold, subleased or used as security for loans or converted to a new tenure type (Wensing et al. 2012). The Native Title Act 1993 guarantees that a pastoral lease can be renewed without compensation being paid to the Native Title holders (Brennan 2001). However, it does not guarantee rights to non-pastoral uses on pastoral leases, and the rights of Native Title holders must be considered before such rights are granted. Tenure conversion for the purposes of land use diversification will therefore require Native Title to be extinguished, such as through compulsory acquisition, or for an Indigenous Land Use Agreement (ILUA) to be negotiated. Compulsory freeholding would require the unlikely repeal of the Racial Discrimination Act 1975 (Holmes 2014), so a negotiated outcome will be required. ILUAs and cover the use of, and access to, traditional land and waters[1]. ILUAs have been negotiated for pastoral lands in all three jurisdictions.

Native Title restricts land use diversification whether the land is owned by Indigenous or non-Indigenous pastoralists (Wensing 2014), but different approaches are appropriate under different combinations of lease ownership and Native Title rights. In the North Kimberley and western Gulf of Carpentaria, where Indigenous landholdings predominate, there is potential to reform land tenure while consolidating Indigenous rights, as has occurred on Cape York Peninsula (Figure ; Holmes 2013)(Holmes 2014). Elsewhere in the Monsoonal North, it is likely that pastoral intensification will take precedence over Indigenous rights, but successful change to other land tenures and uses remain uncertain.

[1] www.nntt.gov.au/ILUAs/Pages/default.aspx

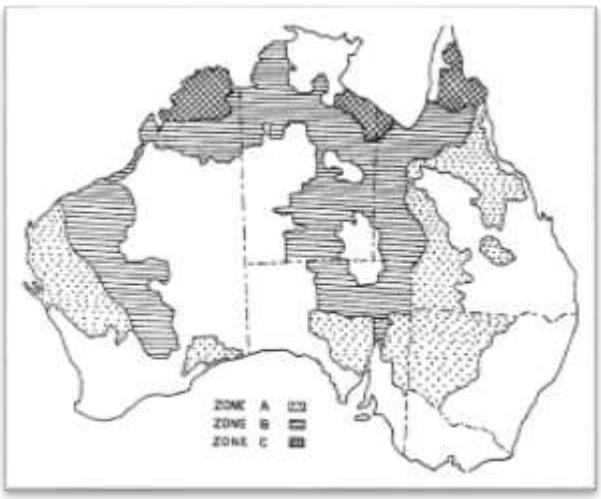


FIGURE 3. POTENTIAL RECOGNITION OF NATIVE TITLE ON PASTORAL LEASES IN RELATION TO ASSUMED LEVEL OF ABORIGINAL CONNECTION TO THE LAND

SOURCE: HOLMES 2014

ZONE A: LIMITED ONGOING CONNECTION TO LAND; LIMITED RECOGNITION OF NATIVE TITLE RIGHTS; PROTECTION OF SACRED SITES WITH NEGOTIATED ACCESS. ZONE B: EXTENSIVE ONGOING CONNECTION TO LAND; NATIVE TITLE RIGHTS RECOGNISED BUT CURTAILED BY ONGOING DEVELOPMENT; RIGHTS OF ACCESS AND TRADITIONAL USE UNDER EXTENSIVELY MANAGED AREAS. ZONE C: WIDESPREAD, ONGOING PHYSICAL AND SPIRITUAL CONNECTION; WIDESPREAD RECOGNITION OF NATIVE TITLE RIGHTS ASSURED BY LIMITED SCOPE FOR AGRICULTURAL DEVELOPMENT; COMPREHENSIVE RESTRUCTURING OF LAND TENURE AND USE THROUGH NEGOTIATED REGIONAL AGREEMENTS.

1.4.4 Traditional Owner engagement in the Northern Gulf region

Over the course of 2014-2015, Northern Gulf Resource Management Group Ltd (NGRMG) conducted a program of Indigenous engagement, with the Traditional Owner groups and Aboriginal organisations of the Grazing lands. This engagement focused on the following groups:

1.4.4.1 Ewamian

The Ewamian people did not go through a strategic planning process with the NGRMG, however they strongly conveyed that as a corporation they are currently very committed to expanding their activities and ranger program based at Talaroo station, on the Einsaleigh River between Georgetown and Mt Surprise.

1.4.4.2 Tagalaka

The Tagalaka country includes the Croydon Shire and the Croydon township itself, and extends into parts of the Carpentaria and Etheridge Shires. In 2012 the Tagalaka were granted Native title rights over these lands. Strategic priorities identified included:

1. Establishing a Tagalaka ranger program, including operating capital for an office and vehicle;
2. Preserve artwork and artefacts;
3. Map all cultural heritage places;
4. Develop language resources such as books and CDs;
5. Taking young ones out on country;
6. Develop cultural tourism opportunities with bird watching, bush tucker and rock art galleries.

1.4.4.3 Western Yalanji

The Western Yalanji are the Traditional owners for the Palmer River catchment in the top of the Mitchell catchment, which includes the Mt Carbine and Laura areas, extending to the Annan river in Cape York. The Western Yalanji acknowledge the very special ecological and cultural values of this area, which have been listed in both the Australian Heritage Estate and UNESCO.

Their aspirations for Natural Resource Management in their area include:

1. Reinstating traditional methods of caring for country entwined with western science for land management;
2. To regain, maintain, share and hand down cultural knowledge to succeeding generations;
3. To use their country-based plan as the vehicle to provide for increased access to country to enable their people;
4. To undertake recreational activities, implement conservation and land management measures, and record the cultural and natural values of the country;
5. To overcome social dysfunction through robust, meaningful and tangible initiatives which encourage current generation to go back to country;
6. To place greater emphasis on low impact sustainable economic development;
7. To stop large scale detrimental mining practices and encourage better environmental management practice;
8. To stop coal seam gas exploration; and
9. Sustainable water supply for current and future use.

Two smaller sub-groups of the Western Yalanji people are the Jawiyabba Warra Aboriginal Corporation and the Gumi Junga Aboriginal Corporation, who work closely together. The latter manage Bonnie Glen Station in the Palmer River catchment. It is understood that they are working with the Cape York NRM and Mitchell River Watershed Management Group on more detailed property planning for this station. The Jawiyabba Warra Aboriginal Corporation is a newly formed group which represent the Kawanji clan estate, and also have an interest in area around Bonnie Glen. They conducted an engagement with NGRMG towards this NRM Planning, which identified the following strategies:

1. Their strongest family values are to involve their young people and children in talking, planning and working for country and future goals;
2. Establish a water quality monitoring program to determine if toxins and heavy metals are in water and if it is getting worse;
3. Establish an old mine rehabilitation program;
4. Better regulate tourism and reduce trespass through no-go zones, education material and presence on country;
5. Apply for grants to protect environmental health;
6. Identify presence and distribution of pests and develop a pest management plan;
7. Develop a fire management plan;
8. To get their own people to do this work.

1.4.4.4 Wokomin/Chillagoe

The Wokomin are not formal Native Title holders and do not have their own Prescribed Body Corporate. This often results in them being left out of funding opportunities and not engaged on the management of their country and culture. They hope to address this by progressing a Native Title determination.

They would also like a greater role in the management of National Parks in the Chillagoe area and regulating tourism in the area, to reduce and manage its impacts. They would like to see more Aboriginal rangers working in the National Parks and looking after country.

The results of this engagement are summarised in the following pages:

Many Ewamian people generously shared their stories for this project. We thank Uncle Noel Lacey, Uncle Ron Richards, Aunty Elma Lingard, Uncle Brian Bing, Uncle Ruben Richards, Aunty Eslyn Wargent, Uncle David Hudson and Gerry and Gillian Collins.

Funding for this project was provided by IPA and coordinated by Sharon Prior. Jean Brickey, Brian Bing and Alice Buhnich conducted the interviews.

Ewamian Country

Talaroo Station

When Noel Lacey and Ruben Richards worked at Talaroo Gertie Lacey told them about the spirit in the Springs.

Sometimes, if you go to the Springs early in the morning, you can see a female spirit in the steam coming out of the water.

Rosie Mud and the Skull Camp Massacre: told to Ron Richards by G. Ryan

There was a big camp of Ewamian people at White Springs on Talaroo, near the Einasleigh River. A band of local white men and native police rode into the camp one day, and attacked. Many people were killed. Rosie and her mother escaped by following the river downstream to Abingdon Downs. In later years, Rosie married Sloper Mud and lived on the Georgetown Reserve in the mud house.

Talaroo Station was purchased in 2012 on behalf of Ewamian People with funding from National Reserve System, Indigenous Land Corporation and Indigenous Protected Areas. Ewamian Land and Sea Rangers commenced operations based at Talaroo in July 2012.

Skull Camp memorial. Each post represents a Ewamian family.

Spring Creek Homestead c1920

Mrs Nancy Collins with Yvonne and Brian Bing and Erolly Collns.

Jean Brickey, Gerry & Gillian Collins, Bring Bing , 2014

Yvonne Tranby & Brian Bing

Forest Home has a special association with Ewamian people. It was Frank Hudson's home, and the property where Ceasar and Ron Richards were born.

Spring Creek & Rosella Plains

Dick Bing & Stan Collins c1924

Brian and Yvonne Bing's grandparents lived at Spring Creek and stayed close to country by working for the Collins. Their children Dick, Arthur, Archie, Billy and Harry grew up with the Collins children and worked on Spring Creek and Rosella Plains.

Yvonne and Brian were born at SpringCreek, but moved to Mona Mona so they could have a proper education. When Brian was 13 he was welcomed back to Spring Creek to work. Like his father and uncles he was well respected for his horsemanship and bush skills. Jobs typically involved fencing, looking for stray cattle (and rescuing them out of the bogs) and burning to maintain grass for the cattle.

Sunday outing: Lenny McLellan, Rita Gutchen (nee Hunter), Dawn Archer, Nookie (back), Johnny Devitt, Eslyn Wargent (nee Hunter), David Hudson (back), Brian Bing, Ron Archer.

Rita Gutchen, Elma Lingard (nee Richards) and Ruben Richards were some of the Ewamian people who worked at Spring Creek and Rosella Plains. They described a typical working day.

Time	Cook's day (As told by Rita Gutchen)	Cowboy's day (as told by Ruben Richards)
5am	Up to prepare breakfast	Milk the cows
7	Breakfast	Breakfast
8-10	Prepare smoko: scones or brownie	Make trailer, fix fences, check the pump
10:30	Smoko	Smoko
	Clean up, prepare lunch	Gardening, weeding, watering, harvesting vegetables and fruit
12	Lunch	Lunch
2-3	Siesta	Feed horses, back up the cows
3	Smoko	Smoko
4-6	Prepare dinner	Ride stockbreed, load trucks
7	Dinner	Dinner
7:30-8	Wash up	

EWAMIAN ABORIGINAL CORPORATION

RECORDING HERITAGE AT TALAROO

Jean Brickey and Alice Buhrich

Talaroo Station was purchased by the Indigenous Land Corporation on behalf of Ewamian people in 2011. Jean Brickey and Brian Bing started as Cultural Heritage Officers in 2012.

Cultural Heritage Officers duties are to record and map significant sites on Talaroo using GPS and cameras and site forms.

Near the Hot Springs is a scatter of a few chipped pieces of chert and a grindstone. On the river bed we found a core, where people have chipped off sharp pieces to use for cutting. It's best to look for these in eroded areas or after a fire. When we find these we record them and leave them where we find them.

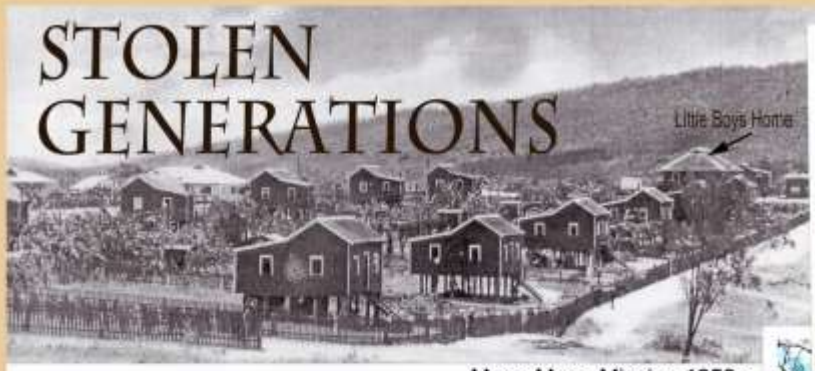
SCARRED TREES

We've found lots of sugar bag scars. The outer bark has been removed and cuts made into the inner bar to reach the hollow centre of the tree to get to the honey and wax. We find sugarbag scars on living and dead Cooktown ironwoods. These trees live for a long time, up to 300 years. These trees like the deep sandy ridges, you might see them on the back road to Skull Camp.

GRINDING GROOVES

Grinding grooves are oval shapes ground into the hard granite rocks in the river. Ewamian people used to sharpen their axes in these grooves, using water from the river. You'll see these down in the river bed in front of the homestead. There are big numbers of grooves at White Springs Creek and some more at Skull Camp.

STOLEN GENERATIONS



Mona Mona Mission 1950s

Moved to Mona Mona, the story of Ceasar and Ron Richards

Brothers Ceasar and Ron Richards were removed to Mona Mona Mission after his mother, Dora, died when Ron was 5 years old. The boys were separated from their father and older brothers, because of the lighter colour of their skin. Their father Tommy and older brothers, Chisolm, George Corbett & Manney worked on stations as stockmen and trackers for the police. Their older sister, Gertie, also worked on the stations. The older boys, Gertie and father Tommy spent their whole lives on Ewamian country. They were not removed to the mission because they had dark skin.

When the Police came to take Caesar and Ron away the boys they did not know where they were being taken. They had grown up with the station owners, the Wilcott family who had treated them like their own children. At this time the Protector of Aborigines controlled Aboriginal peoples lives under the Act. The Wilcott's tried to adopt Caesar and Ron, but were refused by the authorities. Tommy stayed on at the station and worked for the police as a tracker as needed. Although the Protector controlled Tommy's wages, he managed to send money through to Mona Mona for Caesar and Ron's education, probably organised by the Wilcott's.

At Mona Mona Mission Ceasar and Ron were placed in the boys dorm. Their cousins Sarah and Martha Hudson were at Mona Mona with their children and they all looked out for the boys. Sarah and her husband Henry Hunter ran the Little Boys dormintory.

Uncle Ron Richards (right)

Ceasar Richard's Exemption Certificate. This had to be carried everywhere to show exemption from the Aboriginal Proection Act.

Living Under The Act told by Ron Richards

After asking and asking Ron was eventually given a pass to visit his family at Georgetown, with the condition he would report in to every police station on the way. He reported to Almaden, Forsyth and Georgetown police stations. Nearly every day he had to go into the police station, and this prevented him from going out to the properties where his family worked. If Ron had not checked in at the police stations they would have come and found him and sent to Palm Island as punishment.

His brothers came to see his at Georgetown, and Chisolm Fred introduced Ron to family living at the Georgetown Reserve, where Ron stayed. Ron's father, Tommy, was not given time off work to visit his son. After Ron was taken from Forest Home, he and Ceasar never saw their father again until the day before his father died, in Cairns Hospital.

Stolen Wages

Under the Act wages were not collected by the employee, but went to the mission superintendent or the Aboriginal Protector.

In 2002 the Queensland government repaind some of the stolen wages through the Indigenous Wages and Savings Repatriation Scheme. People, who had worked for years under the Proection Act, recieved payments of up to $5000.

Chisolm Fred (on right in photo with Sid Dowling) worked on stations in the Georgetown area his whole life, but only recieved a small amount of his wages as 'pocket money'.

NATIVE TITLE DETERMINATION

In November 2013 the Federal Court recognised Ewamian Peoples' native title rights over 26,000 square kms of land around the Georgetown area. The determination allows the Ewamian People to be present, camp, hunt, gather, conduct ceremonies, and maintain places of importance and significance on their traditional lands in accordance with traditional laws and customs. This decision acknowledges the Ewamian People's ancient connection to their lands and role preserving that land for future generations.

Ewamian Aboriginal Corporation is the representative body for Ewamian People. The vision of EAC is to enhance Ewamian Peoples' culture and connection to country through positive change and by promoting partnerships with key stakeholders. EAC core values are **integrity, respect, collaboration, goal orientation** and **motivation.**

LOOKING TO THE FUTURE

UNCLE RON RICHARDS

Talaroo is a good base for Ewamian to come back to country. It's good for fishing and has the Springs, the river and is close to Georgetown and the main road. There are tourist opportunities at Talaroo like making artefacts, taking rock art tours and camping.

UNCLE DAVID HUDSON

My aspirations for Talaroo are to develop Indigenous tourist products - tours, making artefacts, growing seeds as a carbon initiative. To use it as a place for younger Ewamian to get away from the problems of the towns - a cultural healing centre.

AUNTY ELMA LINGARD

When I was travelling around Australia I saw the wedge tail eagle every day. That's our totem. I knew those old people were looking out for me.

UNCLE BRIAN BING

I want to see Talaroo used as a training place for Ewamian people. It could be used for tourist training,like the savannah guides, and be used by school groups and rangers. I want to see a manager on site who can oversee tourism at Skull Camp and the Springs. There is also the opportunity for some cattle on the property, the yards, dams and fences are already there so why not use them.

COUNTRY PLAN OF THE CUSTODIANS OF TAGALAKA LANDS, CROYDON

The Tagalaka people have persevered through many struggles over generations and continue to fight for our aspiration of self-determination for country. Our old people began our journey to gain recognition and our rights to our ancestral lands. We owe it to the souls that have been, are now and will in the future walk on and care for Tagalaka lands to continue that journey. With strong leadership in place and our on-going heart for our family, country and traditional practices we will provide a better future for our children.

Connection with our ancestral lands, stories and practices is vital in our sense of belonging, peace of heart and overall wellbeing. Land is our beginning, our life and our ending place – it is as important as life itself to us.

The Federal court in December 2012 granted Tagalaka people Native Title rights over lands in the Croydon Shire and Township and extending to include lands in the local government electorates of Etheridge and Carpentaria. Today the Tagalaka people's Native Title rights, interests and assets are primarily managed by the Tagalaka Aboriginal Corporation RNTBC (a Prescribed Body Corporate under the Corporations Aboriginal and Torres Strait Islander Act (2006)

DEDICATION

We are the custodians of Tagalaka lands, waterways, and wildlife. It has for thousands of years been the responsibility of our families to live in balance and manage the nature and our people in this area. As times change our tools and practices may change, but our values remain firm. We dedicate this plan and the outcomes we chose to deliver to all Tagalaka people and hope our parents, our children and all those we love see the commitments we make to our family values, our lore and our rites.

MISSION FOR COUNTRY

To maintain, protect, preserve and practice Tagalaka people's culture and country and to manage the Tagalaka clan estates for community benefit

COUNTRY VALUES

Our country holds deep values for us:

- Country feeds us, and looks after us
- It is sacred, our mother, and forgiving of us
- It is our meeting places, our birthing places and our grave sites
- It is where old people walked and full of memories
- It is a place of healing
- In it we feel happy, good and free
- Out of it we continually miss it
- It is the place we belong

ASSETS OF COUNTRY

The following are a list of our most valued cultural/natural assets.

ASSET	IMPORTANCE	OUR GOAL
Paintings	Record of people and stories	To protect and preserve
Artefacts	Places of gathering and toil	To protect, preserve and make
Dreaming/ Story places	Lore - basis of belonging, behaviour and values	To protect, preserve and share in appropriate way
Wildlife	Many family stories linked to wildlife, including about when & where to fish/hunt	To manage and maintain nautral balance

TAGALAKA

THREATS TO THE COUNTRY

ASSET	THREAT	INFLUENCES
1. Paintings	• Rubbing and covering paintings with dirt • Colour and definition of paintings deteriorating • Loss of site and access • Damage	• Weather • Trespassers • Wasps, cattle, wallabies, pigs • Trees and shrubs, conflicts with other stakeholders
2. Artefacts	• Damage • Loss of sites and access (including sites used to make artefacts)	• Council works, fires, trespassers, dams, infrastructure built over them, property roads (dozers/graders) • Trees and shrubs, conflicts with other stakeholders
3. Dreaming/Story places	• Development • Floods, fires and natural disasters • Station infrastructure • Mining (toxic water/cyanide) • Weeds and scrub overgrowth • Losing cultural knowledge	• Food bowl • Development design • Relationships with developers and landholders • ILUA agreements • Land tenure • Attitude/culture of young peopleMaterial V's Spiritual respect
4. Wildlife	• Development • Hunting • Fire • Introduced pests • Climate change • Grazing/mining • Disease • Natural disasters	• Funding and capacity • Government regulations

Australian Government

This project is supported by Northern Gulf Resource Management Group Ltd, through funding from the Australian Government.

TAGALAKA

MANAGING THREATS AND OPPORTUNITIES

THREATS	MANAGEMENT	PARTNERS
Damage, trees and scrub, fires, pests, wildlife management	• Establish Tagalaka Rangers and operating capital (office, car etc) • Small grant applications for money to undertake some management needs (fencing, shooting pests etc) • Science and monitoring program for health of culture and environment	• NGRMG • State and Federal Government programs • Parliamentarians • Graziers/miners/tourism • RJCP/ Bynoe • Training programs (contact Jenny Petrich) • Landcare and biodiversity programs • Research organisations
Loss of site and access	• Map all cultural heritage sites, story places • Ensure regular family presence in country • Maintain relationships with other relevant stakeholders • Initiate & gain title ownership or trustee arrangements for Tagalaka lands	• Landholders • Councils • NGRMG - mapping capacity/training • ILC/NRS
Cattle, wallabies, pigs and trespassers	• Fencing	• NGRMG • Landholders • Council
Loss of painting integrity	• Acrylic coating	• JCU • Land council • Graziers
Loss of knowledge	• Write and develop story books / CD's or mobile app's • Copy right to protect 'rites' • Rangers practicing and taking young ones out • Our community education • Cultural awareness • Website • Local slide night/BBQ • Traditional knowledge recording (internal database) • Cultural map (depicts knowledge of place, trails, hunting area etc) • Leadership 'attitude' program • Work with Beverly and others to record and speak together our language (do workshops)	• Our youth • Tagalaka people • Affiliated anthropologists • Land council • Medicare Local (wellbeing benefits) • Drug alcohol programs (wellbeing benefits) • Council • Schools • NGRMG • Government grant programs • Inspirational people (Shane Howard etc) • GSD • RDA
Natural disasters	• Assist programs to keep country healthy (rangers) • Work with science and land use design (balance the benefits and losses carefully)	• Landholders • Developers • Council • NGRMG • Government agencies • Research organisations
Loss of painting integrity	• Develop ILUA's with appropriate land use design and agreements	• Land Council • Native Title Tribunal
Station infrastructure	• Maintain good relationships with landholders • Develop internal cultural database and inform landholders of sites in appropriate ways	• NGRMG
Mining & Exploration: environmental issues i.e. contamination	• Small grant applications • Joint venture with DRNM, pastoral • Engagement with mining and exploration.	• NGRMG • DNRM, • Pastoral • State • Bynoe/RJCP, • Croydon Shire Council

OPPORTUNITIES	MANAGEMENT	PARTNERS
Tourism	• Develop tourism products • Rangers to regulate access and take tours	• GSD • Savannah Guides • Croydon Council • Private Joint Ventures
Making artefacts for sale	• Organise regular learning and workshops with mob to make artefacts	• Shops
Acquire land assets	• Identify potential land parcels and agreements • Apply for ILC/NRS funds	• NGRMG • Parliamentarians
Office/home base	• Apply for grants but also look at ways to earn own revenue	• GSD • RDA • Council

OPPORTUNITIES FOR TAGALAKA

ASSET	OPPORTUNITY	INFLUENCES
1. Paintings	• Tourism • Rangers taking young people out and caring for sites	• Communicate within Tagalaka and ensure our people know our sites, decide what to share and what is sacred • Need income for rangers and costs of management
2. Artefacts	• Cultural presentation • Make new artefacts (sales)	• Education/learning by mob to make artefacts • Need income for rangers to maintain and monitor artefact sites • Operational money and equipment
3. Dreaming/ story places	• Cultural presentation • Share some stories for income generation as appropriate	• Protocols/ decision on what and how to share stories
4. Oral knowledge	• Cultural preservation • Wellbeing (knowledge)	• Old people sharing with young ones • Attitude of young ones • Loss over time
5. Wildlife	• Tourism (bird watching) • Bird aviaries/breeding • Jams (plants) • Produce native food/medicinal products (plants – soaps, sauces, healing creams)	• Money and skills • Office/shed or place to make stuff and sell

INTRODUCTION:
TAGALAKA COUNTRY PLAN

This purpose of this country plan is to identify our country and cultural assets and the threats to and opportunities around those assets. We wish to develop and run projects to minimise threats and make good opportunities so that our land, our family and our lore benefits.

Many of our country assets and values including our art sites, our story places and our sacred sites have been damaged and there is much healing needed for these as well as our family. Our family and our land are connected so that when one is healthy the other is also healthy. We recognise the need to heal our country and our family together through this plan and projects.

This country plan aligns with our Determination, Strategic Plan and our Business Plan as follows:

TAGALAKA Prescribed Body Corporate

Determination:
Administer our Native Title Responsibilities
- ILUA's and Agreements
- Compliance Monitoring
- Communications
- Website
- Factsheets
- Letters
- Newsletter

Strategic Plan:
Governance and decision making
- Organisation vision and mission
- Our values and ethos
- Business Strength
- Income for organisation
- Employment
- Housing
- Education
- Office and facilities
- Quarry

Country Plan:
Country - landscapes, rivers, animals, plants
- Culture - lore, art, language, music, dance, stories, sites
- Access to land and sites
- Caring for Country
- Rangers
- Practicing culture
- Preserving culture
- Science and monitoring

Business Plan:
Costings and partnerships for the implementation of all of the above

We realise that we cannot do everything at once and thus we must act strategically and prioritise the actions we feel necessary for Tagalaka. We must also maintain open minds for emerging priorities and opportunities. Thus this plan also needs to be flexible and we will review it on country every twelve months. Our business plan identifies the costs of the projects outlined in this plan and avenues to raise this revenue.

Australian Government

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WESTERN YALANJI

WUNGAR-DARRAY KUKU YALANJI BAMA AND WESTERN KUKU YALANJI COUNTRY

Wungar–darray kuku Yalanji bama in English means western kuku Yalanji people. The wungar-darray kuku Yalanji bama are the direct descendants of the ancestors that have sustainably managed used, harvested and occupied this country for many thousands of years. Although wungar-darray kuku Yalanji bama and country were isolated Traditional Owners, the greater Western Kuku Yalanji nation have always maintained traditional lore and customs and continue to do so today. The wungar-darray kuku Yalanji bama wish to ensure that the Aboriginal customary lores and traditional governance systems practiced and implemented on Country remain that way.

A significant Country landmark known to many as the light house mountain but also known to the Yalanji people as the red kangaroo story place (Julmbanu warra), identifies the Wungar-daray kuku Yalanji bama (sunset kuku Yalanji people), and is the most southern traditional boundary, with Jowell Binna and Laura being the north western boundary and the Annan river to the north east

VISION FOR COUNTRY

To ensure western kuku Yalanji Country retains its cultural and natural integrity through Wungar-darray kuku Yalanji management systems, and;

- The cultural and natural heritage of western kuku Yalanji Country is protected and the living culture of our people is respected.
- Knowledge about our Country and culture is passed on to younger Wungar-darray kuku Yalanji generations.
- Economic development is culturally, environmentally and socially sustainable.

PLANTS AND ANIMALS

The sulphur-crested cockatoo and the red-tailed black cockatoo are two of several significant totems of the Wungar-darray kuku Yalanji bama and can be found in Western Kuku Yalanji Native Title determination areas. These totems work as an emblem of clans and social solidarity and can represent the mythological ancestors of different tribes. Wungar-darray kuku Yalanji bama are surrounded by totems and this sense of connection to the land brings with it an obligation to respect and care for the environment, according to traditional lore and custom.

MISSION FOR COUNTRY

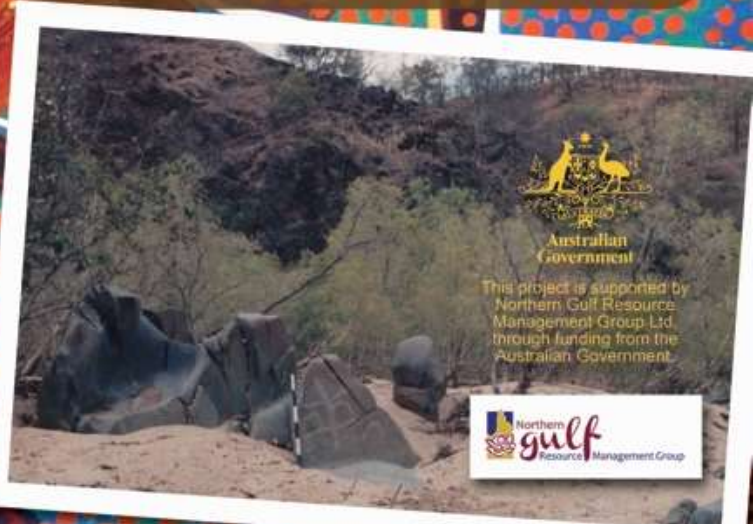
To reinstate and maintain traditional knowledge to ensure that Wungar-darray kuku Yalanji bama have a place to overcome social disparity. To manage Country to the highest standards that meet expectations of the Australian community through the protection of natural and cultural values, and for Wungar-darray kuku Yalanji bama to meet their obligations to care for Country and satisfy their people's aspirations for benefits from land ownership.

OUR COUNTRY & CULTURAL VALUES

Western kuku Yalanji Country is a landscape of theatrical contrasts. Rugged mountains dominate the eastern section, rising to over 1,000m. Annual rainfall on these peaks can reach 4,000mm giving life to some of Australia's richest rainforest communities. Further down the slopes, extensive stands of wet sclerophyll forest cling to the margins of the rainforest. As rainfall drops off sharply, tall woodlands skirt the foothills before making the transition to low, open grassy woodlands. This is the floodplain of the mighty Mitchell River and its tributaries. The Mitchell River is fringed by melaleucas and red gums. The only prominent pinnacle of Lighthouse Peak and the bare granite hills of Mt Alto and Little Alto rise above the Mitchell floodplain. The western kuku Yalanji Country is diverse and biologically significant to the region. It lies within Australia's tropical savannahs, considered the most intact and best condition tropical savannah regions in the world.

Wungar-darray kuku Yalanji cultural values include famous rock art; Quinkan Country contains a large and dramatic body of pre-historic rock paintings. These galleries have been identified as being at least 15,000 to 30,000 years old and have been included on the Australian Heritage Estate and listed by UNESCO as being among the top ten rock art sites in the world.

Known as a meeting ground for the communities of Cape York, the Laura Aboriginal Dance Festival is highly regarded by many Aboriginal people as a place where people meet new and old family members, make new acquaintances and exchange and pass on family histories and stories. In addition, many descendants of Aboriginal people whose people were removed from the area return every festival. For some it is to re-connect and for some it is to experience and learn from the cultural environment and ceremony. Consequently the Laura Aboriginal Dance Festival is seen as a very important event for cultural retention. The performance and practice of Aboriginal Dance and culture at the Laura Aboriginal Dance Festival is a very important element in the preservation and continuance of the unique culture of the region.



WESTERN YALANJI

THREATS

The number of threats deteriorating Wungar-darray kuku Yalanji Country's natural and cultural integrity are predominately a result of over 120 years of land clearing for livestock grazing and more recently small and medium scale mining. Also, altered fire regimes and the encroachment of weeds and feral animals (especially pigs and cats) combine to threaten and overwhelm natural and cultural values.

Causing problems are weeds of national significance (WONS) species including gamba grass, rubber vine, hymenachne, bellyache bush, lantana, parthenium, and salvina. Two additional species listed under the Northern Australian Quarantine Strategy are Siam weed and Kosters Curse. Other serious and declared weeds include Navua sedge, giant rats tail grass, asbestos grass, devils claw, Mossman river grass, coffee senna, laucaena, chinee apple, sickle pod and neem tree.

CULTURAL HERITAGE MANAGEMENT

It is integral that Wungar-darray kuku Yalanji bama maintain the inherent rights and interest for language, culture and kinship for Country in order to ensure the Country is respected, cared for in ways that does not extinguish lore and custom, and we share the wealth of knowledge the elders have to pass on to younger generations walking in their footsteps.

NATURAL RESOURCE MANAGEMENT

Aim: For Wungar-darray kuku Yalanji bama to reinstate traditional land management systems entwined with western science to restore the natural integrity of the land.

We would like to:
1. Reinstate traditional methods of caring for Country, entwined with western science for land management.
2. To regain, maintain, share and hand down cultural knowledge to succeeding generations.
3. To use the Country based plan as a vehicle to provide for increased access to Country to enable Wungar-darray kuku Yalanji bama to undertake recreational activities, implement conservation and land management measures, and record the cultural and natural values of Country.
4. To overcome social dysfunction through robust, meaningful and tangible initiatives that encourage our current generation to go back to Country.
5. To place greater emphasis on low impact sustainable economic development to enhance quality of life for Wungar-darray kuku Yalanji youth.
6. To stop large scale detrimental mining practice and encourage better environmental management practice.
7. To stop coal seam gas exploration and development.
8. Sustainable water supply for current use and to ensure the future has clean, safe water - ground and surface water.

ECONOMIC AND SOCIAL DEVELOPMENT

We would like to:
1. Drive and keep current the aspirations of our people.
2. Have strong governance structures based on integrity and accountability.
3. Integrate Wungar-darray kuku Yalanji knowledge and western science.
4. Have strong cultural connections therefore ensuring the right people talk for Country/clan estates.
5. Have trust and sustainability.
6. Provide/receive high quality targeted training with meaningful job outcomes.
7. Secure adequate funding over an extended period.
8. Form long term strategic partnerships.
9. See broader interest in Country and NRM in our communities.
10. See Elders involved.
11. Empower Traditional Owners.
12. Have long term mentoring support.

Australian Government
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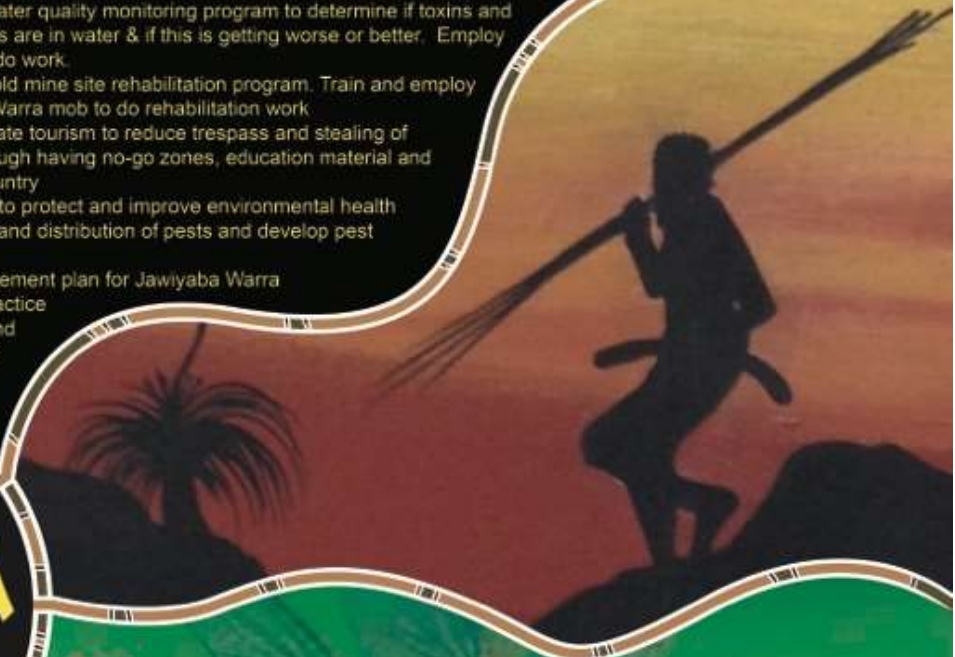
JAWIYABA WARRA

NATURAL RESOURCE MANAGEMENT

The land, animals and plants are intrinsically linked to our life and health by tangible and intangible connections. It is our custodial responsibility to care for this and ensure it stays healthy for our children so that they have wellbeing and lead a fulfilled life.

We would like to:

- Establish water quality monitoring program to determine if toxins and heavy metals are in water & if this is getting worse or better. Employ our mob to do work.
- Establish old mine site rehabilitation program. Train and employ Jawiyabba Warra mob to do rehabilitation work
- Better regulate tourism to reduce trespass and stealing of artefacts – though having no-go zones, education material and presence on country
- Apply for grants to protect and improve environmental health
- Identify presence and distribution of pests and develop pest management plan
- Develop fire management plan for Jawiyaba Warra
- Encourage best practice grading and road and track maintenance



CULTURAL AND ENVIRONMENTAL ASSETS

CULTURAL

- Sacred sites for initiation, birthing and ceremony
- Language & art in telling story and land connection
- Song, dance & ceremony
- Custodial rights and the ongoing practice of our culture

Threats:

- Unregulated tourism removing artefacts and defacing sites
- Misuse of language, song and dance

ENVIRONMENTAL

- Rivers & waterholes
- Relatively healthy areas and areas undeveloped

THREATS:

- Climate change, natural disaster
- Need intense healing in areas of old mine sites & toxic waters
- Much mineral & pretty stone which there is constant mining & fossicking

PLANTS & ANIMALS

- Rare & vulnerable species
- All animal & plant is part of cultural custodianship duty of Jawiyaba Warra

THREATS:

- Pests

RESEARCH AND MONITORING

We want to work with researchers but also skill our own mob to participate in and do research so that we know best what is happening on country as we have most responsibility to care for this.

We would like to:

- Survey wildlife populations to determine presence and distribution
- Establish environmental monitoring program to benchmark and monitor changes
- Identify risks associated with more severe weather events or climate change
- Document the history of our ancestors from an aboriginal perspective

ECONOMIC AND SOCIAL DEVELOPMENT

It is important that in today's world we are realistic about ensuring our young people have income and where this can be derived while also being on country is a high priority for us.

We would like to:

- Establish partnerships to encourage research on our country and employ our mob to work with them on projects
- Develop our homelands on country

Australian Government

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Northern gulf Resource Management Group

JAWIYABA WARRA

JAWIYABA WARRA PEOPLE AND COUNTRY

Jawiyaba Warra is a non profit organisation that looks after the welfare of Kawanji clan estate in cultural heritage, preservation of sites of significance, artifacts, promotion of traditional languages and story lines through song, dance, storytelling and cultural competence. We are the custodians of the Kawanji clan estate & connected to the land, the rivers, the animals and the plants of this area. Our connection is a strong feeling and sense of belonging - our life belongs with and is entwined with the life of our ancestral land. Our ancestors cared for and fought hard for this place and we owe it to them and to our future generations to follow our culture and continue to care for our clan estate. We protect and manage the areas of Two Brother Mountain and the south Palmer region, liaison with pastoral and mining lease holders and other interest stakeholder to seek to protect the interest and cultural heritage of the members.

OUR JOURNEY

Our families were forced by circumstances to live in exile of the place bestowed to our family by the divine grand creator in the heavens. Nevertheless our father Don Brady and his brother, our uncle father Bapu Wau Norman Mitchell, ensured that our spiritual beliefs and culture, our love of 'home', and our long term responsibilities for homelands are firmly engrained through our life and beliefs. We were taught justice and integrity, the tangible and the intangible country and spirit understandings, language, dance and art. We promised to go home and heal our land and to restore our children's rights and responsibilities for the Kawanji clan estate. We need to work together always, and teach our children on country, to meet and beat the challenges that face us and honor the story of our people. One of our strongest family values is to involve our young people and our children in talking, planning and working for country and future goals. In this way we share and grow our skills and ensure our culture and family values will live on – just as our great grandfathers wanted for us when they resolve from the fight of that time and their presence on country. At that moment they sacrificed their lives for us, they did this for the sake of saving our bloodline and the chance for future battle for land.

MISSION FOR COUNTRY

We need to maintain our generational link to country and ensure we have a presence on and with country to heal degraded areas, monitor environmental and cultural health, manage and improve environment health, apply jilla (law) and put people back in country for understanding.

OUR COUNTRY VALUES

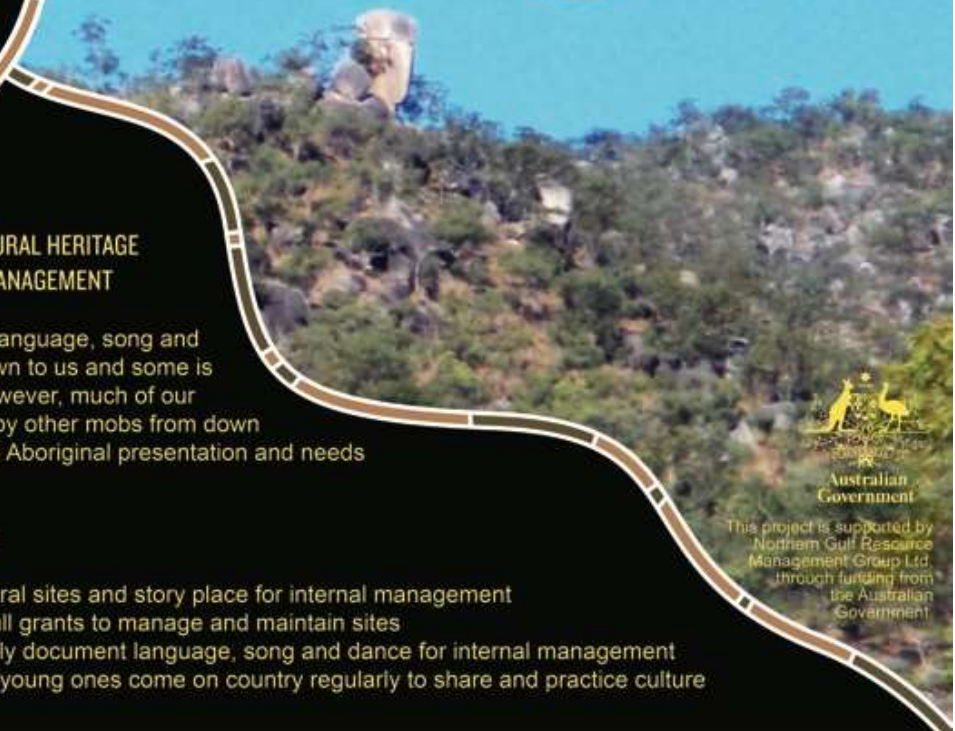
- We must have respect for where we are walking.
- We must have knowledge to 'see and know' country. This knowledge sinks in better when we are learning on country. The teaching should be on country.
- Jawiyaba Wara making decisions for country, by being properly consulted by all levels of bureaucracy.
- Young people are involved – they have to carry it on.
- We work with other people who visit or access our country to make sure they understand and respect our culture and land and do not abuse or poison country or jilla (law).

CULTURAL HERITAGE MANAGEMENT

Much of our language, song and dance are known to us and some is documented. However, much of our culture is misused by other mobs from down south in tourism and Aboriginal presentation and needs to be resolved.

We would like to:

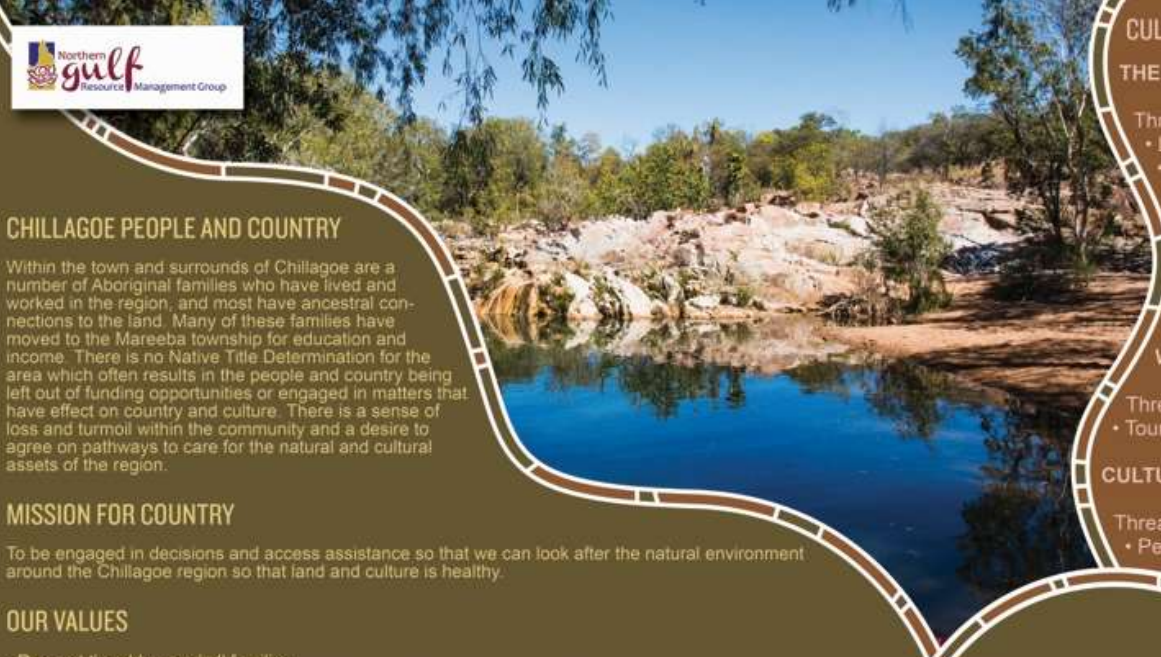
- Map all cultural sites and story place for internal management
- Access small grants to manage and maintain sites
- Appropriately document language, song and dance for internal management
- Ensure our young ones come on country regularly to share and practice culture



Australian Government

This project is supported by Northern Gulf Resource Management Group Ltd. through funding from the Australian Government

WOKOMIN/ CHILLAGOE



CHILLAGOE PEOPLE AND COUNTRY

Within the town and surrounds of Chillagoe are a number of Aboriginal families who have lived and worked in the region, and most have ancestral connections to the land. Many of these families have moved to the Mareeba township for education and income. There is no Native Title Determination for the area which often results in the people and country being left out of funding opportunities or engaged in matters that have effect on country and culture. There is a sense of loss and turmoil within the community and a desire to agree on pathways to care for the natural and cultural assets of the region.

MISSION FOR COUNTRY

To be engaged in decisions and access assistance so that we can look after the natural environment around the Chillagoe region so that land and culture is healthy.

OUR VALUES

- Respect the elders and all families
- Country and people are entwined – if we have sick country, we have sick people
- Looking after country is a responsibility we have to our people gone and our children to come

CULTURAL AND ENVIRONMENTAL ASSETS

THERE ARE MANY CULTURAL SITES IN THE DISTRICT FOR STORY, DANCE, CEREMONY AND ART

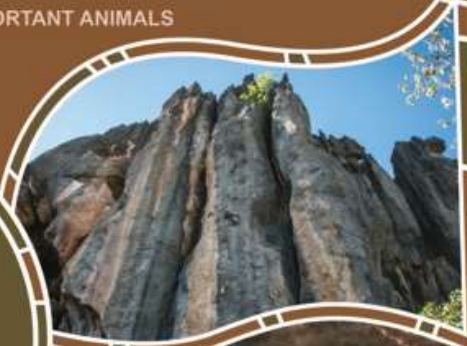
Threats:
- Loss of knowledge – sites not recorded and managed
- No Native Title Determination – not formally involved in a lot of land management decisions that could impact cultural sites
- Unregulated tourism
- National Parks – we don't have control or use of country assets to look after or practice our culture
- Dams – we are downstream of many developments and rarely asked about the impacts to our country and culture.

WATER SPRINGS, CAVES AND LIMESTONE BLUFFS

Threats:
- Tourism and mining

CULTURALLY IMPORTANT ANIMALS

Threats:
- Pests



CULTURAL HERITAGE MANAGEMENT

We would like to:
- Progress a Native Title Determination and form a Prescribed Body Corporate and good engagement of people of this country
- Map all cultural sites and story places
- Get better recognition of birth and burial areas
- Access small grants to manage and maintain sites

NATURAL RESOURCE MANAGEMENT

We would like to:
- Gain better access onto National Parks, ILC and leasehold lands
- Have Aboriginal Rangers working in National Parks and with leases (pastoral and mining) to look after country
- Better regulate tourism to reduce impacts
- Apply for grants to protect and improve environmental health

ECONOMIC AND SOCIAL DEVELOPMENT

We would like to:
- Establish an interim decision making process for the Aboriginal people of the area to ensure we can be engaged in decisions about the country
- Progress a Native Title Determination
- Have rangers working within National Parks that can manage the camping for a fee
- Mungana mine and others are likely to develop in the region. We want to see 'proper' jobs for 'local' Aboriginal people.

Australian Government

This project is supported by Northern Gulf Resource Management Group Ltd through funding from the Australian Government.

1.5 Engagement Outcomes

Over the course of the 2015 dry season (May-August) NGRMG conducted the following Grazing lands engagement program:

9 May	Chillagoe Rodeo
12 June	Community Resilience Fair- Georgetown
20 & 21 June	Croydon Poddy Dodgers
27 June	Mt Surprise Super Social Saturday
5 July	Georgetown Rodeo
28-29 July	Grazing Lands Dilemma's workshop, Georgetown
8 August	Mt Carbine bronco & bull ride
19 & 20 August	Deputations to Etheridge and Croydon Shire Councils.

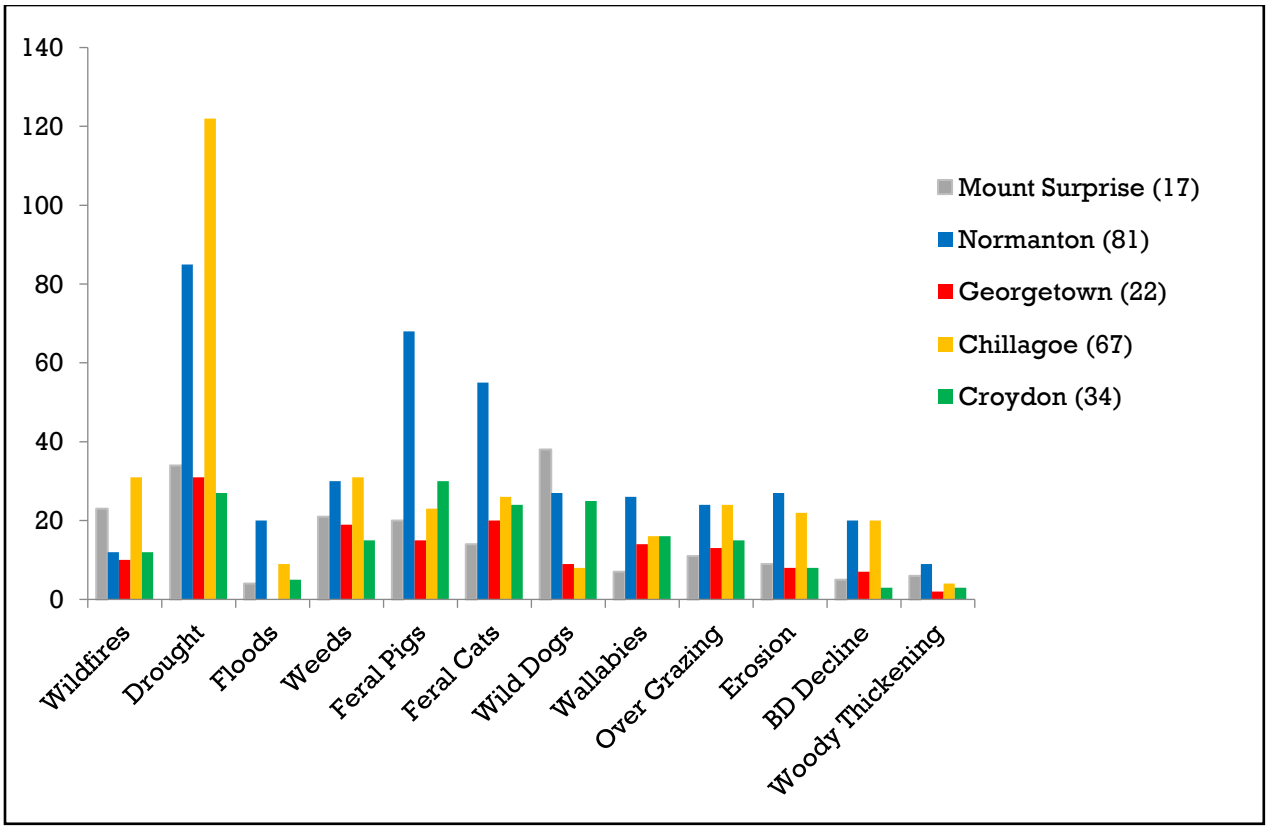
The engagement program targeted community events in key regional centres of the Grazing lands, to gain an even spread over the region which covers over 194,000 square kilometres. Each community was represented by a different coloured dot, so we were able to see a variation of concerns across the region. While conducting these dot surveys at regional events, we also video interviewed people about "what they love about this place", and from this exercise we were able to collect the key words that described aspects of the region which the community values.

Our main stakeholder engagement event was held in Georgetown on 28 July 2015, where NRM dilemmas were explored in more depth, and provided directional input which will shape the NRM Plan content.

The results of the Grazing Lands sticker dot survey are depicted in the following pages.

Sticker dot survey results

1.5.1 Environment priorities



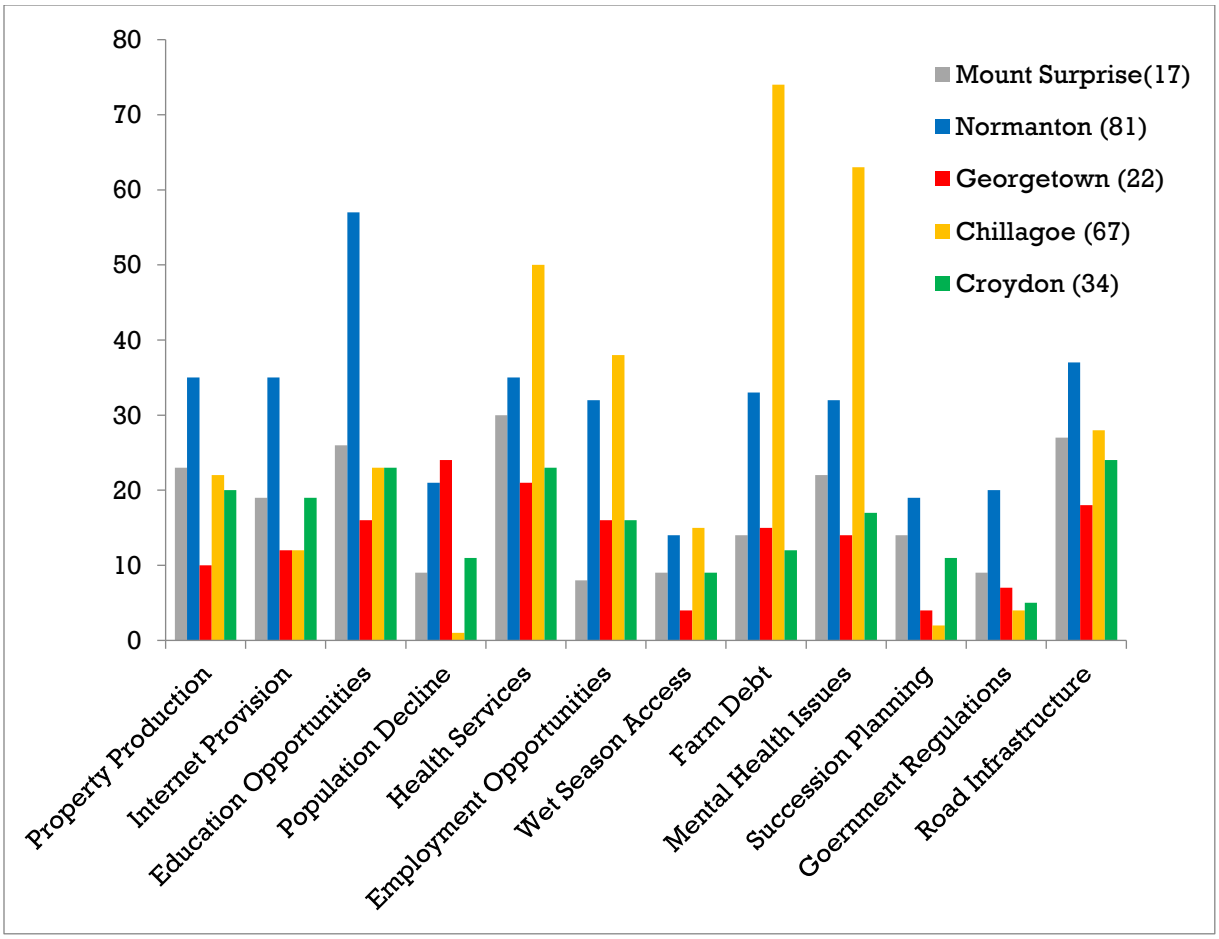
The results of the environment dot survey reveal that drought is the highest concern of Gulf communities in the Grazing lands, which is unsurprising as the region is currently in its third year of drought. This is however alarming, when one considers that meteorologists are predicting a further five years of drought, and drought-like conditions will be more common in even more long term climate change projections. This exercise indicates how much the Grazing land communities are already feeling the impacts of drought. Other high ranking issues for the grazing land communities include feral pigs and cats, whereas wildfire and over grazing rank consistently, but lower than expected.

1.5.2 Community priorities

The two highest community issues were farm debt and mental health, which in many instances are inter-related issues. The strains of financial hardships are clearly evident in the results of this survey, and the toll this is taking on the Grazing land communities.

Other high ranking issues include lack of education opportunities and health services. NRM is ill equipped to deal with the latter, but may be able to promote a greater range of education initiatives in the Northern Gulf region.

Internet provision, road infrastructure and property production are also considered to be key issues for the region.


80
70
60
50
40
30
20
10
0
Mount Surprise(17)
Normanton (81)
Georgetown (22)
Chillagoe (67)
Croydon (34)
Property Production
Internet Provision
Education Opportunities
Population Decline
Health Services
Employment Opportunities
Wet Season Access
Farm Debt
Mental Health Issues
Succession Planning
Goernment Regulations
Road Infrastructure

1.5.2 GRAZING LANDS NRM DILEMMAS WORKSHOP

Participants of the Grazing Lands dilemmas worshop, Georgetown July 2015

On the 28 July 2015, 26 stakeholders in the Grazing lands of Northern Gulf convened at the Georgetown Shire Hall to discuss the key dilemmas and priorities facing the Grazing lands of the Northern Gulf.

The key dilemmas which arose include (in order of rating, top to bottom):

1. How can you be green if you're in the red?
2. How do we promote good pasture management while managing the risk of wildfire?
3. How do we integrate science and research into the Grazing lands?
4. How do we broker payments for public good (alternative income and mechanisms)?
5. How do we drought-proof grazing enterprises for the future?

Workshop discussions at the Grazing lands dilemmas workshop, Georgetown July 2015

Key messages

1. How can you be green if you're in the red?

This group focused on strategies to reverse the trend towards spiraling debt currently being experienced by many graziers, whilst being very careful not to sell false hope to a community under financial duress.

Some possible strategies include combining loans among grazing enterprises for greater purchasing power and better conditions, investing financial profits and off property income into superannuation funds.

Other strategies included approaching Coles and Woolworths about the branding of sustainable grazing (selling the romantic image of outback Australia to city counterparts) and developing case studies (which could be real or hypothetical-but-realistic) about how a grazing business reversed their financial situation from debt to profitability, and the steps they took to achieve this, communicated through a storyline.

2. How do we promote good pasture management while managing the risk of wildfire?

A key message from this group is the need to re-define fire as a management tool. The relationships between fire management and wildfires and different management methods (including ground cover, wet season spelling and rotational grazing) need to be understood.

Fire as a management tool was removed from the landscape over the last two decades in the Gulf, which may have had an influence on the 2012 wildfires across Etheridge Shire.

Once again, infrastructure mapping was listed as an important tool for managing fire, which further highlights the importance of continuing this service to graziers.

NGRMG's role in identifying regulatory hurdles to good fire management was also discussed, as well as the need to influence research priorities into improved species composition in different fire regimes, and the nutritional implications of this on cattle. Finally, the need for grassroots engagement in promoting better fire management was raised.



3. How do we integrate science and research into the Grazing lands?

The discussion focused on the "once in a lifetime" advances, or game-changers for the grazing industry, which were achieved through science, research and innovation (tick-resistant breeds, nutrient supplements). Through aligning science and research with our on-ground works, NRM could be the champion of future innovations.

The main limitation to science and research is the cost. To overcome this, NGRMG needs greater linkages with research and science communities, to increase our influence over research priorities.

Opportunities include forming regional panels to identify NRM research priorities.

Some existing priorities include rainfall monitoring and overland flows (also mentioned in the drought proofing session), ongoing biodiversity monitoring, river bank analysis, soil tracking as an erosion indicator, benchmarking regional resource condition, and refining citizen science.

4. How do we broker payments for public good (alternative income and mechanisms)?

This table discussion involved a number of opportunities for economic diversification, including:

1. Regional branding;
2. Ecosystem services payments;
3. Carbon trading;
4. Eco-tourism.

The need to gain more control on price received by the grazing industry was discussed, with efforts to brand our regional produce seen as an opportunity. Future alignment with regional food networks and initiatives such as Taste Paradise and Regen Ag are seen as part of this solution.

Natural heritage tourism can be expanded but remains limited in how much it can contribute. Current enterprises generally do not generate enough profit through tourism to cover the costs required to maintain a property.

NGRMG is encouraged to explore the mechanisms available for biodiversity payments, which have the potential to support more Indigenous ranger programs and existing nature refuges. There is a need to educate the wider community (including in the cities) that these sorts of stewardship schemes are something worth investing in.

Although carbon trading is unstable, NGRMG could support regional opportunities in this field through supporting carbon farming and savannah burning trials, and then communicating the benefits and pitfalls to the wider region.

A combination of these initiatives and new enterprises does have the potential to contribute to a more diversified, skilled, stable and sustainable region.

5. How do we drought-proof grazing enterprises for the future?

A high rating concern in both the sticker dot survey and the Grazing Lands NRM Dilemmas workshop, was drought resilience. This is clearly a "front of mind" issue for the remote communities of the grazing lands. Combined with the equally clear message from climate change projections that the region should expect more drought conditions in the future, over longer periods, this is an issue which should be the primary concern and priority of the Regional NRM Plan for the Grazing lands.

The consequences of increased and longer drought periods are serious and manifold. The environmental consequences include depleted seed banks, decreased biodiversity and pasture production, genetic losses and declining welfare of stock, and stress on wildlife populations and ecological communities.

The social and economic consequences are dire, with the financial viability of many enterprises in jeopardy if more drought years occur. The implications of this climate induced downturn are mental health issues becoming more prevalent, reduction in quality of life and social wellbeing, and family stress.

There are many strategies to address this, and many of them involve the continuation and expansion of NGRMG's strong foundation of NRM delivery and grazing extension in the Grazing lands, involved in the Tropical Savanna Grazing program. Given the stress that the grazing industry is currently under as well as the climate projections, it is important that this work continues. Property mapping plays an important role in water planning, and overland flow could be included to identify opportunities for water harvesting in the landscape. Up-skilling graziers on managing grazing pressures, sustainable stocking rates and maintaining ground cover remains important priorities in drought-proofing the region. NGRMG can also support or advocate broader scale reform on government and industry policies, including lobbying for concessional loans and freight and water infrastructure subsidies, and collaboration with banks on rural finance. Opportunities for irrigated pasture can also provide drought relief and NGRMG should explore if this would be sustainably viable.

1.5.3 Gilbert Catchment River Catchment landholder survey

A study was conducted by researchers at James Cook University in partnership with Northern Gulf Resource Management Group, which included a survey of environmental management issues and activities in the Gilbert River catchment. 48 land managers from 28 cattle stations were interviewed on a range of topics including their property and production system, the costs of managing a property and individual management activities, as well as their opinions about various land management problems.

Key information relating to this survey included:

- All stations were family-run businesses and ranged between 6,000 and 475,000 ha.
- On average, respondents had managed their property for over 20 years;
- Land tenure was mostly grazing lease;
- 70% identified that their land had important natural values;
- Income was mostly derived from cattle but some had tourism, agriculture, conservation or mining derived income from their land also;
- 60% considered that their land had potential for improved pasture or irrigated agriculture.

The top environmental issues which were identified included overgrazing, wild dogs, rubber vine, grader grass, neem tree, woodland thickening and wildfire management. Written plans to address these issues had only been developed by around 10% of landholders.

Over 70% of landholders reported that they had experienced the impacts of wild fire, with 35% stating that these impacts were high to extreme. The majority of respondents reported changes in the frequency of fire in the past five years, while 35% of respondents reported a reduction in the use of prescribed burning over the same period.

100% of landholders reported issues with scalding and gully erosion, but only 15% reported that gullies were advancing and 15% reported good success in slowing down or reversing gullies through adjusting grazing systems and active reforestation.

This study indicates that mitigating some of these threats can achieve both environmental and production benefits.

Source: Alvarez Romero, 2015

1.5.4 Community survey - Grazing Lands

NGRMG conducted an online and phone survey of the Northern Gulf community. 141 people in the region completed this survey. The results have been separated into Gulf Coasts, Grazing lands and Tablelands for the purposes of the NRM Plan. There were 52 responses from the Grazing lands.

Over 70% of respondents said they had been affected by drought, with less than 10% affected by wildfires or cyclones and approximately 18% having been affected by flooding.

The majority of respondents said better water infrastructure and supply, better weed management and clearing of fence lines were required to be more prepared for natural disasters.

A total of 48% of respondents felt they received adequate support in natural disaster - and 52% said did not (the results were the same as a general question and for whether they received adequate support from NGRMG). Further services that were identified as needs in post disaster situation were funding assistance and an information and communication role.

The most common effects of natural disaster top responses were loss of stock, loss of income, land degradation, followed by damaged infrastructure and increased debt.

The top most supported programs involved education events and programs delivered to school children, and to determine the dollar worth of healthy ecosystems and attracting external funding to help keep the landscapes of the Northern Gulf healthy.

1.6 Community Resilience to Climate Change

Climate change poses many new stresses to the Northern beef industry, despite some potential benefits. Since 1900, rainfall has increased by 10mm per decade in North-west Queensland (Moise et al. 2015). A further 20% increase in rainfall has been modelled as increasing pasture growth by 9% and safe stocking rates by 11% (Whish et al. 2014). However, neither an increase nor decrease in rainfall are predicted with confidence in recent projections (Moise 2015). Rather, large variations in rainfall from year to year will continue, accompanied by increases in temperature and evaporation. These changes are expected to increase the frequency of heatwave conditions and reduce surface water availability, especially in the late dry season (Cobon et al. 2009). While not expected to increase fire frequency, dry hot conditions will mean that fires that do occur are expected to be more severe and spread faster than fires do now (Moise 2015). This would both reduce forage availability and create challenges for pastoralists diversifying into carbon abatement projects.

On top of a demanding lifestyle, high debt levels, complex operating conditions and the need to improve herd dynamics, climate change is a challenge most pastoralists could do without. Its impacts are almost all expected to be negative and to affect:

- Surface water availability
- Soil stability
- Ground cover
- Soil carbon
- Cattle ticks
- Weed spread and water use
- Woody thickening
- Forage production
- Forage quality
- Cost and availability of grain for feed
- Animal heat stress and water requirements
- Animal liveweight gain
- Animal reproductive rates
- Animal mortality
- Animal production
- On-property infrastructure
- Enterprise profitability
- Pastoralists' health and wellbeing
- Water storage and distribution
- Road transport
- Rail transport
- Ports
- Power generation
- Communications
- Buildings, including those of meatworks and port facilities

Resilience to climate change will be built by undertaking the practice improvements identified to improve pastoral productivity and land condition. Of particular importance is the ability to adjust stocking rates in relation to seasonal conditions. At the industry level, decision support, including improved access to climatic information, is required to assist pastoralists make the best decisions for their circumstances.

The Grazing lands region has some very vulnerable populations, particularly with both high Indigenous and economically disadvantaged populations, including the debt laden grazing sector.

The primary industry sector has been and is providing stability to the regional economy however this sector's resource base is vulnerable to climate change and is impacted upon immensely by severe weather which over past years has been slower to recover and has resulted in an increase in farm debt.

It is expected that there will be a higher unemployment rate and some degree of redeployment of workforce in response to climate change because of changes to precipitation and seasonal employment opportunities (Dale 2014; Dale et al. 2014).

THE LIST BELOW DESCRIBES SOME OF THE FLOW-ON-IMPACTS OF DROUGHT ON PASTORAL FAMILIES.

Financial issues
Financial difficulties, possibly leading to poverty and/or bankruptcy
Postponing capital expenditure, sometimes with consequences for farm safety
Drawing down superannuation
Succession issues
Delayed retirement
Inability to keep farm in the family
Employment issues
Increased dependence on off-farm income and employment, which may be difficult to attain
Women and children taking on additional on-farm work
Social issues
Increased stress and other negative health impacts from financial pressures and seeing stock suffer
Forced separation, as one partner moves to take up employment elsewhere
Intergenerational or marital conflict
Social isolation, especially where animals need daily feeding and watering
Difficulty in affording education for children

Source: (Paton 2014)

A recent study used a computer model to examine scenarios of various supply and demand shifts as well as impacts of climate change on the development of irrigated agriculture in remote north-west Queensland. No clear welfare gains were predicted from irrigation development (Wittwer et al. 2014). Water availability is seasonal through potential for targeted water development schemes under the north Queensland Irrigation Strategy. Harvested water is in limited supply during the dry season due to high evaporation rates (Taylor et al. 2011).

Energy security is vulnerable. The regional economy is highly dependent on fossil fuels which are not produced locally and transported to the region through poorly maintained and flood prone roads. Diesel costs increases could provide

system shocks. Policy uncertainty in regard to the national Renewable Energy Target and energy distribution ownership has created underutilisation of abundant sustainable energy resources. Food security is vulnerable and the region is a net importer. More extreme weather events with flooding will make Gulf communities more vulnerable based on current limited transportation (Dale, 2014).

Anecdotal evidence exists of rural communities knowing what to do in the case of extreme events (due to high contact with variability in climate and weather). However, very strong disaster preparedness and response mechanisms in place still require improved information flows (e.g. radar/flood monitoring). Identified barriers to improving resilience included:

- The transient nature of emergency personnel;
- The centralisation of services leading to further marginalisation of remote locations;
- Inconsistencies in emergency management procedures in urban compared with remote communities;
- Limited funding from governments for disaster preparedness and mitigation works; and
- Limited access to remote locations and lack of capability for evacuation from these areas in an emergency (Bird et al, 2013).

1.6.1 Adaptation

While the extent of the projected impacts of climate change on the northern pastoral industry could be seen as dispiriting, options have been identified for providing resilience to weather these impacts. Most of the enterprise-level options (Table) are consistent with current best practice and are already incorporated into extension programs. Industry resilience will therefore benefit from continued support for extension programs and best practice frameworks.

TABLE 2. ENTERPRISE-LEVEL OPTIONS TO FACILITATE CLIMATE CHANGE ADAPTATION

SOURCE: HOWDEN 2008

Options
Pasture productivity and grazing pressure
Select sown pastures and forage crops adapted to higher temperatures and water constraints
Revise fertiliser management through sown legumes and phosphate fertilisation where appropriate
Provide urea and phosphates directly to stock via reticulation and use effective supplementary feeding strategies
Increase use of strategic spelling
Use fire to control woody weeds
Use responsive stocking rate and rotation strategies based on seasonal climate forecasting, alter crop/livestock mix
Develop regional safe carrying capacities i.e. constant conservative stocking rate
Where appropriate, develop software to assist pro-active decision making at the on-farm scale
Improve water management, particularly for pasture irrigation
Pests, disease and weeds
Increase use of biological and other controls (cautiously)
Increase use of insect traps for sentinel monitoring and for population control
Adopt alternative chemical and mechanical methods for reducing woody weeds
Use pest predictive tools and indicators
Use quantitative modelling of individual pests to identify most appropriate time to introduce controls
Animal husbandry and health
Select animal lines that are resistant to higher temperatures but maintain production
Modify timing of mating based on seasonal conditions
Modify timing of supplementation and weaning
Construct shading and spraying facilities to reduce heat stress
Increase use of trees to provide shade and reduce wind erosion

Similarly, peak bodies and government agencies are already progressing industry-wide and policy-level options (see Table 3). These efforts have been facilitated by cross-regional collaboration through the Northern Australia Beef Industry Working Group, and will benefit from and from other collaborative initiatives, such as growNORTH and implementing the recommendation of the Joint Select Committee into the Development of Northern Australia. Moreover, there is need for rebuilding a cross-regional strategic approach to industry development that was provided by the Northern Australia Beef Industry Working Group, no mention of which is made in either the *Developing Northern Australian* or the *Agricultural Competitiveness* White Papers (Howden et al. 2008).

TABLE 3. INDUSTRY AND POLICY-LEVEL OPTIONS TO FACILITATE CLIMATE CHANGE ADAPTATION

POLICY
'MAINSTREAM' CLIMATE CHANGE INTO EXISTING GOVERNMENT POLICIES AND INITIATIVES (E.G. ON DROUGHT, GREENHOUSE SINKS, NATURAL RESOURCE MANAGEMENT, WATER RESOURCE ALLOCATION, RURAL DEVELOPMENT) AND INTO INTEGRATED CATCHMENT MANAGEMENT
MANAGING TRANSITIONS
POLICIES AND MECHANISMS TO PROVIDE TECHNICAL AND FINANCIAL SUPPORT DURING TRANSITIONS TO NEW SYSTEMS THAT ARE MORE ADAPTED TO THE EMERGING CLIMATE
COMMUNICATION
ENSURE COMMUNICATION OF BROADER CLIMATE CHANGE INFORMATION AS WELL AS INDUSTRY-SPECIFIC AND REGION-SPECIFIC INFORMATION AS IT BECOMES AVAILABLE
CLIMATE DATA AND MONITORING
MAINTENANCE OF EFFECTIVE CLIMATE DATA COLLECTION, DISTRIBUTION AND PROJECTION SYSTEMS WITH MONITORING AND ANALYSIS SYSTEMS ADDRESSING LIVESTOCK SECTOR-SPECIFIC IMPACTS TO SUPPORT/FACILITATE ADAPTIVE MANAGEMENT
RESEARCH AND DEVELOPMENT AND TRAINING
UNDERTAKE FURTHER ADAPTATION STUDIES THAT INCLUDE BROAD-BASED COSTS AND BENEFITS TO INFORM POLICY DECISIONS. MAINTAIN THE RESEARCH AND DEVELOPMENT BASE (PEOPLE, SKILLS, INSTITUTIONS) TO ENABLE ONGOING EVALUATION OF CLIMATE/CO2/INDUSTRY/MANAGEMENT RELATIONSHIPS, AND TO STREAMLINE RAPID RESEARCH AND DEVELOPMENT RESPONSES. THIS RESEARCH AND DEVELOPMENT NEEDS TO BE DEVELOPED IN A PARTICIPATORY WAY SO THAT IT CAN CONTRIBUTE TO TRAINING TO IMPROVE SELF-RELIANCE IN THE AGRICULTURAL SECTOR AND TO PROVIDE THE KNOWLEDGE BASE FOR FARM-SCALE ADAPTATION
BREEDING AND SELECTION
MAINTAIN PUBLIC SECTOR SUPPORT FOR AGRICULTURAL BIOTECHNOLOGY AND CONVENTIONAL BREEDING WITH ACCESS TO GLOBAL GENE POOLS SO AS TO HAVE SUITABLE OPTIONS FOR HIGHER TEMPERATURE REGIMES AND CHANGED MOISTURE AVAILABILITY AND POSSIBLE MORE CLIMATE VARIABILITY
MODEL DEVELOPMENT AND APPLICATION
DEVELOP LIVESTOCK SYSTEMS MODELS THAT CAN TRANSLATE CLIMATE/CO2 INFORMATION TO ECONOMIC OUTPUTS, TO IMPLICATIONS FOR ENTERPRISES, LIVELIHOODS, INDUSTRIES AND REGIONS FOR USE IN DECISIONS FROM ENTERPRISE TO POLICY SCALE
IMPROVE PEST PREDICTIVE TOOLS AND INDICATORS
IMPROVE QUANTITATIVE MODELLING OF INDIVIDUAL PESTS TO IDENTIFY MOST APPROPRIATE TIME TO INTRODUCE CONTROLS
SEASONAL FORECASTING
FACILITATE THE ADOPTION OF SEASONAL CLIMATE FORECASTS (E.G. THOSE BASED ON EL NIÑO AND LA NIÑA, SEA-SURFACE TEMPERATURES, ETC.) TO HELP FARMERS, INDUSTRY AND POLICY INCREMENTALLY ADAPT TO CLIMATE CHANGE WHILST

MANAGING FOR CLIMATE VARIABILITY. MAXIMISE THE USEFULNESS OF FORECASTS BY COMBINING THEM WITH ON-GROUND MEASUREMENTS (I.E. SOIL MOISTURE, STANDING FORAGE), MARKET INFORMATION AND SYSTEMS MODELLING
PESTS, DISEASES AND WEEDS
MAINTAIN OR IMPROVE QUARANTINE CAPABILITIES, SENTINEL MONITORING PROGRAMS AND COMMITMENT TO IDENTIFICATION AND MANAGEMENT OF PESTS, DISEASES AND WEED THREATS. IMPROVE THE EFFECTIVENESS OF PEST, DISEASE AND WEED MANAGEMENT PRACTICES THROUGH PREDICTIVE TOOLS SUCH AS QUANTITATIVE MODELS, INTEGRATED PEST MANAGEMENT, AREA-WIDE PEST MANAGEMENT, ROUTINE RECORD KEEPING OF CLIMATE AND PEST/DISEASE/WEED THREAT, AND THROUGH DEVELOPMENT OF RESISTANT BLOODLINES AND IMPROVED MANAGEMENT PRACTICES
WATER
INCREASE WATER USE EFFICIENCY BY: (I) A COMBINATION OF POLICY SETTINGS THAT ENCOURAGE DEVELOPMENT OF EFFECTIVE WATER-TRADING SYSTEMS THAT ALLOW FOR CLIMATE VARIABILITY AND CLIMATE CHANGE AND THAT SUPPORT DEVELOPMENT OF RELATED INFORMATION NETWORKS, (II) IMPROVE WATER DISTRIBUTION SYSTEMS TO REDUCE LEAKAGE AND EVAPORATION, (III) DEVELOPING FARMER EXPERTISE IN WATER MANAGEMENT TOOLS AND ENHANCING ADOPTION OF APPROPRIATE WATER-SAVING TECHNOLOGIES LAND USE CHANGE AND DIVERSIFICATION: UNDERTAKE RISK ASSESSMENTS TO EVALUATE NEEDS AND OPPORTUNITIES FOR CHANGING SPECIES, MANAGEMENT OR LAND USE/LOCATION IN RESPONSE TO CLIMATE TRENDS OR CLIMATE PROJECTIONS. SUPPORT ASSESSMENTS OF THE BENEFITS (AND COSTS) OF DIVERSIFYING FARM ENTERPRISES
NATURAL RESOURCE BASE
DETERMINE THE IMPACT OF CLIMATE CHANGE (INTERACTING WITH LAND MANAGEMENT) ON NATURAL RESOURCE DEGRADATION ISSUES SUCH AS EROSION AND SALINISATION RISKS AND INFORM POLICYMAKERS

Producers have mixed opinions about climate change, but none dispute the impact of ongoing climate extremes. However, one group of farmers concerned about climate change and has written an open letter to politicians asking them for action.

1.6.2 Climate and seasonal conditions

Beef production is highly dependent on seasonal conditions, with droughts leading to loss of forage and destocking to avoid cattle death, and years of good rainfall allowing herd rebuilding. Increases in rainfall can assist pasture recovery, improving land condition and increasing potential carrying capacity and stocking rates (McKeon et al. 2009; Novelly et al. 2011; Payne et al. 2004). However, extended periods of elevated rainfall can lead to unrealistic expectations of long-term carrying capacity (Pickup 1998). Extended or severe periods of drought that have affected the size of the northern herd occurred in 1965-6, through much of the 1980s and the early 2000s (Figure). Following exceptionally good years in 2011-12, properties in large parts of the Northern Gulf began to destock in response to the drought covering in 2013 (Mifsud 2013). Cattle and calf slaughter in Queensland rose 7% in 2012-13 and a further 12 per cent 2013-14. With sales at near-record highs (McRae 2014), cattle prices fell, but the volume sold meant business incomes were only marginally reduced (Martin 2013). Prices recovered as the number of stock for sale fell again, with increasing competition between the various market sectors (Thomas 2015a). Capacity to adjust stock numbers in response to seasonal conditions is important for maintaining pasture condition, but also places financial stress on beef enterprises when the whole country is trying to restock at the same time.

2. Drivers and Barriers

2.1 Regional Drivers

2.1.1 The Northern Gulf cattle industry

Cattle production is Northern Gulf's most important agricultural industry, with over 90% of the region currently used for cattle grazing. The Northern Gulf region has a land area of approximately 194,000 km2, which currently support an estimated 933,000 cattle over 160 pastoral properties (based on data from Australian Bureau of Statistics and Australian Government Land and Coasts).

After spreading rapidly across the north of Australia in the late 19th century, the grazing industry's growth has been aided by low wages paid to Aboriginal stockmen until the late 1960s; progressive introduction of drought-hardy and tick-resistant Brahman stock (*Bos indicus*) from the 1940s; the shift away from sheep from the 1960s; eradication of brucellosis and tuberculosis in the 1980s (with replacement herds further increasing the proportion of Brahman stock); introduction of pasture species; supplementary feeding; hormone growth promotants; improvements in herd management; and infrastructure development (Ash et al. 1997). As a result, cattle numbers in Queensland have doubled since 1965 (Figure).

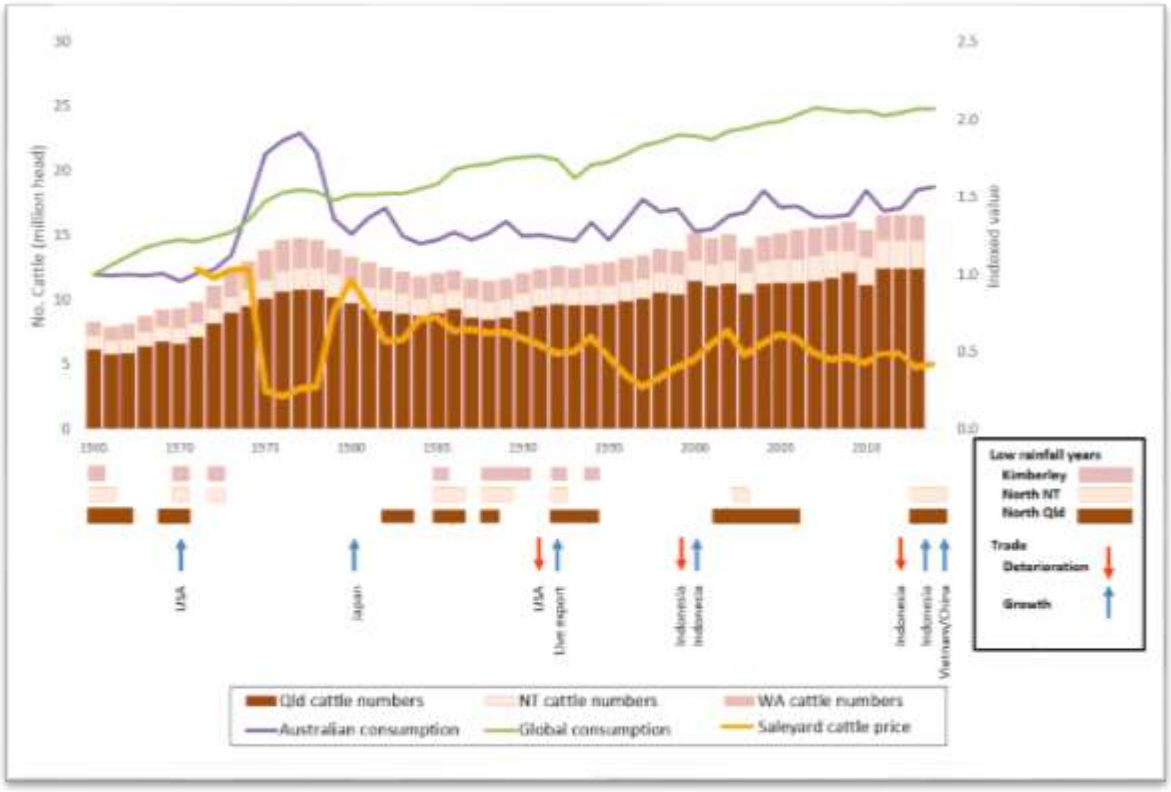


FIGURE 4. GROWTH OF THE NORTHERN CATTLE HERD

SOURCE: CATTLE NUMBERS, AUSTRALIAN BUREAU OF STATISTICS; BEEF CONSUMPTION, UNITED STATES DEPARTMENT OF AGRICULTURE; SALEYARD PRICES, AUSTRALIAN BUREAU OF AGRICULTURAL AND RESOURCE ECONOMICS; RAINFALL DATA, AUSTRALIA BUREAU OF METEOROLOGY

High export demand from Asia and drought destocking has seen the region's cattle numbers fall and prices rise through 2014-15. In the longer-term, continued growth in global demand, a reduced Australian dollar and high global prices, and improved incomes are forecast for Australian beef producers.

Recent growth in the Northern cattle herd has been achieved through intensification (spreading grazing pressure using water points and fencing) and development of under utilised properties. Indigenous pastoralism is growing rapidly, with developments in all parts of the sector from cattle breeding to slaughter.

However Northern Gulf cattle enterprises have been struggling because of increased input costs and stagnant cattle prices. Burgeoning debt has been exacerbated by spiralling land prices through the 1990s and 2000s, against which many landowners increased their mortgages to levels that were unsustainable once land prices fell. Compared to pastoralists in a good financial position, pastoralists in debt have less resilience to cope with drought, are less likely to adopt practice improvements needed for improving enterprise viability and environmental conditions; and are more likely to suffer adverse health effects.

Many enterprises, especially those with small herds, derive more income from off-farm work than they do from cattle operations. While large cattle enterprises allow economies of scale, increasing cattle herd size seems less important to profitability than does improving herd performance. Research and extension has therefore focused on the following areas of improvements that should reduce the input costs per kilogram of meat produced:

- Improving land condition;
- Improving diet through exotic pastures and supplementary feeding, especially at finishing;
- Improving reproductive performance by culling non-productive animals, vaccinating against reproductive diseases and improving diet quality;
- Increasing live weight gain through early weaning and improving diet quality; and
- Spreading grazing pressure by increasing fencing and water points.

These changes can be achieved through improved ground cover, especially of deep-rooted grasses, increases soil carbon and reduces soil loss (when cover is at least 50%) and gully formation (when at least 75%).

Diversification options being pursued include mosaic irrigation of pasture crops for finishing cattle on the property, grain and oil seed crops and ecosystem service delivery. Of the latter, only Savanna Burning is currently providing a regular income stream through carbon abatement combined with reducing the extent of wildfires, with considerable biodiversity benefits. Methodologies have also been approved for projects to sequester carbon in soil or vegetation, and reducing methane by feeding cattle nitrate supplements. Also, biodiversity offsets may provide income for on-property conservation, with a system for doing so well advance in Queensland.

However, as practices to improve performance are adopted and/or diversification options are pursued, careful management will be required to avoid potential adverse environmental impacts by

- Avoiding the use of “transformer” grasses (with high biomass and fuel loads), or at least ensuring they do not escape from improved pasture plantings;
- Protecting areas of high biodiversity values when increasing extent and/or intensity of grazing, in particular protecting biodiversity values on riparian corridors when planning irrigated cropping projects;
- Ensuring wet season supplementary feeding does not weaken native perennial grasses;
- Ensuring early dry season burning does not lead to vegetation thickening and biodiversity decline.

Industry viability is constrained by lack of infrastructure, including feedlots, saleyards and meatworks, inactive ports and poor quality roads, all of which combine to make freight expensive, pushing up input costs.

Climatic and seasonal conditions are also serious constraints, particularly in inland Queensland, where periods of drought of two or more years are not uncommon. Conversely, extended periods of above average rainfall may encourage pastoralists to stock land beyond its long-term carrying capacity, and develop unrealistic impressions of what consists as average conditions.

Water for cattle operations and irrigated crops may be at risk if extraction for these and other activities is not properly allocated. In particular, extraction for mining and irrigated agriculture has the potential to impose water constraints on pastoral operations.

Weeds, fire, pest animals, disease and cattle theft all impose financial burdens on northern pastoral operations. Production losses caused by weeds have been estimated at costing the industry around $1,000 million/year; pest animals: around $36 million/year; disease and parasites: around $390 million; and cattle theft between $1.5 and $2 million a year in Queensland alone. No estimates are available for either fire or other natural disasters. Conversely, pastoral manager perform important roles in control of weeds, fire, pest animals and diseases that would not be undertaken if no one was living on the lands they manage.

Legislation and regulation govern much of the activity on pastoral properties, most of which are pastoral leases and so coexist with Native Title. This type of land tenure allows pastoralists to undertake most activities that can be justified as core business to a pastoral operation, including grazing, fencing, clearing, burning, forage cropping and pastoral tourism. This also includes carbon farming exercises that contribute to pastoral production, such as improving soil carbon or reducing methane emissions, but not necessarily Savanna Burning, tree planting or promoting regrowth. Tree clearing is now permitted in Queensland as long as it is essential for pastoral operations.

The NRM implications of the current trajectory of the pastoral industry are mixed. Herd building will put more pressure on the natural environment. However, performance improvement has many benefits by reducing the number of hooves and mouths required to produce a kilogram of meat. If well managed, mosaic agriculture can contribute to herd performance while taking pressure off pastures and the natural environment during the wet season, but managed poorly could result in further degradation of alluvial environments and over stocking of adjacent areas.

Historically, the Northern Australian cattle industry has been subject to changes in domestic and global demand, which has affected both cattle prices and stock numbers. Since the 1960s, beef consumption and stock numbers have continually increased and sale yard prices have decreased in real terms, with some variations. Global demand for beef was stimulated by global economic growth in the early 1970s (Smith et al. 1979). Herd-building to take advantage of the high prices followed both in Australia and overseas. From the 1970s, stocking rates began to exceed carrying capacity. In the less resilient land systems, intensification of the northern grazing lands was accompanied by degradation (Ash et al. 1997; Mott et al. 1979; Winter 1990), with negative impacts on production, biodiversity and water quality.

A rising Australian dollar through the early 2000s combined with high domestic prices saw a drop in Australian beef exports (Martin et al. 2007). In 2010, aiming to have a self-sufficient beef industry, Indonesia imposed import quotas on Australian beef and a weight limit of 350 kg (Gleeson et al. 2012). In 2011, live exports to Indonesia were suspended over welfare concerns (ABARES 2011) and, when trade recommenced, Indonesia reduced import quotas. The Australian herd reached record numbers in 2013 (Thomas 2015c). Prices once again slumped (Keogh 2013). Overstocking led some producers to shoot cattle, rather than let them starve (Keogh 2013).

The Northern Gulf region rose from under 5% in 2000 up to 20% in 2005 reliance of the beef industry on the live export trade, however compared to other regions of Northern Australia in the Northern Territory and Kimberly which are over 50% reliance, this rate is relatively moderate(ABARES 2011, 2014c, 2014d).

By the end of 2014, following successful implementation of the Exporter Supply Chain Assurance Scheme, exports to Indonesia had almost returned to pre-2011 levels with 730,000 head exported to this market. New markets opened and exports reached record levels. This growth was only possible through investment in specialised infrastructure, such as holding yards at ports and specially fitted-out ships (Gleeson et al. 2012). Proximity and all-season access to these facilities determines which producers in the region benefit most from the live export trade, especially when demand weakens (Martin et al. 2007). Unfortunately many of the cattle that had originally been destined for the Indonesian market now exceeded 350 kg (Hydros Consulting 2011). Producers left with these “out-of-specification” cattle had difficulty selling stock because of a lack of market appeal and high cost of transport to alternative markets, leading to overstocking. Average incomes of northern beef producers suffered a 43% decline between 2011-2 and 2013-4,

36% of producers recording negative farm cash incomes and 12% of producers in a position where they are unable to service further debt (Thompson et al. 2014).

Based on continued growth in demand, a reduced Australian dollar and high global prices, improved incomes are forecast for Australian beef producers in the short-term (McRae 2014). At the start of 2015, drought and record exports have reduced the size of the cattle herd (Thomas 2015b). Many pastoral operations are restocking to take advantage of improving climatic conditions, driving prices higher, reducing the cattle available for slaughter and export (Thomas 2015), and forcing northern exporters to source cattle from southern states. Producers burdened with high levels of farm debt will have difficulty rebuilding their herd and producers left with out-of-specification stock may still have financial problems and overstocking issues, as highest demand is for small young cattle needed for live export, restocking or feedlots.

In the longer term, ABARES modelling projects Australian beef production will increase by a further 80% by 2050 (Linehan et al. 2012). Whether this is achieved will depend on the drivers of, and barriers to, beef production in the north. These include supply and demand dynamics worldwide, including trade relations; policies and programs of government, industry and financial institutions; the necessary infrastructure being in place; the capacity of the land and water resources to support greater stock production; and the pastoral industry's capacity to weather current and emerging stresses, including climate change, and adopt business models and management practices necessary to support intensification.

2.1.2 Cattle enterprises

The cattle industry in the Northern Gulf is based on extensive grazing of native pastures with low stocking rates, with introduced pasture species used on most properties, but with limited extent (Grice et al. 2013). Although the region supports a range of production systems, poor productivity means most enterprises breed animals for the low-value live export trade or for fattening and finishing elsewhere. Calving generally occurs at the end of the dry season and cattle are mostly sold at the start of the dry season, when weaner steers or store steers are turned off for the southern market, live export or finishing (DEEDI 2010). Most fattening occurs outside the region, on coastal pastures or in feedlots. Within the region, fattening and finishing is focused on the most fertile native pastures, such as Mitchell grass, on introduced pastures or in feedlots.

2.1.3 Profitability

Profitability of the northern cattle industry has not improved over the last 30 years and has declined for the best performing enterprises. This is because costs of cattle production have increased thirty-fold since 1950 (or stayed level in real terms) compared to an eight-fold increase in income (or a 60% decrease in real terms) (McLean et al. 2014). Indeed, after interest payments have been made, most cattle businesses made losses and are deemed to be unsustainable. In addition, cattle theft has been estimated to cost the industry between $1.5 and $2 million a year in Queensland alone (Cowley et al. 2013). Costs would be even higher without current biosecurity efforts, which are estimated to save beef producers an average of $12,927 per enterprise, largely through the through preventing the introduction of Foot and Mouth Disease and spread of exotic pests, weeds and diseases (Hafi et al. 2015).

While there is marked variation in enterprise performance across the region, the majority of northern beef enterprises are not considered viable in the long term (McCosker et al. 2010; McLean et al. 2014). Over 2001-2012, the top performing 25% of enterprises averaged a profit of $66 per head of cattle sold compared to an industry average of $6 per head (McLean et al. 2014). Performance was found to be related to good management rather than constrained by environmental factors. Top performance was characterised by higher reproductive rates, lower mortality rates and better sale weights relative to industry averages. Therefore adoption of management practices to improve herd performance (as outlined in the next section) should flow through to improved enterprise profitability. Top performers also had larger herds, high income, low operating expenses, high labour efficiency and low ratios between asset value and herd size. Businesses with fewer than 800 head typically made a loss (McLean et al. 2014). Even the best performing businesses in this size class averaged losses of nearly $14 per head.

The average price paid per head (Adult Equivalent/AE) has declined over the last ten years from close to $200 to around $160, and cattle prices have rarely been higher than they were in the 1970s (McLean et al. 2014). Hence, average income across surveyed northern beef properties in 2013-14 was 43% lower than in 2012-13, and 48% than the ten-year average (Thompson et al. 2014). After accounting for costs, losses on northern beef enterprises averaged $63,000 in 2013-14, considerably more than the losses of $6,100 in the previous year. As a result, off-farm income is particularly important for propping up small enterprises, which receive more income from off-farm activities than they do from cattle production (**Error! Reference source not found.**). While off-farm work improves financial capacity for cattle and land management, it also restricts time and physical capacity available (Richards et al. 2005). Off-farm work also increases in times of drought, placing considerable stress on family businesses (Paton 2014).

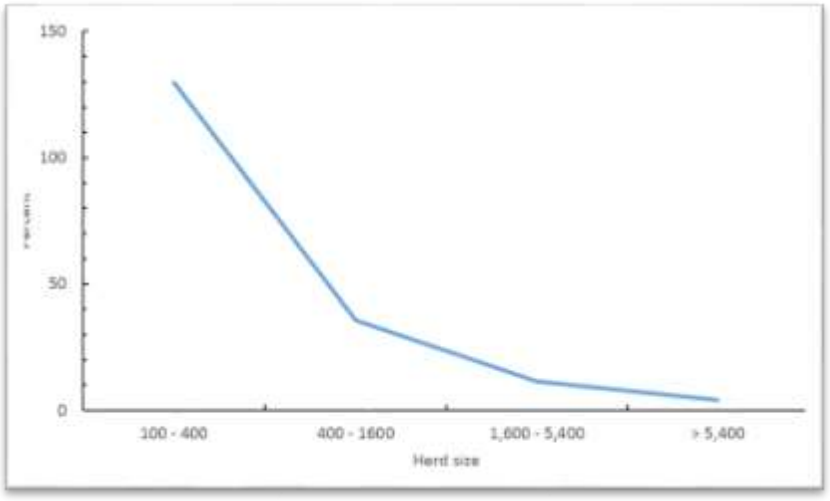


FIGURE 5. RATIO BETWEEN OFF-FARM AND ON-FARM INCOME IN RELATION TO HERD SIZE (MARTIN ET AL. 2014)

Land prices rose steeply between 1990 and 2008 (**Error! Reference source not found.**), reflecting land speculation rather than productivity, which has increased by less than 1% a year since 1977 (Thompson et al. 2014). At the same time, debt levels across the region increased as pastoralists were encouraged to borrow against their assets. Cattle producers responding to the Gulf Cattlemen's Association survey suggested bank managers actively encouraged over-extended borrowing during this period (ABARES 2011, 2014a, 2014b, 2014c, 2014d). This strategy came unstuck when land prices collapsed in 2008. Gulf cattlemen reported property values had declined by an average of 28% between 2010 and 2014 (ABARES 2011, 2014a, 2014b, 2014c, 2014d). Growth in borrowing since 2009 has resulted in interest payments reaching 13% of farm income (Thompson et al. 2014).

Combined with a halving of property prices from 2008 (**Error! Reference source not found.**) and the Queensland drought, the live-export ban made mortgage repayments increasingly difficult. In some cases, this was exacerbated by more stringent mortgage arrangements, including increased interest rates and overdraft margins (18% of respondents to Gulf Cattlemen's Association survey (ABARES 2011, 2014a, 2014b, 2014c, 2014d). The majority of pastoralists surveyed (59%) considered that changes to mortgage arrangements have adversely affected their businesses and a further 8% saw these changes being a threat to long-term viability.

FIGURE 6. LAND PRICES AND DEBT BURDEN OF GRAZING PROPERTIES IN MONSOONAL CLUSTER REGION (AUSTRALIAN BUREAU OF AGRICULTURAL AND RESOURCE ECONOMICS AND SCIENCES 2012)

The number of Queensland beef producers in debt rose by 15% from 5,658 in 2009 to 6,499 in 2011 (Government 2011)(Qld Government 2011). Over this period, their combined debt increased from $7.8 billion (54.5% of the state's total) to $9.2 billion (54%). The average debt of Queensland gulf pastoralists to financial institutions increased by 22% between 2010 and 2014 and their debts to rural businesses increased by 600% (ABARES 2014a, 2014b, 2014c, 2014d). In mid-2012, 23 Queensland Gulf pastoralists were more than 90 days overdue on bank loan repayments (1.9% bank customers) (ABARES 2014a, 2014b, 2014c, 2014d). By mid-214, this figure has almost doubled. This has led to an increase in forced sales, particularly in Queensland. Although ANZ announced a 12-month moratorium on foreclosures in drought affected parts of Queensland in December 2014 (DPIF NT 2013a, 2013b) other banks did not follow suit. Across the wider pastoral industry, ongoing loss of equity is reducing the capacity to undertake work that requires capital investment (McLean et al. 2014). The flow-on effects of reduced capacity to service debt on beef enterprise sustainability, pastoralist health and well-being and natural resource condition are dealt with in other sections of this document.

Despite spiralling debt, pastoral businesses in northern Australia still have relatively high equity in their businesses, averaging 89 per cent in 30 June 2013 (Thompson et al. 2014). This may explain why the vast majority of these borrowers in the Queensland cattle sector are considered either viable in the long-term or potentially viable despite current debt-servicing difficulties (Queensland Government 2011). This stands in contrast to industry assessments indicating the majority of northern beef enterprises to be unviable in the long term (McLean 2014, McCosker 2010) and the majority of pastoralists surveyed in the Queensland Gulf having no confidence in the industry's future in the region (Nason 2014).

At the start of 2015, cattle prices are as good as they have ever been and demand from international and domestic markets and from pastoral enterprises restocking after drought is expected to grow (Thomas 2015b). However, increased beef cattle turn-off during the drought and in response to high prices has reduced the size of the Australian herd by 8.5% (Thomas 2015b) and, as a consequence, the value of cattle inventories (Thompson et al. 2014). The size

of the Australian cattle herd is not expected to recover before 2020 (Thomas 2015b), so many pastoralists may be unable to take advantage of these conditions.

2.1.4 Diversification

The difficult financial situation faced by many in the northern pastoral industry is a driver to find other sources of income to future-proof pastoral businesses against market restrictions or a drop in prices, and many enterprises already derive income from off-farm work (**Error! Reference source not found.**). On-farm diversification opportunities for northern pastoral operations include forage crops, crop production and ecosystem service delivery (Gleeson et al. 2012)

2.1.5 Forage crops

Small-scale production of irrigated pasture and pasture crops on the most fertile parts of the property has been proposed as another means of improving enterprise profitability (Cresswell et al. 2009; Grice et al. 2013). Most properties in northern Australia are considered to have adequate water and soil resources to support such development. Modelling was undertaken of the economics of supplementing the diet of cattle reared on native pasture with irrigated pasture crops in late spring and summer on three properties in Monsoonal North Australia and adjoining Barkly Tablelands (NT). While most enterprises have offset cost increases by reducing their labour costs, this is not an option for the top 25% of businesses, which are already operating at a high level of input efficiency. This explains the closing of the gap between the best performing and average businesses.

The most profitable scenarios combined irrigated tropical perennial grass or lablab with between 18% more and 8% fewer stock . In comparison to cattle reared under a no-irrigation scenario, cattle finished on the irrigated pastures had faster growth rates and improved reproductive rates, thus allowing early weaning and a more rapid turn-off of higher quality animals. Increased growth rates also meant that animals should be market-ready at a younger age, and thus can be sold in higher value markets (see Figure). Hence the modelled properties increased both beef production and profitability. It has been estimated that up to 120,000 ha of irrigation is possible, with the potential to increase beef exports by $150-250 million annually (Hogan et al. 2014a; Hogan et al. 2014b)

Additional adverse environmental impacts potentially include soil disturbance; decline in plant species richness as a result of vegetation clearance; conditions conducive to weed spread; risk of pollution from fertiliser and pesticide over-application; changed hydrology; and salinisation. However, Grice et al (2013) consider that, as the operations are of a small scale (covering less than 0.1% of the northern pastoral area), adverse impacts should also be minimal and manageable. The sites most suitable for mosaic irrigation – the most fertile and well-watered areas – are also likely to have high natural and cultural values (Grice et al 2013). Such areas are already the focus of grazing operations across the rangelands and so may be in an already degraded condition and in need of restoration (Stokes et al. 2006). Careful placement of irrigation developments, with reference to the *Environmental Protection and Biodiversity Conservation Act 1999* (Cwlth) and relevant State or Territory legislation will therefore be required to minimise risks endangered flora and fauna or sites of high cultural or biodiversity value.

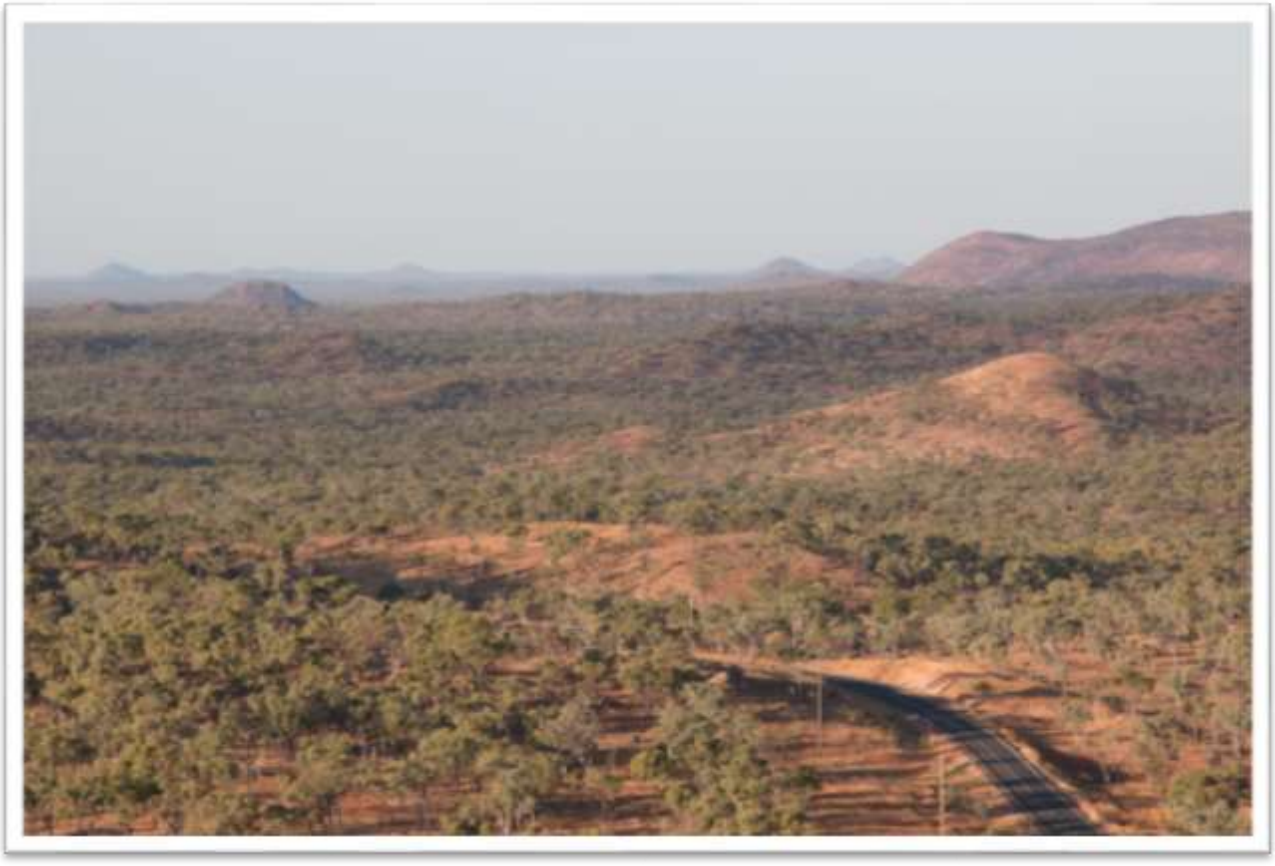
What is not discussed in the report is how pastoralists using mosaic irrigation will change their management of grazing pressure on the non-irrigated parts of the property. Managed wisely, mosaic irrigation should allow stocking rates to be adjusted in line with land condition. However, by providing feed during the late dry season "protein drought" (Grice et al. 2013), pastoralists may be tempted to maintain herds at unsustainable densities through the wet season. Also, while the pasture species used in the model have a low invasion risk, selection of more invasive species, such as Gamba Grass, would have serious implications for biodiversity. Gleeson et al. (2012) stresses the importance of providing extension to pastoralists to enable them to adopt irrigation practices. Equally important will be continuing extension programs, such as the Grazing Land Management (GLM) courses, that explain maintenance of land condition and its link to profitability.

Fencing, water point and irrigation all require up-front capital investment, and a business case to demonstrate return on investment (Grice et al. 2013). Mosaic irrigation for pasture cropping has been endorsed as a viable investment by ANZ economists (Hogan et al. 2014a; Hogan et al. 2014b) – along with rejection of short-term profitability of other forms of agricultural expansion – as well as their decision to temporarily freeze foreclosure sales shows a confidence

in the long-term viability of the northern pastoral industry. Capital will be hard to raise for enterprises already having difficulty servicing their debts (McLean et al. 2014) or where security of land tenure is uncertain (James Cook University et al. 2013).

2.1.6 Irrigated agriculture

Within the Northern Gulf region, small-scale irrigation enterprises are likely to be viable on most northern properties, but potential for more extensive irrigated agriculture appears to be limited to a areas with reliable overland flow, such as the Gilbert river catchment (CSIRO 2013; Grice et al. 2013; Petheram et al. 2013a). The viability of such schemes has been questioned (Hogan et al. 2014a), as more irrigation schemes have failed than have succeeded in North Australia (Ash 2014). Moreover, irrigated agriculture that does not contribute to on-property cattle production on pastoral leases is not permitted under existing land tenure arrangements. Hence, land tenure reforms to support diversification are underway in all jurisdictions (JCU 2013). Irrigated agriculture may also conflict with Indigenous interests, which are required to be addressed where Native Title coexists with pastoral operations (Head 1999; jackson 2005). Structural difficulties and requirements for access to water resources, capital investment, skills training and high labour requirements (Gleeson et al. 2012, Grice et al. 2013) will mean that any venture into irrigated agriculture needs to be a substantial commitment, not just a minor component of the business. This commitment is likely to beyond pastoralists with high debt levels and/or heavy dependence on off-farm income.



2.2 Barriers to Industry Viability

Constraints identified as affecting profitability of the northern cattle industry include lack of property infrastructure; land use regulation and lease conditions; lack of processing facilities; transport costs and access to skilled labour (Burns et al. 2010; Gleeson et al. 2012; Martin 2013; Martin et al. 2014; McGowan et al. 2014; McLean et al. 2014; Thompson et al. 2014). These challenges are examined in detail below, along with efforts to overcome them.

2.2.1 Supply chain

Access to facilities for selling and processing cattle is critical to the success of agriculture enterprises. If cattle are not finished on the property or sold to another grazing enterprise, they will need to be transported to a saleyard, port or feedlot. Lack of such facilities in the local area raises freight costs and reduces market access options (Ash 2014).

2.2.2 Sale yards

The number of sale yards in Australia has been declining as a result of increasing costs, urban encroachment into industrial areas and the burden of complying with occupational health and safety and animal welfare regulations (Sd&D 2008). This has led to closure of small council-run abattoirs and concentration of larger processing facilities close to end markets. There are few sale yards in the north, and none in north-western Western Australia (Figure), where virtual auctions have been successfully trialled[2] through AuctionPlus online selling[3]. There appears to be no plans to build new sale yards in northern Australia.

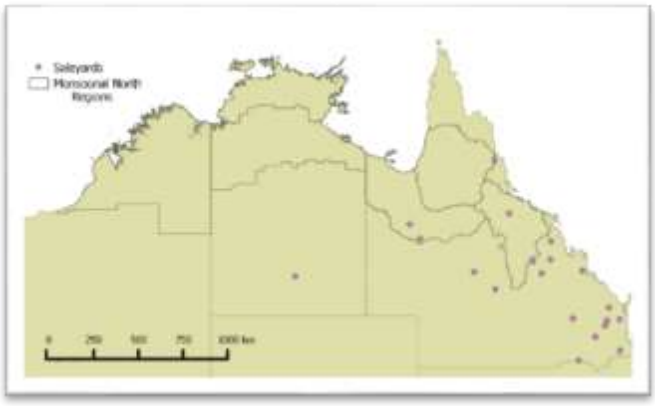


FIGURE 7. LOCATION OF SALEYARDS IN RELATION TO THE MONSOONAL NORTH REGIONS

SOURCE: LOCATIONS FROM HTTP://WWW.SALEYARDS.INFO/

2.2.3 Meat works

Abattoirs are required for the processing of packed meat and can have an impact on transport costs. There are few meat works in the north, with several having closed in the second half of last century (Figure) (Berry 2012). Pressures that forced the closure included poor financial viability; company mergers; increased hygiene standards and increased competition from feedlots and live exporters (Gleeson et al. 2012). Cattle not exported are freighted to Townsville or further south for processing (Higgins 2013; QDAFF 2012). Hence transport is a significant component of input costs for northern cattle producers (Higgins 2013). The location of Cloncurry on the tick line makes it the most economically viable place to construct an abattoir in north-western Queensland, as this would allow cattle to be transported to it from any direction without incurring tick inspection costs (QDAFF 2012). The economic benefit to producers of building an abattoir

[2] www.landmark.com.au/livestock-news-194_699.html

[3] www.auctionsplus.com.au/

at Cloncurry was estimated at $41.10 per head of cattle, $2.55 better than of building one at nearby Mount Isa, which is several kilometres inside the tick-free zone. Another option for reducing costs that has been suggested is to waive compulsory tick inspection of cattle crossing the tick line when being transported directly to an abattoir (Higgins 2013).

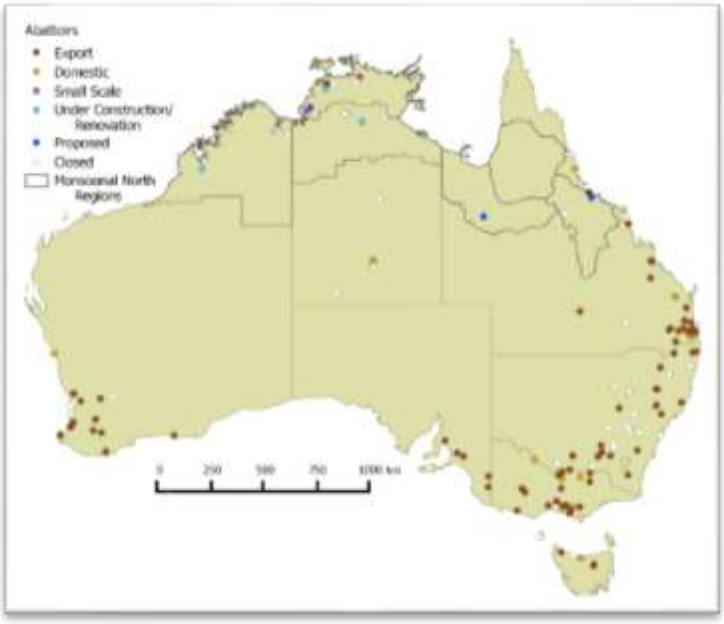


FIGURE 8. LOCATION OF MEATWORKS IN RELATION TO THE MONSOONAL NORTH REGIONS (HTTPS://AUSTRALIANABATTOIRS.WORDPRESS.COM)

2.2.4 Freight

As cattle stations are dispersed across the north and there are few sale yards or export facilities, most cattle need to be transported large distances (Higgins 2013). Most cattle are transported by road through a dispersed road network using local or regional carriers, and very few by rail (Sd&D 2008). Most cattle raised in north-western Queensland are transported between 500 and 1,000 km (QDAFF 2012). Freight costs are a therefore a significant component of input costs, being approximately 7% of the total costs of northern cattle operations (Thompson 2014) and accounting for up to 35% of the market price (Higgins 2013).

As well as distance to processing facilities, freight costs and logistics are influenced by condition of road networks, availability holding paddocks on freight routes, and the necessity to interrupt transport for tick inspection (Ash 2014, QDAFF 2012). Weight restrictions on some Queensland roads prohibiting road trains necessitate diversions to longer routes or separating loads (Higgins 2013). Seasonal road closures also interrupt supply and, where diversions are possible, increase transport costs (Ibid).

Governments provide financial support to pastoralists in the times of hardship (www.agriculture.gov.au/ag-farm-food/drought/assistance). Most support is provided only at times of declared droughts or natural disasters. One of the most significant forms of support is in the form of concessional loans for debt restructuring, to cover operating expenses or for drought recovery and preparedness activities. There has been a move away from concessional loans to programs to assist producers to increase the capacity, efficiency and sustainability of their operations (Cockfield et al. 2006). In 2013-15, the Australian Government is also subsidising pest animal management in drought affected areas, and in 2013, Queensland Government granted drought affected pastoralists grazing rights on National Parks (abc.net.au/news/5076268).

As the vast majority of farmers have historically managed climate variability independently, there is concern that drought assistance subsidises poor management (Productivity Commission 2009). Inquiries into government assistance

programs have concluded that government support should concentrate on assisting farmers to improve their business management skills and build self-reliance through research, development, extension, training and professional advice, and that support provided to farmers should be based on the level of hardship, not its cause (Productivity Commission 2009).

2.2.5 Herd performance and market access

Indifferent pasture quality, resulting from the harsh climate and infertile and erodible soils, limits cattle growth rates and reproductive success. In the Northern Gulf region, breeding performance is typically poor, with low pregnancy rates, high foetal and calf death rates, and high rates of cows going missing (Burns et al. 2010; McGowan et al. 2014). Low levels of productivity necessitate large properties and limited resources for infrastructure development and minimal handling (McLean et al. 2014). Lack of fattening and finishing options means that most enterprises are supplying the less profitable end of the market (Grice et al. 2013).

It has been argued that the level of performance achieved at the 75th percentile of enterprises should be within reach of all enterprises in a given region or country type (McGowan et al. 2014). An example is provided for the rate at which mature cows were pregnant within four months of calving. The median rate was 17%, meaning that on half the enterprises, 17% or fewer cows were pregnant by the fourth month. However, as 75% of enterprises achieved a rate of 31%, this is the rate that is considered achievable by all enterprises. For negative measurements (such as calf loss), the 25th percentile represents the achievable level of performance. This approach shows that significant improvements in performance are achievable in the Northern Gulf region.

2.3 Drivers of Industry Growth

2.3.1 Demand

Consumption of beef has increased with global population growth and economic development (see Agriculture Chapter). Worldwide, beef consumption increased 40% in the last 40 years (Figure). Growth and economic development has been greatest in Asia, with both beef production and beef consumption increasing increased nine-fold since 1975.

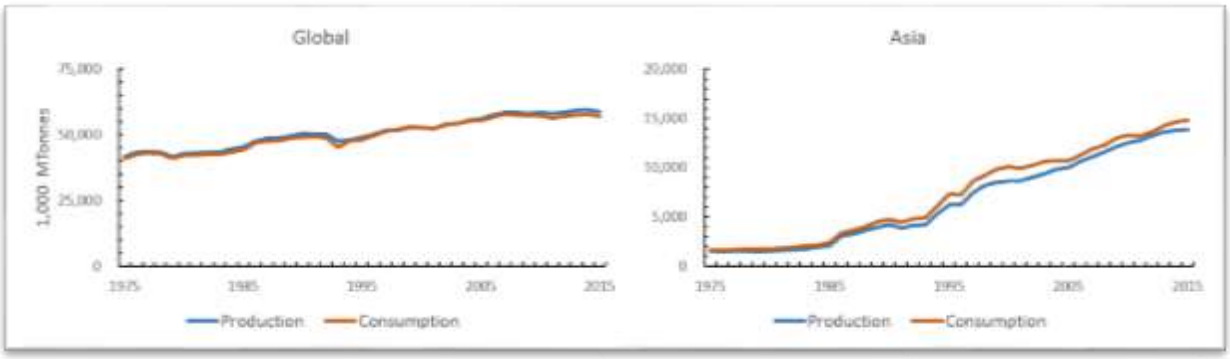


FIGURE 9. GLOBAL AND ASIAN BEEF PRODUCTION AND CONSUMPTION

SOURCE: DATA FROM UNITED STATES DEPARTMENT OF AGRICULTURE (HTTPS://APPS.FAS.USDA.GOV/PSDONLINE)

Global demand for beef is expected to continue to grow. By 2050, an annual population growth of 0.8%, combined with a 2.7% growth in real world income, is expected to result in a 70% increase in food demand and a 300% increase in beef consumption (using 2007 as a base level) (Linehan et al. 2012). Food consumption is expected to double in Asia over the same period, with the value of food imports increasing five-fold (Ibid). Beef imports into Asia are expected to increase astronomically, with most of the demand coming from China.

Short term changes are more difficult to predict. In early 2014, a levelling of live exports to Indonesia was projected, along with year-on-year doubling of live exports to Vietnam, steady growth in demand from China, further decline in exports to Malaysia and the Philippines (McRae 2014). In February 2015 came the realisation that reduced availability of cattle for sale will limit growth in all these markets, and a decline in exports to Indonesia (Thomas 2015a, 2015b, 2015c).

Countries importing meat may have very specific requirements for their beef. Many countries place restrictions on beef imports from countries with Bovine Spongiform Encephalopathy or Foot and Mouth Disease (Gleeson et al. 2012). Asian feedlot markets prefer Brahman cattle, as these animals tolerate the hot and humid conditions (LiveCorp et al. 2013; Martin et al. 2007; Poppi 2014). Lack of refrigeration in many non-urban areas in Indonesia means live export is required to supply the fresh meat trade (Drum et al. 2008). In addition, local slaughter gives the Muslim population confidence that slaughter has been undertaken according to halal requirements (DAFF 2011), particularly during religious festivals (Poppi 2014). Northern Australia is in a good position to supply these specific requirements because of its disease-free status and suitability for Brahman stock.

Dependence of the northern beef industry on the Indonesian market makes it highly vulnerable (www.abc.net.au/news/6348020). This market was suspended for two months in the peak export season in 2011, as a result of animal cruelty concerns, only resuming once the Federal Government was satisfied that Exporter Supply Chain Assurance System ESCAS was in place to safeguard animal welfare (Commonwealth of Australia 2015), and the Indonesian Government was prepared to resume issuing permits. Restrictions imposed by Indonesia on cattle imports, however, have the effect of raising the price, to the benefit of Australian producers (www.abc.net.au/news/6273314). Maintaining good relations with the Indonesian Government is seen as essential to providing economic certainty for the northern beef industry (Gleeson et al. 2012). However, access to a broader range of export destinations and northern meat processing facilities will provide additional security in the long-term. Therefore expanding Vietnamese and Chinese markets for both live cattle and packed meat should improve resilience in the northern beef industry.

Global beef production has increased in response to demand, overtaking consumption in 2003 (Figure in previous section). Australia was the world's top beef exporter for over 40 years from 1960. Brazil exceeded Australia's export of beef in most years since 2004 and India since 2012. These nations, along with Argentina, are strong competitors in the South-east Asian market, although disease concerns prevents them supplying some of Australia's other important export markets, such as the United States (Bilharinho 2012; Gleeson et al. 2012). United States, Canada and New Zealand are also considered key competitors in Australian beef exports. Production in these countries drives price and has the potential to limit Australian access to markets (Gleeson et al. 2012).

Therefore, while global demand, favourable exchange rates and trade agreements that recognise Australia's disease free status drive beef production in northern Australia, they may be offset by trade restrictions imposed by potential importing nations or where other beef exporting nations are increasing beef production, have favourable exchange rates or benefit from their own agricultural subsidies.

2.4 Drivers of Practice Change

Inefficient herd management, especially retention of animals regardless of their contribution to turn-off, leads to poor performance and profitability, as well as unnecessarily high stocking rates and elevated carbon emissions (Berndt et al. 2013; Perkins et al. 2010). Research and extension has identified where inefficiencies exist and how they can be overcome.

Recent studies have shown that reproductive performance can be improved by through heard management, vaccination, supplementary feeding and matching stocking rate to long-term carrying capacity (Burns 2010). Further, Hunt (2014) identified four land management principles for sustainable and economically viable management of the northern grazing lands, covering stocking rates, pasture rest, fire management and infrastructure. Many of these practices not only increase herd performance but also effectively reduce stocking rates for the same level of beef production, and so have benefits to pasture production and biodiversity (Ash et al. 2011; Fisher et al. 2006). Improving efficiency of

livestock production should also reduce emissions at the enterprise scale (Berndt et al. 2013). Hence the drive to improve herd performance without increasing stock numbers is likely to have both biodiversity and carbon benefits.

Grazing Land Management courses and the grazing BMP aim to increase uptake of these practices through extension programs covering all aspects of enterprise management (AgForce 2014; NT et al. 2002). These and other extension programs have been shown to motivate practice improvement (Chudleigh et al. 2009). Uptake of these principles is examined below based on surveys of pastoral enterprises undertaken in the Pilbara and Kimberley in 2010 (Dray et al. 2011; Stockdale et al. 2012), in the Northern Territory in 2011-12 (Cowley et al. 2013), in the Burdekin Dry Tropics in 2008-9 (ABS 2010) and 2010 (Solutions Marketing and Research 2010), and in the Dalrymple region of the Burdekin Dry Tropics (Gordon et al. 2008). In addition, management practice information collected between 2008 and 2011 from properties in the Mitchell Grass region (Northern Downs) and remainder of the Monsoonal North (Northern Forest) in the CashCow project was also used (McGowan et al. 2014).

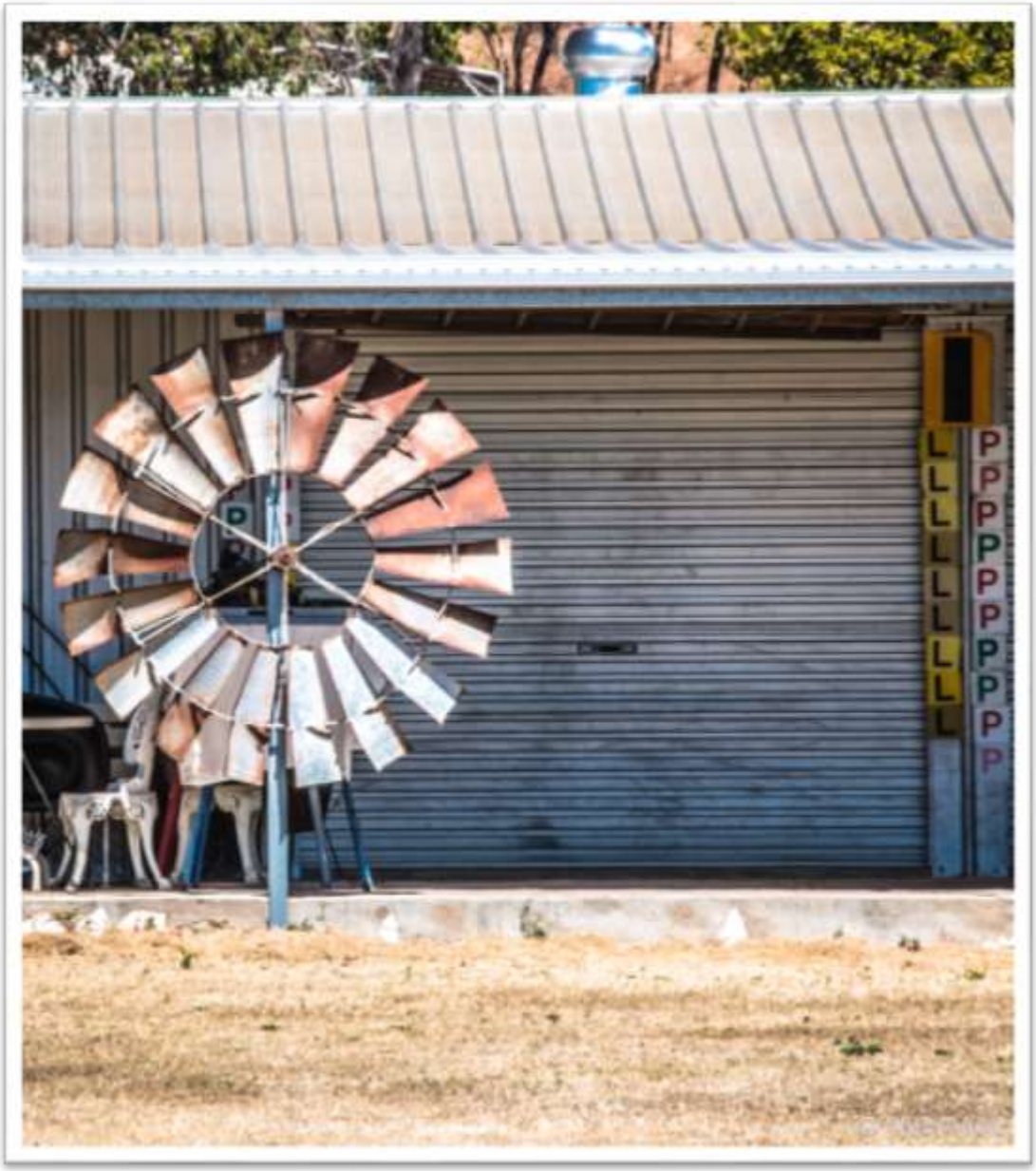


TABLE 5. TIMELINE OF RECENT SIGNIFICANT EVENTS AFFECTING NORTHERN BEEF EXPORTS

SOURCES: 1, (PRODUCTIVITY COMMISSION 2005); 2, (MCCARTHY ET AL. 1995); 3, (GLEESON ET AL. 2012); 4, WWW.DFAT.GOV.AU/FTA/ 5, (DGLAHS 2010); 6, (COMMONWEALTH OF AUSTRALIA 2015); 7, (THOMAS 2015A, 2015B, 2015C)

Date	Event	Source
1970-	Progressive withdrawal of subsidies to Australian agriculture	1
1983	Australian dollar floated	2
1987	Australia first exports live and slaughter cattle to the Philippines	3
1990	Australia's first live export to Indonesia	3
1998–9	Asian financial crisis	3
	Live export to Philippines peaks	3
2000-	Exchange rate reduces competitiveness of Australian beef	3
2000-5	Australian beef exports to Philippines slumps	3
2003	Singapore-Australia Free Trade Agreement comes into force	4
	• Elimination of all tariffs for Australian imports into Singapore	
2005	Thailand-Australia Free Trade Agreement comes into force	4
	• Reduced the tariff on Australian beef imports to Thailand from 51% to 40%, reducing to 0% by 2020	
2005	Australia-United States Free Trade Agreement revised	4
	• Australian beef imports to increase to 70,000 tonnes in year 18, with free access from 2023 • Immediate elimination of in-quota tariffs for beef imports into USA, and phasing out of over-quota duties between years 9 and 18	
2010	Indonesia imposes weight limits and quotas on live cattle imports, aiming to achieve beef self-sufficiency by 2014	3,5
Jun 2011	Australia suspends export of live cattle to Indonesia, mandating Exporter Supply Chain Assurance System	6
Jul 2011	Australia lifts ban on export of live cattle to Indonesia, but Indonesia delays issuing import permits till August	3,6
Aug 2011	Live export trade to Indonesia resumes	3,6
2012	Indonesia imposes further export restrictions on Australian live cattle imports	
2013	Malaysia-Australia Free Trade Agreement comes into force	4
	• Tariff-free treatment for the vast majority of Australian agricultural products imported into Malaysia	
2014	Korea-Australia Free Trade Agreement comes into force	4
	• Progressive elimination of 40% tariff on Australian beef imports into Korea by 2028	
2014	Agreement Establishing the ASEAN-Australia-New Zealand Free Trade Area – First protocol signed	4
	• Elimination of agricultural export subsidies for trade between partner countries	
2014	China-Australia Free Trade Agreement negotiations concluded	4
	• Removal of tariffs of 12% to 255 on beef over nine years	
2014	Depreciation of Australian dollar	7
2015	Japan-Australia Economic Partnership Agreement comes into force	4
	• Immediate reduction on tariff on frozen beef from 38.5% to 30.5%, phased to 19.5% over 18 years • Immediate reduction on tariff on fresh beef from 38.5% to 32.5%, phased to 23.5% over 15 years • Replacement of "global snapback" to 50% tariff in the event of escalating imports, to discretionary tariff rise to 38.5% if the import volume exceeds Australia-specific triggers within a given year (14.5 per cent above 2013 exports for frozen beef and 12 per cent above 2013 exports for fresh beef), rising each year for ten years before being reviewed.	

2.5 Legislative Drivers

Legislation and regulations have the potential to drive the direction of the industry; mandate adoption of management practices or affect the capacity to do so; and improve or reduce industry viability by imposing compliance costs. The following section is not a comprehensive review of legislation and regulations, but covers land use and management practices, as well as animals and workforce regulations that influence operational costs.

Legislation controlling pastoral lease renewal, operating conditions and vegetation management are key drivers of pastoral management and reflect the agenda of governments of the day. Conditions of leases limit the ability of pastoralists to respond to drivers to develop and diversify their operations to achieve financial sustainability, and so are under review. Moreover, non-pastoral purposes require consideration of the Native Title interests before developments are permitted.

Through the first decade of the 21st century, there was a move towards legislation restricting development, particularly in Queensland. With election of conservative governments in Queensland 2012, there has been a move to self-assessment of activities associated with pastoral purposes, with permits being largely restricted to non-pastoral activities or for high value conservation areas.

Legislation and regulations are imposing increasing obligations on pastoralists with respect to the treatment of livestock and wages and conditions. There is general recognition for the need to maintain standards in these areas, but also of the financial and transactional costs of complying with these regulations. This is reflected in policies for red tape reduction to assist industry development in the north.

2.5.1 Tenure

Cattle grazing occurs on a number of tenures across northern Australia, including pastoral and perpetual leases, freehold and Indigenous lands. However, the vast majority of grazing in the Northern Gulf occurs on pastoral leases. Security of tenure affects a cattle operation's capacity to obtain finance. This becomes more difficult approaching the end of the lease tenure, and pastoralists may become reluctant to make improvements, and financial institutions to provide finance (State Development Infrastructure and Industry Committee 2013). Also, current tenure arrangements do not support diversification into non-pastoral pursuits. Recent recognition of the limited management options on pastoral leases has led to a widespread review of tenure and lease renewal arrangements (DRDL WA 2011; James Cook University et al. 2013; State Development Infrastructure and Industry Committee 2013).

2.5.2 Environmental management

As with all industries, beef operations are subject to environmental legislation protecting threatened species and ecosystems and heritage sites at both the national and State/Territory level. Environmental matters are most likely to come into play when new developments are proposed. Australia is a signatory to the international *Biodiversity Convention 1992* (UNEP 1992), which aims to ensure conservation and sustainable and equitable use of biological diversity. Under this convention, Australia has the right to exploit and make policies concerning its own resources, but by signing the convention agrees to institute measures to protect biodiversity, including through a protected area estate and management of environmental values outside that estate. The *Australian Biodiversity Conservation Strategy 2010-2030 (National Biodiversity Strategy Review Task Group 2010)*, endorsed by Ministers from the Australian Government and all State and Territory governments, identified strategies for addressing each of the following threats:

- Habitat loss, degradation and fragmentation
- Invasive species
- Unsustainable use and management of natural resources
- Changes to the aquatic environment and water flows
- Changing fire regimes
- Climate change.

The Strategy is underpinned by four national frameworks covering native vegetation, weeds, pest animals and protected areas, to which most State and Territory governments are also signatories. Each Australian jurisdiction has a different process by which environmental matters are managed. Relevant legislation includes the *Environment Protection and Biodiversity Conservation Act 1999*, *Wildlife Conservation Act 1950* (WA), *Territory Parks and Wildlife Conservation Act (NT) Nature Conservation Act 1992* (Qld). Each of these acts and their associated regulations provide a list of threatened species and ecosystems that are a priority for conservation management, as well as threats that need managing and mechanisms for doing so. Each jurisdiction also has an environmental offsets policy through which environmental damage caused by developments can be offset by environmental management in other places.

This hierarchy of laws, regulations and policies has implications for pastoralism, including through their capacity to promote or mandate sustainable resource management and control of weeds and pest animals, or to restrict vegetation clearance. Alongside regulation, mechanisms are also provided for payment for environmental services as a means to incorporate biodiversity conservation into commercial enterprises. These shift the emphasis on penalising pastoralists for the presence of threatened species or ecosystems on their land by resuming land or restricting development to rewarding them for good environmental management that protects biodiversity values.

2.5.3 Pastoral lease conditions

Amendments to the *Queensland Lands Act 1994* in 2007, introduced a stepped renewal process (which came to be known as the Delbessie process) in which all pastoral leases could be renewed for 30 years, with an additional 10 years where the land was assessed to be in good condition; and a further 10 years where an Indigenous Access and Land Use Agreement (ILUA) and a conservation agreement or covenant were in place. The *Queensland Lands Act 1994* was further amended in 2014 to remove the stepped renewal process and requirements for ILUAs, and conservation and land management agreements. Pastoral leases can now extended (rolled over) for a period equivalent to the original term of that lease (but for no more than 50 years), and renewal can be granted once 80% of the lease term has expired. It remains to be seen whether the Palaszczuk government maintains these changes. Significantly, restrictions preventing Aboriginal- and family-owned corporations from owning pastoral leases in Queensland and individuals from holding multiple pastoral holdings were not removed until the Act was amended in 2014 (Parliament 2014)(Qld Parliament 2014).

2.5.4 Land clearing

Pastoral operations rely on productive pastures. The majority of Monsoonal North Australia is native pasture, but increasingly operations are depending on development on at least parts of their properties to improve viability. Developments such as mosaic irrigation of pasture crops will require vegetation clearance (Grice et al. 2013). Parts of the region have been degraded by woody thickening (Bray et al. 2007; Cook et al. 2010; Crowley et al. 1998; Lewis 2002), and returning it productive condition may require thinning using fire (Cowley et al. 2014) or other means. Tree clearance may also be undertaken where introduced pasture species are used to improve productivity.

The *Vegetation Management Act 1999* (Qld) was amended in 2004 with the aim of phasing out broad scale clearing of remnant vegetation by 2006[4]. Throughout Monsoonal North of Queensland from mid-2014, landholders are able to clear native vegetation for most pastoral purposes, using self-assessable codes and submitting a notification form. Clearing for environmental works can also be conducted under a self-assessable code, enabling the clearing of native vegetation where clearing is necessary to restore the environmental condition of the land or prepare for a natural disaster. However, restrictions are still in place for vegetation with recognised conservation value. The Palaszczuk government came to power promising to re-introduce strict tree clearing laws (www.abc.net.au/news/6032484). However, recent liaison between the Queensland Agriculture minister and the industry suggests these changes might not proceed (www.abc.net.au/news/6280876).

[4] The Vegetation Management and Other Legislation Amendment Bill 2004 www.austlii.edu.au/au/legis/qld/bill_en/vmaolab2004491/vmaolab2004491.html

TABLE 6. CONDITIONS FOR VEGETATION CLEARANCE FOR PASTORAL PURPOSES IN QUEENSLAND

SEE HTTPS://WWW.QLD.GOV.AU/ENVIRONMENT/LAND/VEGETATION/ FOR DETAILS

Purpose of clearance	Classes
Permitted without notification or permit	
Control weeds in recognised grassland regional ecosystems	All
Build or maintain fences, roads or tracks (up to 10m wide)	LC
Build or maintain fire management lines (up to 10m wide)	All
Build or maintain firebreaks to protect infrastructure	All
Reduce fuel hazard	All
Build and source timber for new infrastructure (buildings, fences, roads & water points)	LC
Maintain and source timber for existing infrastructure	All
All other purposes	X
Permitted under self-assessable code with submission of notification	
Control weeds (listed non-endemic native, non-native & declared plants)	B
Restore land condition	B
Selectively clear thickened vegetation to restore regional ecosystem	B
Manage invasion of grassland by native woody species (western bioregions)	B
Manage regrowth state-wide (for grazing; control of weeds, thickening or encroachment; fodder harvesting & infrastructure)	C
Manage regrowth in Burdekin catchment (for control of weeds or thickening; restore land condition or channel formation & infrastructure)	R
Harvest recognised fodder species to feed livestock (western Queensland)	B
Prepare for natural disaster	B
Build or maintain infrastructure (fences, roads, firebreaks, and dams)	B, C & R
Permitted under "Area Management Plan for the control of pest plants in the Dry Tropics region"	
Control weed species listed in plan	B, C, R & X
May be permitted on other vegetation classes subject to approval	
Control weeds	
Harvest fodder	
Thin thickened vegetation	
Clear encroachment	

[A] ***LC, LEAST CONCERN REGIONAL ECOSYSTEMS; A, AREAS SUBJECT TO COMPLIANCE NOTICES, OFFSETS AND VOLUNTARY DECLARATIONS; B, REMNANT VEGETATION; C, HIGH-VALUE REGROWTH VEGETATION; R, REGROWTH VEGETATION WITHIN 50M OF WATERCOURSES IN PRIORITY REEF CATCHMENT AREAS; X, OTHER NON-REMNANT***

2.5.5 LABOUR

Labour is one of the biggest input costs in pastoral businesses, accounting for about 70% of overhead expenses and 50% of the total expenses (McLean et al. 2014). Improving wages and conditions and strengthening of OH&S laws increases costs to pastoral enterprises and have resulted in a steady reduction in the labour force on pastoral stations. Before 1967, up to 200 Aboriginal stockmen were employed on the larger cattle stations (Lehane 1996). When Aboriginal workers were awarded equal pay in 1967, most Aboriginal stockmen were dismissed (Skyring 2012). Pastoral enterprises continue to reduce the number of staff they employ, increasingly depending on owner/manager and family to provide the workforce (Thompson et al. 2014). This is increasingly difficult where there is a reliance on off-farm income, leading to financial stress and associated health issues. On the smallest properties (fewer than 1,000 cattle) employed labour accounts for less than 20% of the workforce (McLean et al. 2014). Even on the largest properties (more than 10,000 cattle), this figure only rises to 57%, so regional employment opportunities for both Indigenous and non-Indigenous people suffer. However, finding skilled labour remains a challenge (McLean 2014) and will be increasingly important if new technologies, such as mosaic irrigation are adopted (Grice et al. 2013). (Grice 2013).

2.6 POLICY DRIVERS

North Australian beef production is influenced by the policies and programs of numerous government agencies and industry bodies at national, State and Territory and regional levels. Influence is also exerted directly by service providers, such as banks and extension providers, and by lobby groups and the media.

Government agricultural policies and programs aim to drive development in the north. Traditional forms of government support to agriculture, such as trade protection and vast extension programs, have declined over the past half century (Marsh et al. 2000; Productivity Commission 2005). Recent government support for the beef industry is currently focused on:

- Increasing access to international markets
- Building more conducive business and financial environments
- Identifying infrastructure needed to provide a reliable supply chain and attract investment in priority infrastructure
- Identifying practice improvement required for industry resilience and growth.

2.6.1 BEEF INDUSTRY ACTION PLAN 2014-2016

Queensland Department of Agriculture, Fisheries and forestry released a draft Beef Industry Action Plan (Chilcott et al. 2014) for public comment in April 2014[5]. This Plan aims to support Queensland's objective of doubling food production by 2040. It proposes a 38% increase in the State's cattle herd and a 31% increase in carcass weights, to be achieved through irrigated forage crops and improved pastures, and a significant increase in grain feeding (Table). The plan concentrates on three areas: infrastructure development; research, development and extension services; and a creating a supportive business environment (Table).

TABLE 6.QUEENSLAND BEEF PRODUCTION TARGETS (CHILCOTT 2014)

		2012/13 production	2040 target	Increase
				(%)
Cattle herd	(no.)	12,200,000	16,800,000	37.7
Cattle slaughtered	(no.)	3,800,000	5,200,000	36.8
Average carcass weight	(kg)	270	354	31.1
Beef production	(t)	1,100,000	1,800,000	63.6
Beef exports	(t)	635,477	1,000,000	57.4

[5] https://www.daff.qld.gov.au/services/consultations/draft-beef-industry-action-plan-2014-2016

TABLE 8. QUEENSLAND'S DRAFT ACTION PLAN TO SUPPORT DEVELOPMENT OF THE BEEF INDUSTRY (CHILCOTT 2014)

Resource availability
Attract investment into grazing land
• Promote new opportunities in the regulatory framework for investment to increase production from current grazing areas
Support producers to prepare for drought
• Support beef producers to manage climate risks
Productivity
Invest in new research
• Invest in RD&E to improve cattle production
Promote best practice to producers
• Support increased adoption of existing innovations across the beef supply chain
Support intensification of production
• Support feedlot development, use of forage crops and improved pastures to intensify production
Support long term investments by meat processors
•
Build relationships
• Support building international relationships between Queensland and key beef markets
• *Advocate for market access*
• Support industry to realise market opportunities by advocating for market access for beef
• *Promote Queensland's standards*
• Promote Queensland's excellent food safety and cattle biosecurity standards
•
Reduce red tape
• Identify and promote opportunities to reduce regulation compliance costs in the beef supply chain, across portfolios and jurisdictions
• *Improve transport efficiency*
• Work with industry to identify and promote opportunities to reduce cattle transport costs

2.7 Financial institutions

Most producers across the north have mortgages with banks. High debt levels across the industry mean that mortgages must be renegotiated with the banks, and may be conditional on specific practices, including stocking regimes. Pastoralists in debt may be likely to overstock their properties to service their loans (Greiner et al. 2006), and on average in the Burdekin, as farm debt increases, grass cover decreases (Greiner et al. 2007b). However, there is no evidence of banks insisting on unsustainable stocking rates. Rather, the drive to repay loans may be an incentive for the pastoralist to overstock in the short term despite causing long term degradation (www.abc.net.au/news/5969748). A high level of dependence on the volatile live export cattle trade exposes producers to high costs of servicing their debt, some having to pay interest rates that up to 2% higher than those paid by other producers (Hydros Consulting 2011).

Banks also have a role in advising investors of the best prospects for investment. ANZ recently commended the incorporation of irrigated pasture crop into northern beef operations, but was less positive about the economic viability of developing a new grain and oilseed industry in the north (Deane 2014). Such a recommendation is likely to affect the availability of credit for these developments.

3. The Grazing Lands Conservation Economy

3.1 Drivers of the conservation economy

Across northern Australia, Indigenous people are looking for opportunities to provide livelihoods. Foremost among preferred options are sustainable

CONCEPT DEFINITION: THE CONSERVATION ECONOMY

This term first appeared in the 1949 Bulletin of the Montana State University (Missoula) Forest and Conservation Experiment Station (Morris 1960), in which it is stated "A ***conservation economy*** provides for sustained yield under natural conditions. Under an improvement economy, with modern techniques, the productivity of the resource may be raised and a higher sustained yields can be obtained" (p75). Since then a conservation economy has come to mean an economy in which healthy resources are not just sustained, but degraded resources are also restored (Gill 2009).

The conservation economy does not involve locking up all resources to prevent them being exploited. Rather, it means making sensible decisions for natural resources to ensure their condition is maintained, so that they can continue to support livelihoods into the future. Nor is investment in the conservation economy a drain on resources. Numerous studies have shown the benefits protected areas and healthy wildlife populations can bring to a regional economy) (Adrian 1998; Balmford et al. 2002; Driml 2010; Lorah et al. 2003; Southwick Associates 2013; Stoeckl et al. 2005). Moreover, improved environmental management can increase profitability by reducing input costs, efficiencies (Landsberg et al. 1998; Roebeling et al. 2007) or increasing production (Di Bella et al. 2014; O'Reagain et al. 2011). Finally, when the environment is valued economically, new economic opportunities can emerge, such as biofuel production (Puri et al. 2012). Some types of environmental services, such as biosecurity surveillance or carbon sequestration and emission abatement, do require investment from government, industry or philanthropic organisations unless self-sustaining markets emerge. But even these activities can provide a multiplier-effect that benefits regional economies (Courtney et al. 2013; Richards 2008) or protect the profitability of enterprises in the region by reducing their exposure to risks, such as weed spread (Martin et al. 2006) or climate change.

The most commonly cited examples of the conservation economy involve direct payments for services by land or water managers, (e.g. stewardship payments (Adams et al. 2012; Fitzhardinge 2012; Morrison et al. 2008; Parker et al. 2006); taking land out of pastoral production for biodiversity conservation (Greiner 2015a, 2015b; Greiner 2015c) or carbon capture and emission abatement (Murphy et al. 2015). However, a broad interpretation of the conservation economy includes any economic decisions in which natural capital is considered and protected (Ehrlich et al. 2004; McNeely et al. 2003).

development and payments for environmental management as these options enable people to maintain and restore their connection to country as their ownership of their traditional lands is recognised through Native Title. In partnership with government, researchers and philanthropic organisations, Indigenous organisations are developing a conservation economy to restore social justice while improving environmental conditions.

The community is also increasingly concerned about environmental degradation of agricultural land and primary producers are under increasing pressure to reverse this trend. Community expectations of land managers include managing the natural resource base on which primary production depends sustainably; reducing water and energy consumption and carbon emissions; and preserving wildlife habitats. Across the globe, consumers are also demanding products that are produced ethically and sustainably. As primary production depends on natural resources for their livelihood (Sandhu et al. 2012), these expectations both increase pressures on managers and provide opportunities for them to derive income – or at least ensure market security – through environmental restoration, protection and sustainable management, as well as through ecotourism that takes advantage of the experiences a healthy environment provides (Fitzhardinge 2012; Garnett et al. 2010; Garnett et al. 2008; Greiner 2009; McKenzie et al. 2014).

This chapter describes how these changing aspirations and expectations are developing into a conservation economy that is already operating in northern Australia to improve livelihoods and environmental conditions. It also examines future opportunities and tries to separate the rhetoric from reality. Much of the writing on the conservation economy is highly theoretical, providing a framework that is only just starting to bear fruit. So, wherever possible, this report provides real-world examples to examine which of the various opportunities proposed in the literature are most promising for northern Australian natural resource managers.

CONCEPT DEFINITION: ECOSYSTEM SERVICES

Ecosystem services are the services that the environment provides that sustain human life and values[111]. Examples include water purification, nutrient cycling, food, shelter and spiritual experiences. While definitions between authors vary, most are based on whether ecosystem services provide us with immediate products or experiences, or whether they keep the ecosystem functioning so that these products and experiences can continue to be produced into the future. Food and water fall into the first category, but so do experiences that fulfill our spiritual, cultural and recreational needs. Examples of how the environment nourishes these needs include the stories associated with sacred sites that help to explain connection to country, or awe-inspiring scenery and rugged landscapes that intensify tourism experiences. Soil formation and photosynthesis (required to produce food) and consumption of mosquito larvae by fish and frogs (which helps to limit spread of malaria and other diseases) are examples of services that benefit us as a society – though not ones we need to directly consume or experience. Other services that we do not directly experience, but we value as a society, include the persistence of wildlife and intact landscapes for future generations.

It is important to distinguish between ecosystem services (which are provided by the environment) and environmental services (which are provided by people managing the environment to maintain or improve ecosystem services), although the terms are often confused (Greiner 2009).

3.2 Instruments of the Conservation Economy

The conservation economy is made up of numerous mechanisms for maintaining, protecting and restoring environmental and cultural values. These are often referred to as market-based instruments (MBIs), because they adjust the economics of the market in favour of goods and services that deliver a positive environmental outcome.

Several attempts have been made to identify which of these mechanisms are most effective at improving environmental outcomes. One consideration is who stands to gain most benefit from the management that needs to be undertaken (Greiner 2014b). Where the public gains from the landholder undertaking a service that the community demands, but has little benefit to the enterprise, then it is reasonable for the community to bear the cost, so positive incentives, especially payments are most applicable. If the landholder stands to gain through improved productivity, then it is considered reasonable that the landholder should bear the cost, and negative incentives, such as taxes and charges may be applicable. This is called the public-private benefit ratio.

Payments, taxes and charges affect the profit margin, acting on the principle that profit is a powerful motivator. Improvements in environmental management are most likely to be gained when more profit can be gained from managing sustainably than from degrading environmental resources (Greiner 2015a; Greiner et al. 2009; Greiner et al. 2011; Morrison et al. 2011).

Regulations or taxes and charges are considered the best mechanisms to address resistance to the adoption of sustainable practices where sustainable management is highly achievable and within expected levels of duty-of-care (Gorddard et al. 2007; Lockie 2013). Examples include regulations aimed at reducing agricultural pollutants reaching the Great Barrier Reef (Aydos 2014); vegetation management regulations adopted by each of the northern State and Territory governments (See Beef Industry case study); and the Emissions Trading Scheme implemented by the Australian Government in 2009 (Andrew et al. 2010), but since repealed (Andrew et al. 2010; Aydos 2014; Jotzo et al. 2009). However, financial incentives will be required to address intractable environmental problems that require landholders to adopt practices that are outside reasonable duty-of-care expectations, especially those that require structural adjustment of enterprises. Most financial incentives do not reward pre-existing good practice, rather a new service must be provided (Schneider 2009). This is called additionality. Some see this as a perverse outcome, as it rewards those with bad practice to improve, rather than early adopters of good practice (Wunder 2009).

So, while the conservation economy provides payments directly to landholders, financial benefits can also be achieved through improved profitability or resource security. In summary, there are essentially four elements to the conservation economy:

Concept definition: Decisions about resource use

Decisions about resource allocation are meant to be made in the best interest of the nation. This is often interpreted as meaning financial gain and jobs. However, in the conservation economy the concept of best interest is much broader, including social, environmental and cultural wellbeing (Dale et al. 2002). The literature on the conservation economy refers to measuring impacts on human, produced, natural and social capitals and economists talk about quadruple bottom-line accounting (Foran et al. 2004).

Dale (2015) identified steps that can be taken to form a robust quadruple bottom-line decision-making process:

1. Implement stable, long-term land use planning;
2. Reform the approvals system for major projects;
3. Improve regional development and natural resource management;
4. Encourage 'ecosystem service markets';
5. Invest in new and innovative regional industries; and
6. Support Traditional Owners to plan their own future.

The outcomes of such a system would also improve the confidence of investors by providing certainty around community support for approved projects.

1. Direct payments, including:
    - Livelihoods derived from payment for environmental work covering the full cost of work (e.g. ranger groups undertaking cultural mapping or feral animal control)
    - Partial payment (usually through auctions or tenders) where benefits are likely to accrue to both the provider and the purchaser (e.g. practice changes that reduce input costs as well reduce pollution) (Lockie 2013)
    - Debt forgiveness or loan guarantees to allow structural adjustments to be made by providers in financial difficulty, where restructuring will provide both environmental benefit and improved enterprise viability (IFAD 2014, Greiner and Lankester (2006)
    - One-off subsidies for improving environmental conditions (e.g. fencing riparian areas).
2. Taxes, charges and trading schemes, including:
    - Pollution trading schemes
    - Biodiversity offset programs.
3. Financial benefits from improved industry viability, including:
    - New industry opportunities to meet the demand for products to reduce societal impacts on the environment (e.g. biofuel production, carbon storage and abatement)
    - Productivity improvements as a result of caring for the natural resource base or *natural capital* (e.g. reducing stocking rates to improve land condition and liveweight gain)
    - Price premiums and market security achieved through ecological certification.
4. Planning decisions based on environmental and social values:
    - Resource allocation and planning decisions that include assessment of ecosystem services and environmental values, and the cost or replacing these services (Jackson et al 2014)
    - Formal recognition of landscape elements as green infrastructure (e.g. in water purification and storm-water control (Lockhart 2009; Sandhu et al. 2012; Tzoulas et al. 2007; Valderrama et al. 2013), although this is currently largely restricted to urban environments and water catchments.

Regulations (such as lease conditions, reef regulations and vegetation management regulations) are not generally considered part of the conservation economy as are not designed to affect market dynamics, but compliance may have an economic impact. Moreover, most aspects of the conservation economy require legislation, regulation and policy frameworks, whether to enable trading of carbon credits or biodiversity offsets or to establish ranger programs or Indigenous Protected Areas.

3.2.1 Market and policy essentials

Like any other market, in addition to a product, payment for environmental service delivery requires willing providers (or sellers) and willing investors (or buyers) linked by a supply chain. Because of the complexities of regulations and high establishment costs, brokers are often involved in establishing links between buyers and sellers and aggregating the efforts of numerous land managers into a saleable commodity (Figure).

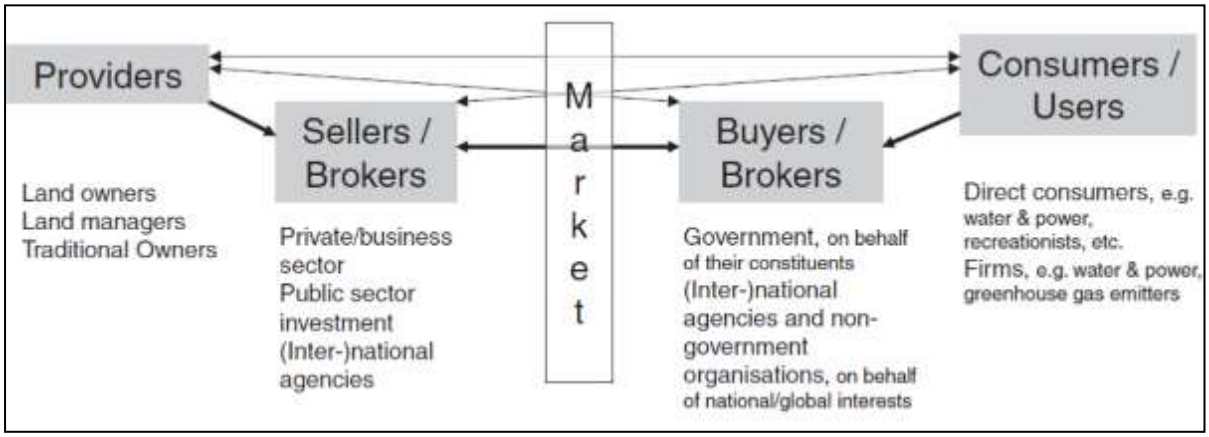


FIGURE 12. MARKET CHARACTERISTICS OF THE CONSERVATION ECONOMY FROM GREINER ET AL (2009).

As discussed above, a number of policy elements are required to support payment for environment (McNeely et al. 2003; van Grieken et al. 2013). These include means of measuring, valuing and verifying the services provided, setting pricing and rules for exchange. The most sophisticated market for environmental services in Australia at present is the Australian Government's Emission Reduction Fund (Fitzhardinge 2012). This has a policy and regulatory framework that approves both methodologies and projects and establishes a market place for purchase.

Markets for most products are driven by demand from the consumer (Masterson et al. 2014). The conservation economy has largely been driven by a philosophical belief that the market should exist, or by providers willing to participate. For this reason, markets for the different services discussed above are at all stages of development from concept to reality. Nature Refuges, conservation agreements, ranger programs, biosecurity and emissions reduction are already reaping payments for north Australian natural resource managers (though mostly with an uncertain future certainty), systems for payments through biodiversity offset schemes are in development, but debt for conservation swaps are only at the concept stage. The following sections describe the state of play for the wide range of carbon economy opportunities, and what can realistically be expected in the future.

Finally, the provider must have the right to undertake the project and sell the product (Dore et al. 2014; Whitten et al. 2005). To undertake a project, it is necessary to be the owner or leaseholder of the land on which the project will be undertaken and for the project to be consistent with the allowed uses for that piece of land. For example, projects that are not related to livestock production may not be permitted on a pastoral lease, and will usually require permission from both the state and the Native Title holders (Dore et al 2014). Rights to provide the commodity being sold are also required. Each State and Territory has a different set of rules on who owns the rights to carbon, and Native Title holders also have interests in carbon (Dore et al 2014).

3.2.2 Prioritisation of conservation investment

Decisions made about investments in the conservation economy are based on the investor's priorities. While the processes they use to determine those priorities are not always clear, they often draw on prioritisation processes that have been undertaken at the international, national or State/Territory level. Priorities are usually based on asset values and condition, perceived threats to them and capacity to protect and manage them, and are then expressed spatially (Luck et al. 2012).

3.3.3 Biodiversity and cultural heritage

Spatial prioritisation of biodiversity conservation effort has mostly been done by non-government organisations and researchers. Individual prioritisation systems tend to focus on either values or threats. At an international level, Northern Australia features in the systems based on biodiversity values, but not in systems based on threats. Value-focused systems that prioritise parts of the Monsoonal North include those focusing on endemic bird areas (Stattersfield et al. 1998), centres of plant diversity (UNEP-WCMC 2013), mega-diversity (Mittermeier et al. 1997), ecoregions (Olson et al. 2002), undeveloped forests (Bryant et al. 1997) and minimum human impact (Sanderson et al. 2002). These prioritisation processes highlight the Kimberley, Top End and Cape York over the Northern Gulf region.

Refer to Appendix 1: Australian national and State/Territory-level conservation prioritisation systems for more details.

Although Australian and State and Territory government obligations to list and protect threatened species and conserve biodiversity through a national reserve system are inviolate, the mechanisms that they choose to employ to do this are subject to change. Australia's Biodiversity Conservation Strategy 2010-2030 (National Biodiversity Strategy Review Task Group 2010) proposes action in "priority areas" but neither explains where these are, nor provides any criteria for identifying them. The National Landcare Programme has no priority areas, but sub-programs that spatially bias investment by prioritising populous areas and degraded landscapes (see Grants, funds and partnerships). Therefore, prioritisation schemes can be used to inform investment, but there is no obligation for governments or other investors to invest according to them.

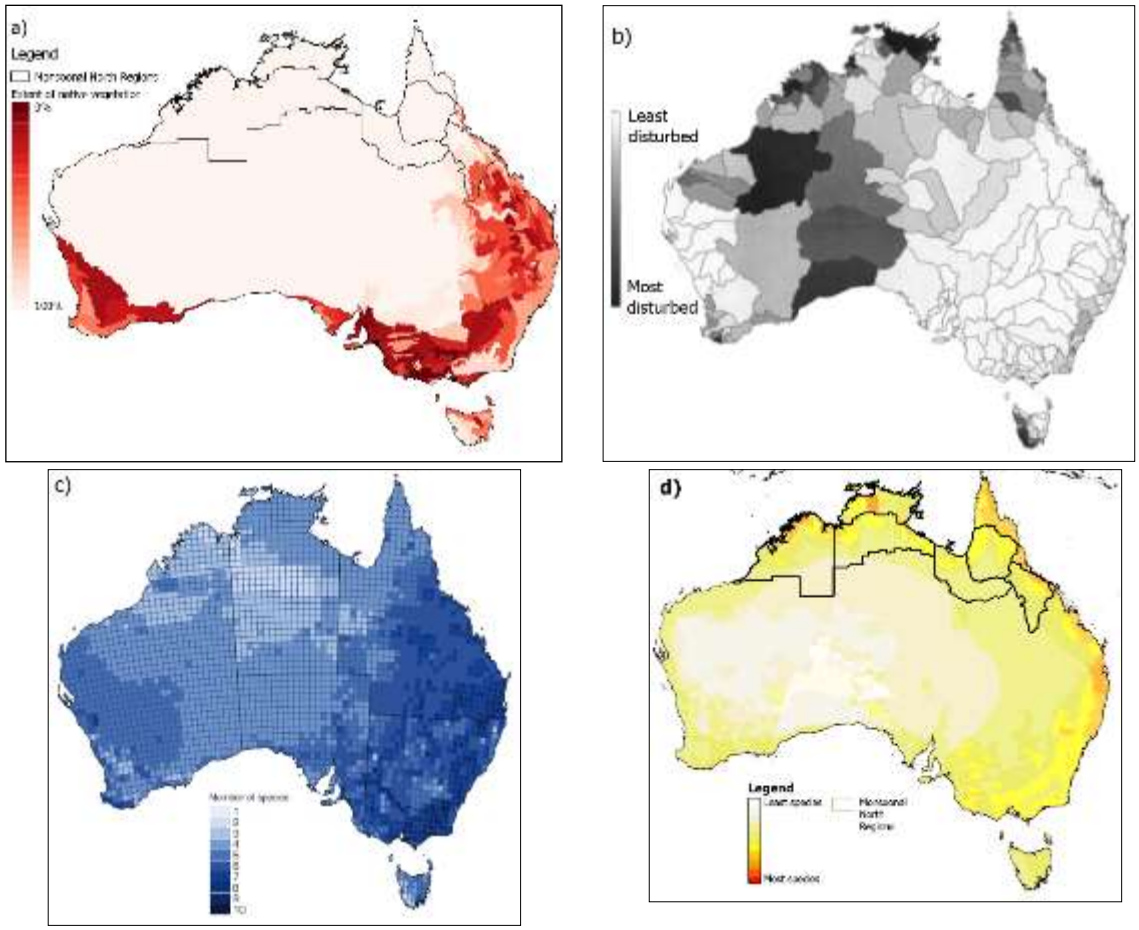
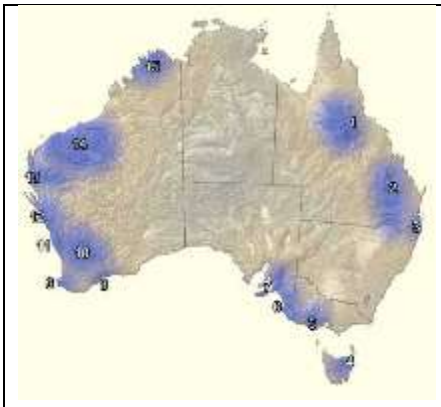


FIGURE 14. PRIORITISATION OF AUSTRALIAN LANDSCAPES BASED ON NATURALNESS A) BIOREGIONAL EXTENT OF NATIVE VEGETATION, B) LEAST DISTURBED RIVER SYSTEMS, C) NUMBER OF INVASIVE VERTEBRATE SPECIES PRESENT AND D) MIGRATORY SPECIES (SOURCE: A) ADAPTED FROM NATIONAL LAND AND WATER RESOURCES AUDIT 2002(NATIONAL LAND AND WATER RESOURCES AUDIT 2002); B) (STEIN ET AL. 2001; STEIN ET AL. 2002)STEIN ET AL. 2001, 2002; C) (WEST 2008)WEST 2008 AND D) (GARNETT ET AL. 2010)ERIN 2009, GARNETT, S.T., ET AL. 2010.)



1	Einasleigh and Desert Uplands
2	Brigalow North and South
3	Border Ranges North and South
4	Midlands of Tasmania
5	Victorian Volcanic Plain
6	South Australia's South-East/ Victoria's South-West
7	Mt Lofty/Kangaroo Island
8	Fitzgerald River Ravensthorpe
9	Busselton Augusta
10	Central and Eastern Avon Wheatbelt
11	Mount Lesueur-Eneabba
12	Geraldton to Shark Bay sand plains
13	Carnarvon Basin
14	Hamersley-Pilbara
15	North Kimberley

FIGURE 15 AUSTRALIAN BIODIVERSITY HOTSPOTS

SOURCE: DEPARTMENT OF ENVIRONMENT[6]

[6] www.environment.gov.au/biodiversity/conservation/hotspots

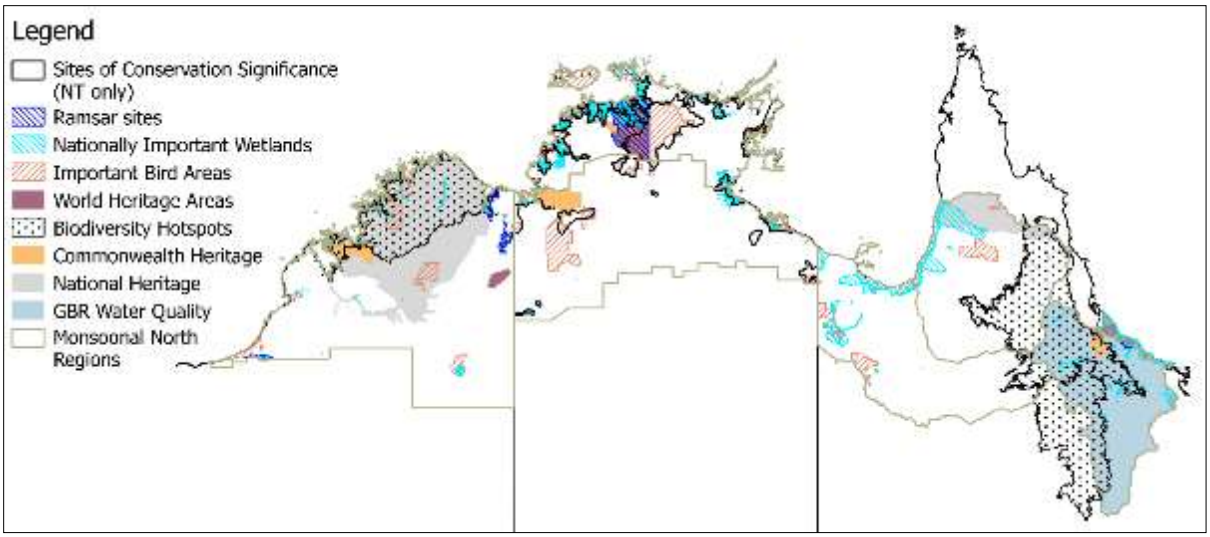


FIGURE 16. PRIORITY AREAS FOR BIODIVERSITY AND HERITAGE CONSERVATION IN THE MONSOONAL NORTH REGIONS

Biodiversity conservation effort needs to be invested in areas that are most resilient to climate change. This does not negate the importance of addressing current knowledge gaps and threats. Rather, it means extending knowledge about species and environments and targeting measures to protect species in areas that are most likely to remain viable habitat for the most species in times of climatic stress (Hodgson et al. 2009; Morecroft et al. 2012). Areas of high elevation are particularly important for retaining species vulnerable to heat stress, but are generally lacking in the Northern Gulf.

Habitat suitability is expected to decline Northern Gulf region (**Error! Reference source not found.**). These projected changes incorporate a combination of species loss and species gain (Figure). Highest species gains are expected in the Einasleigh Uplands as it has the most stable climate (Figure). Species loss is likely if habitat becomes unsuitable as predicted. However, species gain is less certain because of barriers to dispersal caused by areas of unfavourable climate, habitat and land use (Cabrelli et al. 2014). Therefore, high emphasis is placed on areas that are likely to remain suitable for their current suite of species and connectivity to facilitate species movement (Morecroft et al. 2012; Sgrò et al. 2011). Figure 17 indicates that the Gulf plains bioregion of the Northern Gulf region is particularly exposed to species loss.

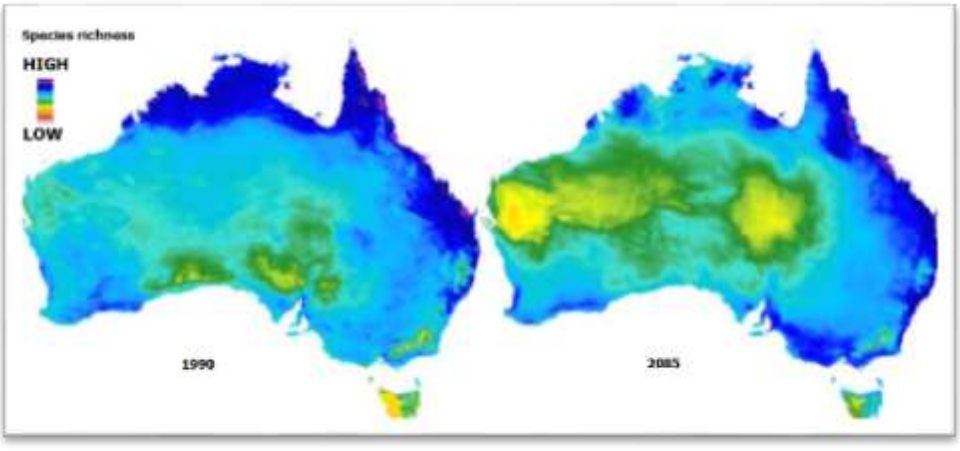


FIGURE 17. PROJECTED CHANGES IN RICHNESS OF BIRD, MAMMAL, REPTILE AND AMPHIBIAN SPECIES, AS MEASURED BY HABITAT SUITABILITY. SOURCE: RESIDE ET AL. (2013)

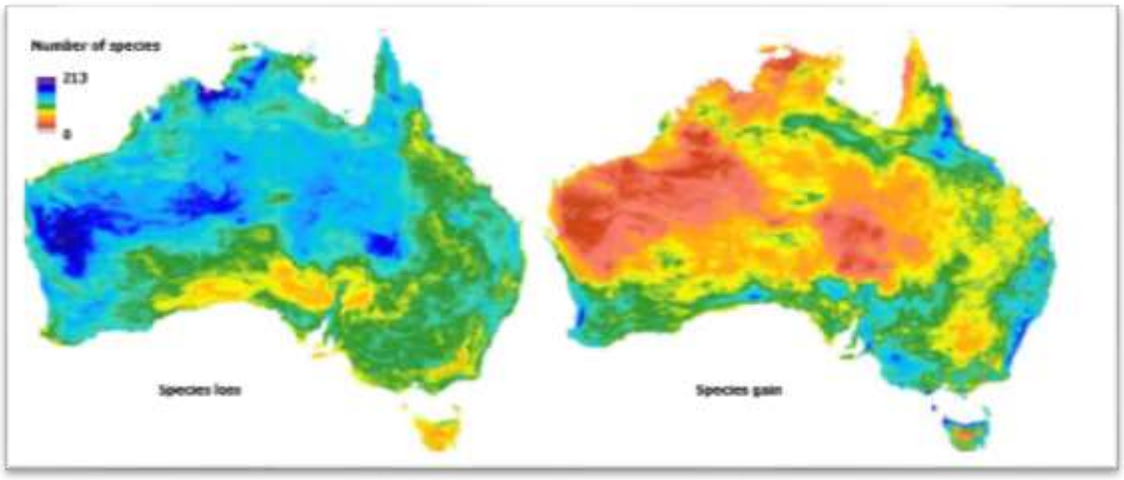


FIGURE 18. PROJECTED LOSS AND GAIN OF BIRD, MAMMAL, REPTILE AND AMPHIBIAN SPECIES BY 2085 AS MEASURED BY HABITAT SUITABILITY. SOURCE: RESIDE ET AL (2013)

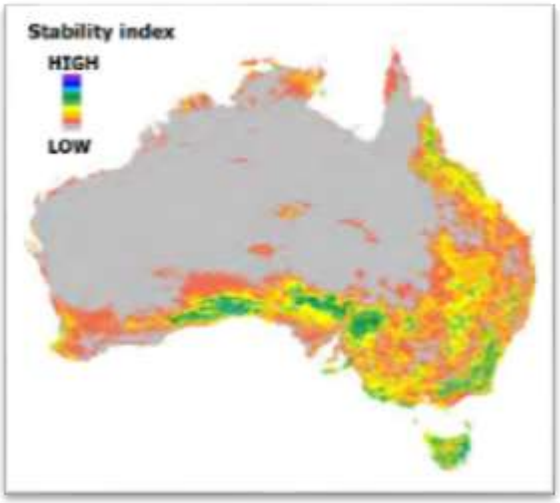


FIGURE 19. PROJECTED STABILITY OF HABITAT SUITABILITY. SOURCE: RESIDE ET AL. (2013)

Incorporating climate change considerations – focusing on areas with expected highest habitat stability and making provision for movement across the landscape by maintaining habitat condition – into prioritisation of conservation effort largely reinforces the importance of the areas and activities prioritised under current climates (Figure). It places additional emphasis on the Einasleigh Uplands bioregion.

Actions critical for biodiversity conservation in Northern Australia include management of fire, weeds pest animals, total grazing pressure and protection of water-remote areas, although these actions need to be backed by strategic research and planning (Bradshaw et al. 2007; Carwardine et al. 2012; Fensham et al. 2008; Fensham et al. 2014; Fisher et al. 2004; James et al. 1999; Myers et al. 2004; Russell-Smith et al. 1992; Woinarski et al. 2003; Woinarski et al. 2011). Declining mammal fauna has been shown to benefit from cattle exclusion in studies in the Kimberley (Legge et al. 2011) and exclusion of cats in the Northern Territory (Frank et al. 2014). While the value of a diverse fire regime has been questioned (Parr et al. 2006), we do know that several species of plants and animals can be eliminated by widespread, intense fires (Yates et al. 2008), and that a patchy fire regime allows species to recolonise burnt areas as the vegetation recovers (Murphy et al. 2010).

Measures to address biodiversity decline in the north have included the establishment of protected areas by State, Territory and Federal governments, non-government organisations and Indigenous groups (Figgis et al. 2005; Langton et al. 2014; Ross et al. 2009; Whitten et al. 2011; Woinarski et al. 2003). Reservation of lands in conservation reserves provides areas with minimal pressures from grazing and weeds, but the value of these reserves is influenced by the condition of land across the region (Woinarski et al. 2013). Therefore conservation of good condition habitat outside reserves is essential.

3.3.4 BIOSECURITY SURVEILLANCE

Australia is currently free of many pests, parasites, diseases and pathogens that are present in neighbouring countries (Thompson et al. 2003; Whittington et al. 2007). These non-native organisms have the potential to affect agricultural crops, livestock, native biodiversity and human health. The risk of them entering Australia is forecast to increase as a result of agricultural expansion and intensification along with increasing global travel and trade and climate change (Black et al. 2008; Meyerson et al. 2002; Simpson et al. 2014; Thompson et al. 2003). Priority areas for averting biosecurity risks in remote areas are Cape York Peninsula extending into the Northern Gulf (Figure).

FIGURE 20. SOURCES OF BIOSECURITY RISKS FOR NORTHERN AUSTRALIA

SOURCE: NORTHERN AUSTRALIA QUARANTINE STRATEGY

3.3.5 Weed and pest animal control

Weeds and pest animals already in Northern Australia have a substantial impact on biodiversity, cultural values, water quality and agricultural production (Bradshaw et al. 2007; Finlayson et al. 1997; Gong et al. 2009; Grice 2006; Kloessing 1994; Robinson et al. 2005; Sinden et al. 2004; Woinarski et al. 2007b; Woinarski et al. 2014). Their control is an environmental service that can be provided by natural resource managers. A certain level of control is expected of agricultural and pastoral producers, and therefore comes under duty-of-care provisions of the legislation in all jurisdictions (Western Australia: ***Biosecurity and Agriculture Management Act 2007***; Northern Territory: ***Weeds Management Act and*** *Territory Parks and Wildlife Conservation Act; Queensland*: ***Land Protection (Pest and Stock Route Management) Act 2002)***. However, there are public benefits to controlling weeds and pest animals. Pastoral properties in north Queensland and the Daly River region of the Northern Territory that manage their weed and pest animals well have the best production and conservation outcomes (Stoeckl 2015; Stoeckl et al. 2015); and effective management reduces weed and pest animal impacts on adjoining conservation and pastoral lands (Bray et al. 2008; Hansen et al. 2007; Preece et al. 2010).

The intractable nature of weeds means that governments are willing to subsidise their control for wide public benefit (Martin et al. 2006). Subsidised weed and pest animal control has been a central part of government sponsored NRM programs from their inception (Curtin et al. 2000; Curtis et al. 1996; Curtis et al. 1998) and continues to be so (Altman 2003)(Altman 2003 OR http://www.nrm.gov.au/national/pest-animal-weed-management). Australian Government NRM funding, which covered weed and pest management, peaked between 2008 and 2012 (Adams et al. in prep). Queensland Government funding for weed control peaked between 1995 and 2003 with the SWEEP program (Martin et al. 2006). The willingness of governments to fund weed and pest animal programs appears to be declining. However, a renewed commitment was shown in the Agricultural Competitiveness White Paper, with an additional $50m being allocated to weed and pest animal management over four years from July 2015, along with $50m to improve biosecurity emergency response capacity (Australian Government 2015).

3.3.6 Carbon

Internationally, action on climate change is coordinated through the United Nations Framework Convention on Climate Change 1992 (UNFCCC) (Pearson 2014)(Pearson 2014 OR http://unfccc.int/essential_background/convention/items/6036.php), to which Australia is one of 195 signatories. The aim of the convention is "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". UNFCCC commits parties to report on emissions generation and develop plans to reduce emissions and their impact on climate change. While individual countries commit to emission reduction targets through the protocols, mechanisms for doing so are left to the discretion of the country. It also directs parties to support climate change mitigation in developing countries by contributing to the Global Environment Facility.

The Convention's Kyoto Protocol OECD[7] countries (which includes 32 first-world countries and 12 countries with economies in transition) were expected to reduce emissions to 5% below 1990 levels between 2008 and 2012. Because of its heavy dependence on fossil fuels, Australia committed to limiting its growth in emissions over this period to 108 per cent of 1990 levels, and achieved a growth limited to 102.5% (Climate Change Authority 2014). Australia has subsequently committed to reducing its emissions to 5% below 2000 levels by 2020 (and 26-28% below 2005 levels by 2030).

Australia's reduction in greenhouse gas emissions has largely been achieved through Land Use, Land-Use Change and Forestry (LULUCF) (Figure), mostly through regulation limiting vegetation clearance (Climate Change Authority 2014). However, changes to tree clearing regulation and improving agricultural commodity prices are expected to increase emissions from the land use sector (Figure).

[7] Members of the Organization for Economic Cooperation and Development in 1992

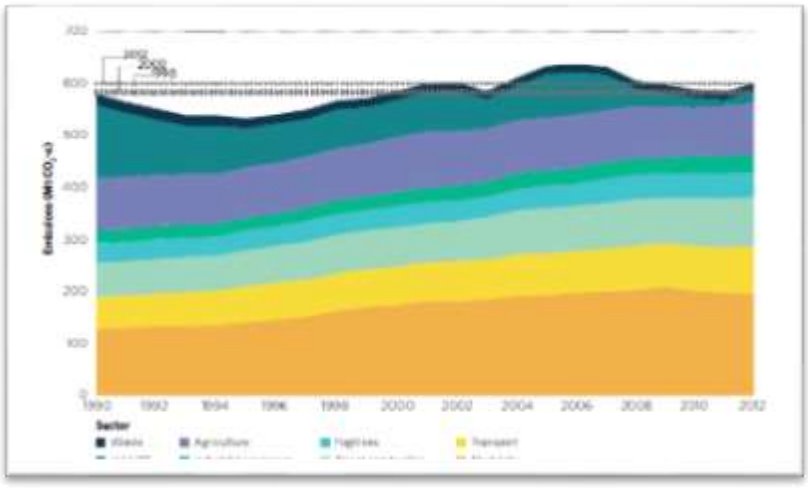


FIGURE 21. AUSTRALIAN GREENHOUSE GAS EMISSIONS BY SECTOR. SOURCE: CLIMATE CHANGE AUTHORITY (2014)

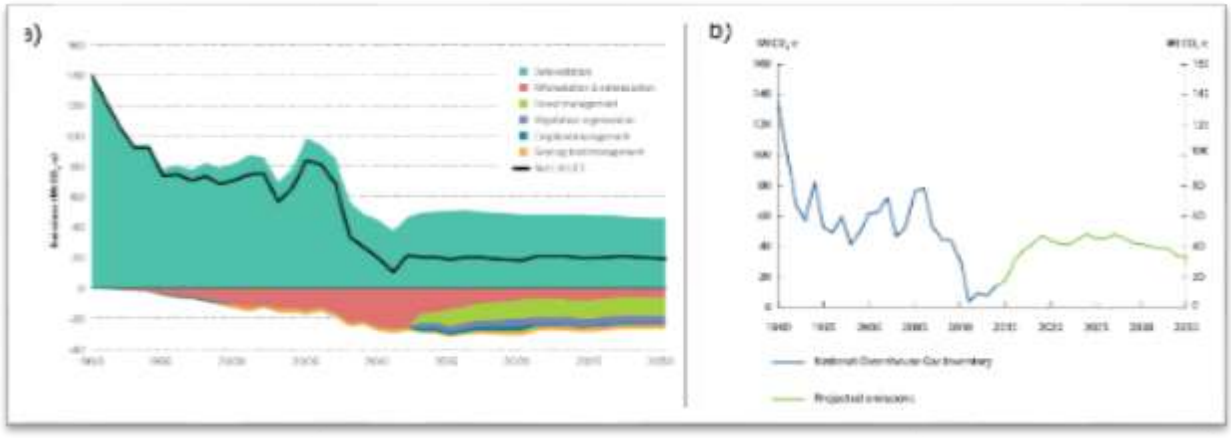


FIGURE 22. HISTORICAL AND PROJECTED AUSTRALIAN GREENHOUSE GAS EMISSIONS FROM LAND USE, LAND USE CHANGE AND FORESTRY BEFORE (A) AND AFTER (B) ACCOUNTING FOR CHANGES TO VEGETATION MANAGEMENT LEGISLATION. SOURCE: (DOE 2015A)

The projections in Figure (a) indicate that forest and vegetation regeneration and forest management are seen as particularly important in helping Australia meet its 2030 greenhouse gas (GHG) emissions reduction target. Avoided deforestation also becomes important to avert the spike in emissions expected as a result of tree clearance. Improved management of crop and grazing lands constitutes a small portion of expected emissions reduction from LULUCF.

Emissions from agriculture (which accounts for approximately 17% of Australia's GHG emissions) are accounted separately from those generated by LULUCF, and include livestock digestive processes; manure management; nitrous oxide emissions from cropping and pastureland soils; and burning of savannas and crop residue. Total agricultural emissions are expected to remain unchanged through to 2020 and then escalate as a result in expansion of cropping and livestock production (Figure). Efforts to improve efficiency are therefore important.

FIGURE 23. HISTORICAL AND PROJECTED CONTRIBUTION OF LIVESTOCK, CROPPING AND SAVANNA BURNING TO AUSTRALIAN GHG EMISSIONS. SOURCE: DEPARTMENT OF ENVIRONMENT (2015)

Most states and territories reduced their GHG emissions between 2000 and 2013[263]. Only Western Australia's emissions substantially increased, largely as a result increased energy production. Queensland consistently ranks as one of the highest GHG emitters, producing 29% of Australia's emissions in 2013. It also produced the most agricultural emissions (31%), notably from livestock (34%). While most jurisdictions had negative emissions from LULUCF (with abatement from reforestation and forest management more than compensating for emissions from deforestation), Queensland produced nett emissions of 25.2 Mt CO_2-e from LULUCF. This was because Queensland generated by far the most emissions from vegetation clearance (48%), despite a 63% reduction in emissions from this source since 2000. Only three jurisdictions generated substantial emissions from savanna burning: Northern Territory (40%), Queensland (30%) and Western Australia (30%). As many Northern Gulf pastoralists do not use fire extensively, the opportunities for reducing carbon emissions by adapting fire regimes is limited (Rolfe, pers comm, 2015).

There are several potential ways landholders can store carbon or reduce GHG emissions. These include avoided deforestation, tree planting and regrowth, reducing the spread of late dry season fires, reducing emissions from livestock and increasing soil carbon. Methods that are approved or under development are discussed below. Despite the large amounts of carbon being sequestered in tropical wetlands each year (Chmura et al. 2003; Mitsch et al. 2010), wetland restoration is not recognised under the Kyoto protocol. So there is currently no Emissions Reduction Fund (ERF) method available to account for wetland sequestration.

3.3.7 SAVANNA BURNING

Modifying burning regimes in tropical savannas is applicable across much of the Monsoonal Northern Australia[8]. As with methods that involve sequestering carbon in trees, savanna burning will be most effective in areas that have the greatest biomass, which provides the fuel to burn. However, it is the methane and nitrous oxide products of burning that provide the carbon credits, as these greenhouse gases are assumed to remain in the atmosphere for several decades longer than carbon dioxide does.

Areas where modifying savanna burning is viable depends on the price of carbon (Figure). At $60/tonne, it is viable across most of northern Australia (Heckbert et al. 2012). At the 2015 price of ca $15/tonne the viable area is considerably reduced, but still provides the basis of a carbon economy across much of the north.

[8] Emission reduction fund methodologies: Savanna Burning (repealed), Savanna Fire Management

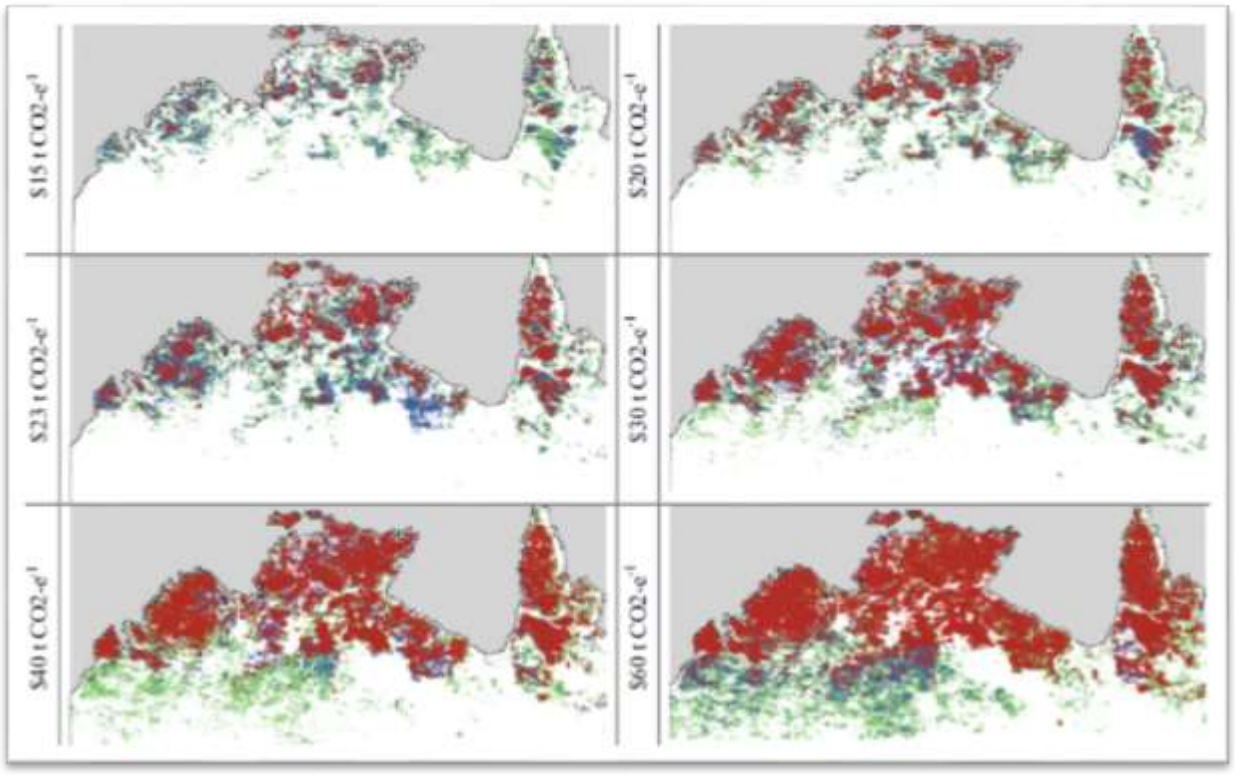


FIGURE 24. VIABILITY OF MANAGING FIRE TO REDUCE CARBON EMISSIONS ACHIEVING REDUCTIONS OF 25% (RED), 34% (BLUE) AND 48% (GREEN) UNDER SIX CARBON PRICES

SOURCE: HECKBERT ET AL. (2012)[270]

3.3.8 REDUCING METHANE EMISSIONS FROM BEEF CATTLE

Cattle produce methane through enteric fermentation: methane conversion to carbohydrates by microbes living in the digestive system, which is then belched back into the atmosphere (Moss et al. 2000). Methane is a significant GHG because it has a high global warming potential. Enteric fermentation accounts for 66% of Australia's agricultural emissions, and around 10% of Australia's total emissions (DoE 2015a) . It is therefore the agricultural emission source that is the highest priority for targeted reduction. Conversion of carbohydrates to methane reduces the efficiency of food conversion by up to 12% (Patra 2012), so reduction in enteric fermentation has productivity benefits as well as emission reduction benefits.

The Monsoonal North of Australia carries about one-fifth of the Australian beef cattle herd, so includes some of the highest priority areas for reducing enteric emissions in the country (Figure , Table).

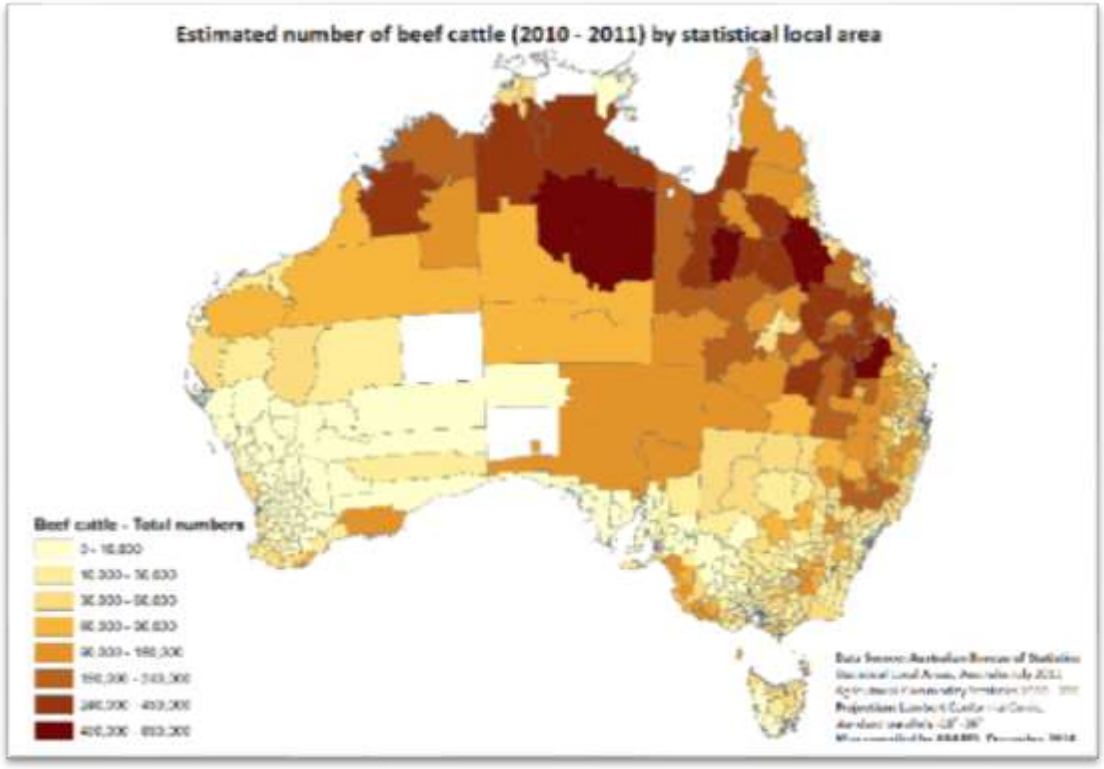


FIGURE 25. NUMBERS OF BEEF CATTLE IN AUSTRALIA IN 2011. SOURCE: ABARES

TABLE 9. NUMBER OF BEEF CATTLE OPERATIONS IN THE MONSOONAL NORTH IN 2010-11, AND THEIR RELATIVE IMPORTANCE. SOURCE: AUSTRALIAN BUREAU OF STATISTICS; (CROWLEY ET AL. 2013A)

	Kimberley	Top End	Gulf Savanna	Southern Gulf	Northern Gulf	Burdekin Dry Tropics	Total
Number of cattle businesses	68	40	108	272	313	750	2233
Percentage of Australian cattle herd	2.6	0.5	3.3	5.3	3.2	5.0	20.0
Average herd size	10,400	3,800	8,400	5,400	2,800	1,900	3,500

3.3.9 INCREASING SOIL CARBON

In a grazed landscape, soil carbon concentrations are highest around the bases of perennial grasses (**Error! Reference source not found.**). Therefore, poor grazing management that eliminates perennial grasses reduces the amount of carbon entering the soil. Reducing vegetation cover also increases soil temperature, which, in turn accelerates decomposition of soil organic matter (Piñeiro et al. 2010). Hence, improvements to grazing management practices have potential to increase soil carbon and contribute to Australia's GHG emission reduction targets (Allen et al. 2010; Lal 2004); and an Emission Reduction Fund method has been developed for *Sequestering carbon in soils in grazing systems*[9].

[9] www.environment.gov.au/climate-change/emissions-reduction-fund/methods/sequestering-carbon-in-soils

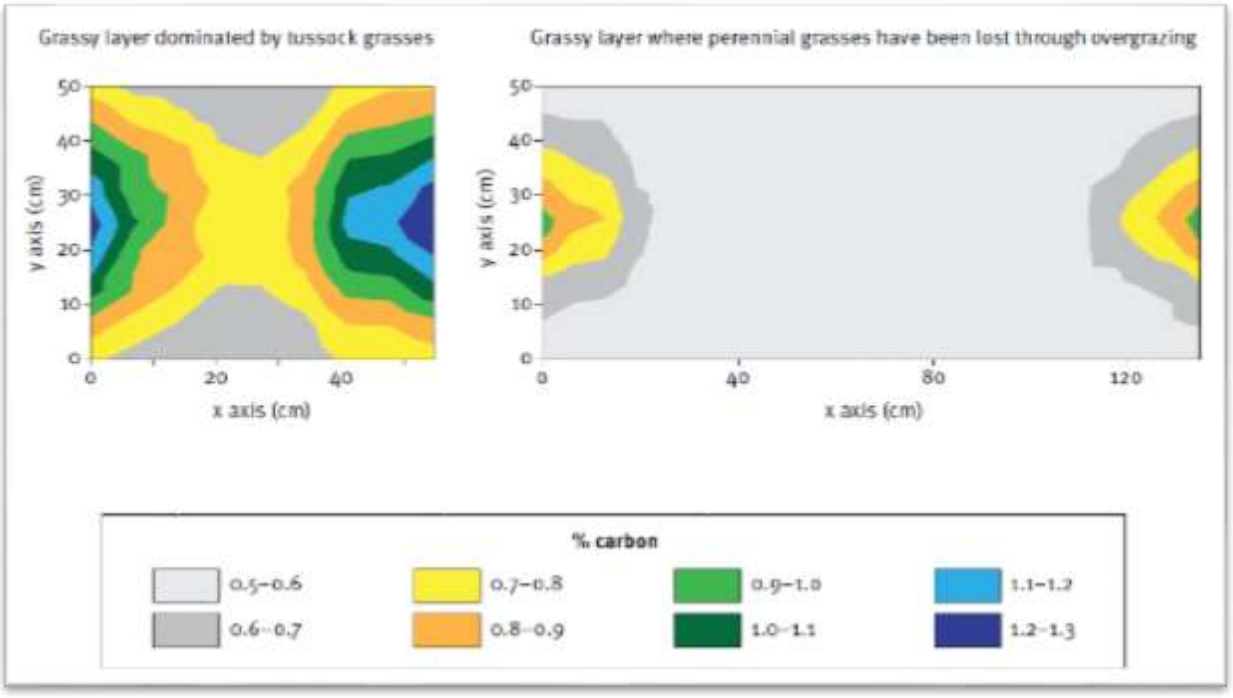


FIGURE 26. SOIL CARBON CONCENTRATION IN RELATION TO PERENNIAL GRASS TUSSOCK IN GOOD CONDITION LAND (LEFT) AND POOR CONDITION LAND (RIGHT). SOURCE: ASH ET AL. (2002)

However, a review of the science indicates that soil carbon concentrations cannot be predictably linked to any set of management regimes (Bray et al. 2009; Hunt 2014; Lam et al. 2013). While, in any one location, carbon is likely to be found in highest concentration around plants, this pattern is not necessarily repeated across the broader landscape (Conant et al. 2001; Post et al. 2000). In fact, landscape-scale studies have variously shown no difference in carbon between grazed and ungrazed areas; lower carbon in grazed than in ungrazed areas; and higher carbon in grazed than in ungrazed areas (Carter et al. 2009; Medina-Roldán et al. 2012; Pringle et al. 2014; Walsh 2014). Failure of carbon to respond predictably to changes in grazing pressure at the landscape-scale has been attributed to the effects of soil texture and condition (Pringle et al. 2011); nitrogen fertilization from dung (which influences organic matter production) (Piñeiro et al. 2010; Walsh et al. 2014); relative cover of shrubs and grasses (Asner et al. 2003) [289]; relative cover of C3 and C4 plants (Derner et al. 2006); fire regime (O'Neill et al. 2003; Riedell et al. 2011; Wardle et al. 2003); activity of termites and other soil biota (Bignell et al. 1997); and variation in temperature, rainfall and soil moisture (Piñeiro et al. 2010). As a result, instead of improved grazing management increasing the amount of carbon stored in the soil, it may just be making it available for loss through another pathway, such as fire, termites or soil respiration.

The uncertainty of how management affects soil carbon is recognised by the Emission Reduction Fund. Unlike for other methods – in which models can be used to determine the carbon credits generated from practices such as reducing fire extent or growing trees – the *sequestering carbon in soils in grazing systems* method requires rigorous sampling be undertaken to demonstrate changes in soil carbon. This involves baseline sampling and resampling before each carbon crediting report is submitted (which must be at least every five years). The requirements of the methodology are presented here, as their complexity and expense will affect the viability of a project to sequester soil carbon and the willingness of landholders to participate.

At each sampling period, the project area is divided into one or more carbon estimation areas, each of which is divided into three or more strata (**Error! Reference source not found.**). A sample is taken from each stratum and combined to form a composite sample. This is repeated at least three times to form three composites across the project area.

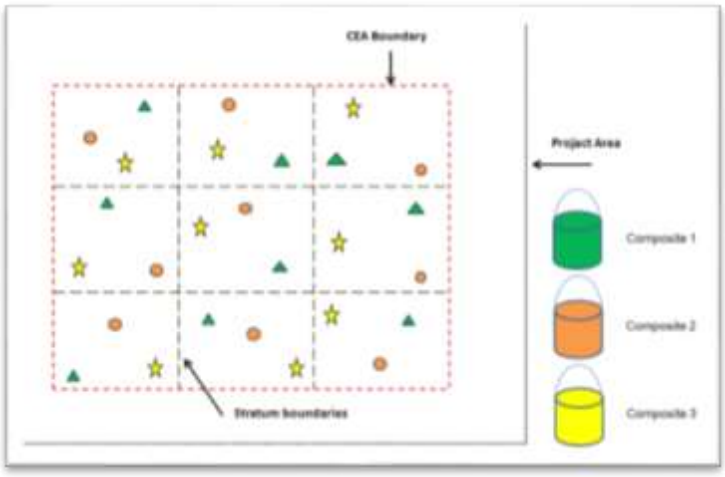


FIGURE27. EXAMPLE SAMPLING REGIME FOR A CARBON ASSESSMENT AREA (CAE) SHOWING NINE STRATA, EACH WITH THREE SAMPLE LOCATIONS. SOURCE: DEPARTMENT OF ENVIRONMENT (2014)

The number of composite samples that must be taken is dictated by the level of change that is to be detected (Figure). Recorded changes in soil organic carbon with practice change range from a decrease of 0.09 t/ha/year to an increase of 0.71 t/ha/year, with grazing exclusion producing changes of between -0.09 to +0.35 t/ha/year (Conant et al. 2001; Post et al. 2000). This is equivalent to a range of -0.45 to +1.75 t/ha over a five year period. Examination of Figure indicates that changes of this order of magnitude would require at least ten composite samples over ten strata. This is effectively 100 samples combined into 10 composites.

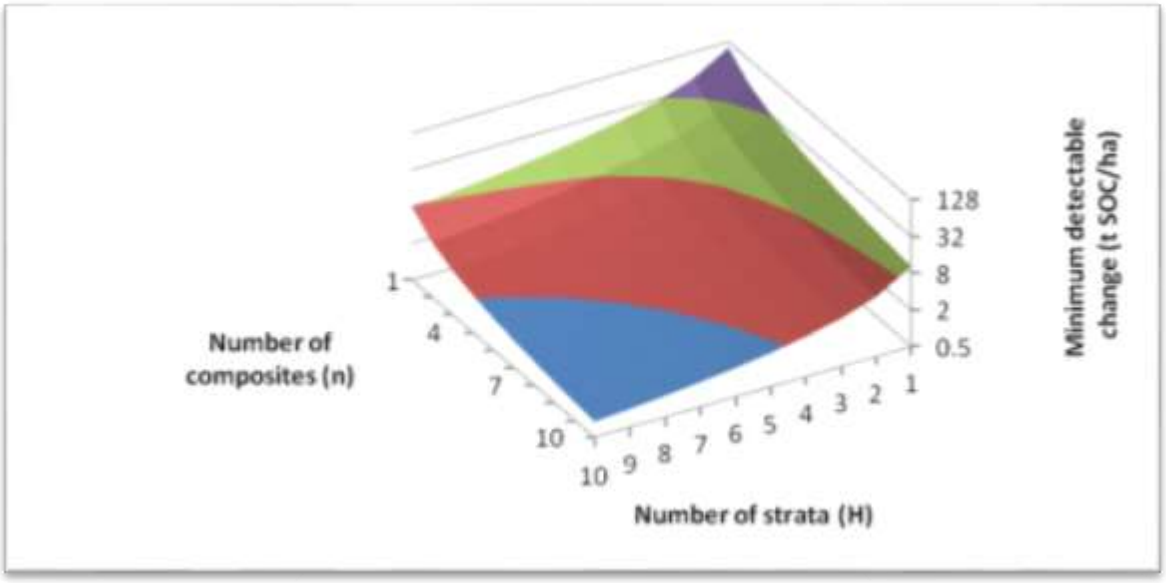


FIGURE 28. RELATIONSHIP BETWEEN THE NUMBER OF COMPOSITE SOIL SAMPLES AND SAMPLING STRATA AND THE MAGNITUDE OF CHANGES IN SOIL ORGANIC CARBON (SOC) THAT CAN BE DETECTED. SOURCE: DEPARTMENT OF ENVIRONMENT (2014)

Uptake of this methodology will also depend on the expected level of return. At the current price of ca $15/t, landholders achieving soil carbon improvements the top end of the expected range (an increase of 1.75 t/ha in five years) would receive an income of ca $26/ha once every five years. At the lower end of the range (a decrease of 0.45t/ha), the landholder would be required to pay ca $7/ha every five years. These amounts do not include the

deductions that must be made for emissions generated in the project from livestock production, tillage and any application of lime and other fertilisers. These compulsory deductions would reduce the income that could be derived in the most optimistic scenario and increase the debt in the most pessimistic one.

As there is currently no reliable way to identify practices guaranteed to improve soil carbon, the transaction and financial costs of establishing a project are likely to be inhibitive, and it is impossible to identify the priority areas for undertaking such a project. That said, by September 2015, there were 10 ERF approved projects using the soil carbon method, two of which include land in the Monsoonal North (see Table). It is hoped that these projects identify methods that can permanently sequester carbon in the soil profile in the monsoonal tropics.

3.3.10 Grazing land stewardship

Much hope has been invested in the potential for Grazing land managers to derive additional income from conservation and stewardship arrangements (Greiner 2009; Greiner 2014a; Greiner 2014b; Greiner 2015a, 2015b; Greiner 2015c). The sustainable management of agricultural lands provides numerous public benefits. These include providing food for the nation and export income; maintaining a labour-force to address pests, weeds and fire issues; maintaining biodiversity; improving water quality; and preserving lands in a condition that leaves open options for future use of the land (Attwood et al. 2009; Dobbs et al. 2008; Scherr et al. 2008). Stewardship payments aim to protect and restore agricultural lands for these functions (Dobbs et al. 2004).

3.3.11 Synthesis

The above assessment of conservation priorities identified many opportunities for the conservation economy in Northern Australia. It also explains why some propositions may never progress beyond the concept stage. Conservation agendas are set at the international level by conventions to which Australia is a party, and to which the states and territories have committed through COAG. Each convention includes prioritisation of sustainable development and social justice, directing the investment of most foreign governments and NGOs to developing countries. This philosophy also informs the operation of NGOS operating in Australia, with biodiversity conservation on Indigenous land seen as a win-win situation.

Biodiversity conservation offers opportunities for Indigenous businesses and employment in in the Kimberley and Top End. Fire management for carbon abatement is viable through much of the Monsoonal North.

The following section explores how these priorities have been translated to market.

3.4 Conservation economy opportunities for the Monsoonal North

Despite lacking an overarching framework (Dale 2015), the conservation economy already exists in Australia (Figure). Governments have regulated to improve biodiversity, soil and water conservation and sustainable production. Australia has international obligations under the UN Convention on Biological Diversity to protect biodiversity (UNEP 1992) and, while biodiversity management has traditionally been the reserve of the state, recognition of the need to extend conservation outside state-owned reserves is being supported by government policies and programs that include offset and incentive payments.

Exotic weeds, pest animals, diseases and pathogens threaten biodiversity, cultural values and production systems. Governments have therefore long provided financial support for landholders to control them. Indigenous organisations have also been successful in earning income from biosecurity surveillance.

Improving economic, social and spiritual wellbeing through payment for other forms of cultural and natural resource management is a priority of many Indigenous communities, and they have been supported in this by government programs and non-government organisations. This includes, but is not restricted to, managing Indigenous lands as formalised conservation reserves.

Moving agricultural production into the conservation economy requires producers to improve the sustainability of their management systems. Numerous extension programs are in place to assist producers do so, and loans to support this

transition are available in Queensland, although there is perhaps a greater need to assist those already burdened with crippling debt. While great store has placed on the potential for stewardship payments to provide incentive payments for improving sustainability of pastoral enterprises, few such schemes exist outside Europe and those established in Australia have been short-lived. There is also potential for product branding to reward producers who adopt sustainable management by improving market share and prices.

Carbon and energy efficiency are central to the conservation economy, with both major parties committed to reducing emissions, although with different approaches. Land management has an integral role to play in delivering Australia's emission reduction commitments.

Finally, two developing areas that are beyond the scope of his report are the growing market for alternative energy and reliable low-cost energy supplies is also providing new business opportunities in biofuel and renewable energy production, and the recognition of ecosystem services in the form of green infrastructure, such as water purification, sewerage treatment and storm water control.

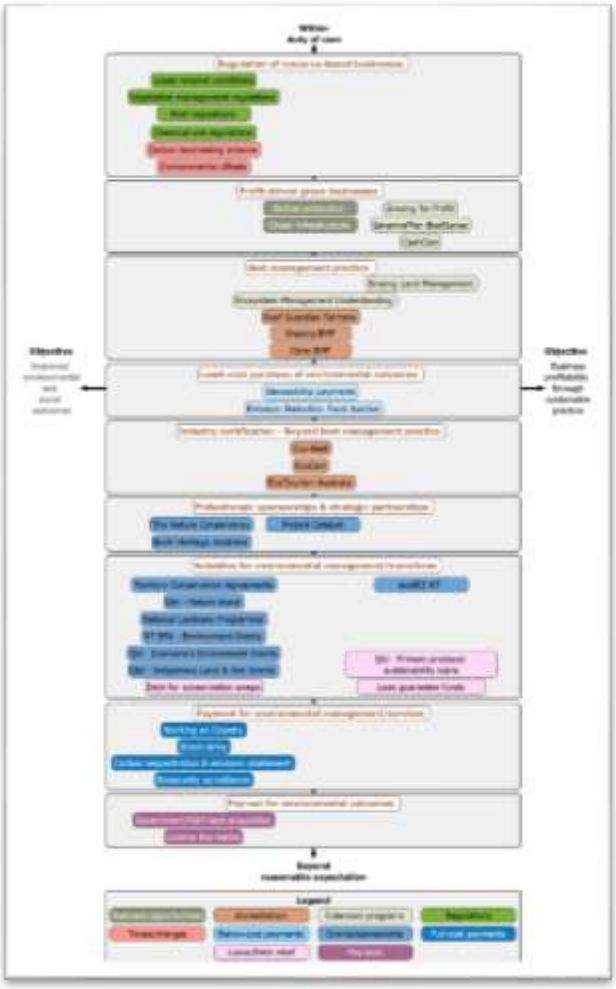


FIGURE 29. CONSERVATION ECONOMY OPPORTUNITIES PRESENTED ON THE LOCKIE MATRIX

The main sources of funds for NRM are the Australian and State Governments. Each program and funding round has a different emphasis. There are also numerous non-government granting bodies that support efforts to improve livelihoods and sustainability. Several non-government organisations also support livelihood and sustainability projects through targeted partnership arrangements. These opportunities are outlined below.

3.4.1 Australian Government funding programs

Several Australian Government programs provide financial support for support cultural and natural resource management (Table). The nature of these programs has changed with changing administrations (see Table). Some programs are targeted at specific outcomes, such as Indigenous cultural and natural resource management, reef water quality or GHG emissions reduction. Others are more general, and provide support for a broad range of activities to improve environmental conditions or agricultural sustainability. Funding rounds are usually announced annually, and may cover a period of six months to several years.

Historically, the Monsoonal North (which covers approximately 20% of Australia's land surface) has received representative funding from National and State Government granting schemes only for Indigenous NRM and reef water quality. As discussed earlier, the low percentages of funding received from most NRM programs can be attributed to the priorities of these programs not aligning with the biodiversity values of the region, but being focused on land rehabilitation and employment (Dale et al (in press)..

There is also a lack of a coherent strategy to address national NRM needs as a result of Australia's Biodiversity Conservation Strategy (National Biodiversity Strategy Review Task Group 2010) being replaced by "The Plan for a Cleaner Environment", with its four pillars of Clean Air, Clean Land, Clean Water and National Heritage, each with isolated programs.

The conservation economy opportunities provided by these federal programs and their relevance to the Monsoonal North are discussed in the following sections of this chapter.

TABLE 10. RECENT FUNDING BY CURRENT AUSTRALIAN GOVERNMENT PROGRAMS FOR NATURAL AND CULTURAL RESOURCE MANAGEMENT

SOURCES: *WWW.DPMC.GOV.AU/INDIGENOUS-AFFAIRS/GRANTS-AND-FUNDING/IAS-GRANT-EXPENDITURE; WWW.ENVIRONMENT.GOV.AU; DPMC (2015)*

NOTES: N/A = NOT AVAILABLE; *COMPONENTS OF THE JOBS, LAND AND ECONOMY PROGRAMME

Focus	Funding period	Budget	Grant limit	Monsoonal North	
				Projects (%)	Funds (%)
Indigenous Advancement Strategy – Jobs, Land and Economy Programme					
Providing Indigenous employment and business opportunities in land management	2014-18	$2.5 b	N/A	N/A	N/A
Working on Country*					
Indigenous NRM	2014-16	$19.4 m	N/A	63.6	90.5
Indigenous Protected Areas*					
Protection of cultural and natural and resources on Indigenous lands	2013-18	$78.3 m	N/A	36.4	36.2
National Landcare Programme					
Environment stream – • Invasive species management • Sustainable agriculture • Erosion management • Capacity building	2014-15	$2.5 m	$20k	3.5	4
Agriculture stream – • Invasive species management • Revegetation • Habitat fencing • Indigenous land & sea country planning • Indigenous Ecological Knowledge • Capacity building	2014-15	$2.5 m	$20k	5.1	6.4
Regional funding • Lead, prioritise and support regional NRM • Build and broker NRM partnerships • Support Indigenous NRM • Contribute to Australia's national & international conservation obligations	2014/15 - 2017/18	$450 m	N/A	N/A	ca 6.0
Threatened Species Strategy					
Creating safe havens for species most at risk	2015-	$2.7 m	N/A	0	0
Improving habitat	2015-	$0.7 m	N/A	0	0
Intervening in emergencies to avert extinctions	2015-	$0.6 m	N/A	0	0
Tackling feral cats	2015-	$2.7 m	N/A	28.6	18.0
20 Million Trees					
Tree planting for revegetation and emission abatement	2014-2015	$9 m	$100k	0	0
Green Army					
Employment scheme to • Protect habitats • Restore native vegetation restoration • Regenerate wetlands • Restore heritage	2014-2015	$175 m	Labour (& material to $10k)	3.8	N/A
Reef Trust					
Phase I - On-ground action - Innovative, targeted investment to improve water quality, restore coastal ecosystem health and enhance species protection	2015-	$8 m	N/A	50.0	ca 15
Phase I – Species management	2015-	$7 m	N/A	Reef-wide	
Heritage					
Community heritage & icons grants	2014-15	$0.28 m	$10k	6.7	7.1
Emissions Reduction Fund					
Market-based GHG emission reduction from land, agriculture, waste, energy and fuel sectors	2015	$660 m	N/A	7.9	ca 9.8

TABLE 11. PAST FUNDING ROUNDS OF DISCONTINUED AUSTRALIAN GOVERNMENT SOURCES OF FUNDING FOR NATURAL AND CULTURAL RESOURCE MANAGEMENT

SOURCE: ***WWW.ENVIRONMENT.GOV.AU***
NOTES: /A = NOT AVAILABLE; INFORMATION FROM MOST RECENT FUNDING ROUND ONLY

Focus	Funding period	Budget	Grant limit	Monsoonal North	
				Projects (%)	Funds (%)
Caring for our Country					
Environmental stewardship 10 to 15-year agreements to improve the condition and extent of nationally-threatened ecological communities	2008-	$50 m	N/A	0	0
Caring for our Country 2					
Target Area Grants • Central Australian Connection • Cape York • Kimberley • Tasmania • south-west Western Australia • urban waterways and coastal environments	2013-14	$36.6 m	$2.5 m	6.5	5.9
Innovation grants • Improving sustainability of food production & fishing • Reducing weed and pest impacts on agriculture • Capacity building	2013-14	$21.3 m	$1.5 m	8.2	6.5
Reef Rescue Support land management practices to reduce sediment, nutrients and pesticides in runoff to the Great Barrier Reef	2013-14	$61 m	N/A	14.3	24.6
World Heritage grants	2013-14	$36.1 m	N/A	14.3	1.7

3.4.2 INDIGENOUS PROTECTED AREAS

About one-third of Australia's National Reserve System is in Indigenous Protected Areas (IPAs) (Figure 30)[10]. Traditional Owners can establish an IPA over land or sea that they have decided to manage for biodiversity and cultural resource conservation. Designation as IUCN Category VI (A Protected Area managed mainly for the sustainable use of natural ecosystems) enables Indigenous people to continue to derive livelihoods from hunting and harvesting. As part of Caring for our Country, the Australian Government budget to support the planning and consultation required to establish IPAs between 2008-2013 was $50 m. Funding for management was provided through the Working on Country program (see below). Funding was also used to establish co-management arrangements over non-Indigenous protected areas. The program was extended in 2013, with a further $78 m provided up until 2018[11], and again in October 2014, providing $7.2 m 14 IPAs under the Job, Lands and Economy Program of the Indigenous Advancement Strategy (see below)[12].

[10] www.environment.gov.au/indigenous/ipa/index.html

[11] www.environment.gov.au/indigenous/ipa/news.html

[12] www.indigenous.gov.au/news-and-media/announcements/minister-scullion-14-indigenous-protected-areas-care-country

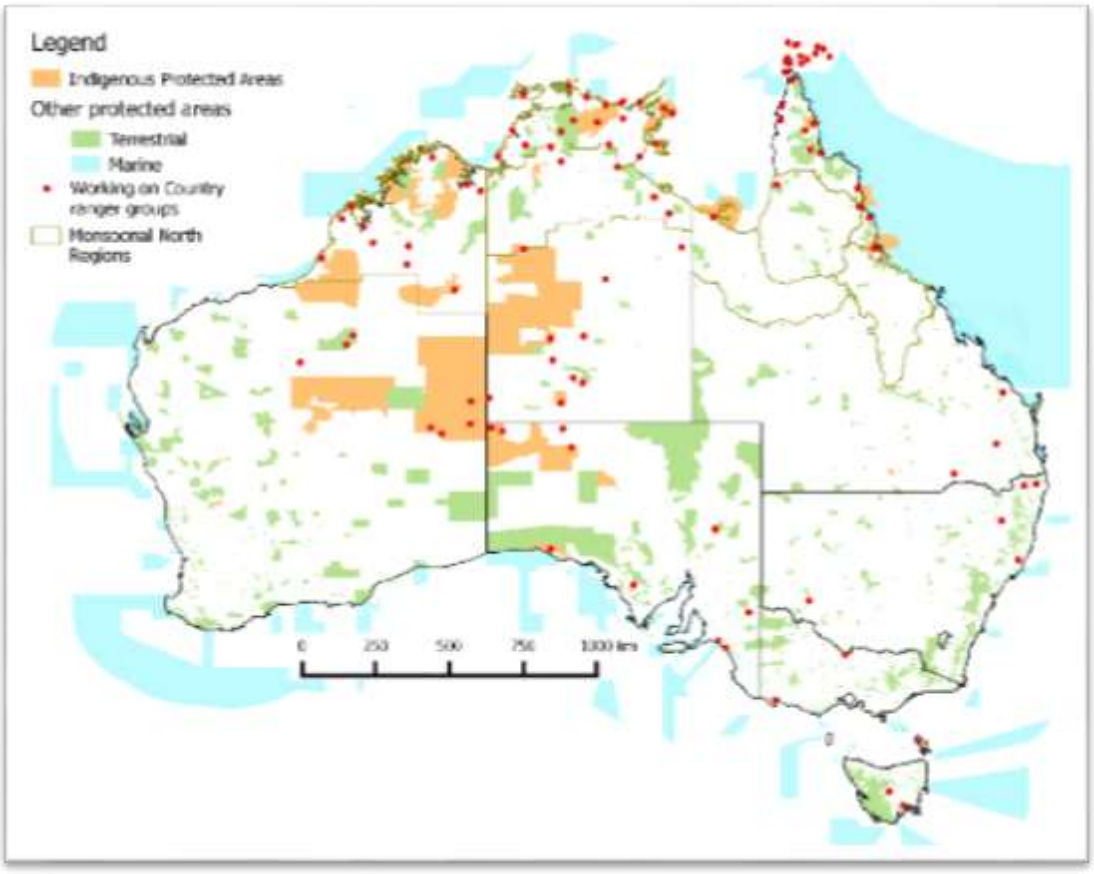


FIGURE 30. LOCATION OF WORKING ON COUNTRY RANGER GROUPS AND INDIGENOUS PROTECTED AREAS

SOURCE: RANGER GROUPS: ***WWW.ENVIRONMENT.GOV.AU/INDIGENOUS/WORKINGONCOUNTRY/INDEX.HTML***

PROTECTED AREAS: ***WWW.ENVIRONMENT.GOV.AU/FED/CATALOG/MAIN/HOME.PAGE***

3.4.3 Working on Country

Since 2008, the Australian Government Working on Country program has provided wages to Indigenous rangers to fulfill their Caring for Country aspirations and protect and manage environmental and heritage values (Allen Consulting Group 2011; Baker et al. 2001; May 2010; Urbis Pty Ltd 2012). The original commitment was $90m to fund 300 rangers over five years and subsequently increased to $244m. A second $320m, five-year program commenced in 2013. The program currently employs around 700 rangers in 95 ranger groups across Australia (Burgess et al. 2005), about one-third of which are based in the Monsoonal North (Figure 30). Working on Country has increased the income of Indigenous participants and their communities and reduced welfare dependence (Allen Consulting Group 2011).

The program provides funding on a competitive basis to ranger groups or host organisations to support a mix of full-time positions, part-time or casual positions and targeted traineeships. Funding is only available to Indigenous groups and must be used to employ Indigenous people. The area on which the work is to be done must have a current environmental management plan, and permission must be obtained from Traditional Owners and other interested parties before an application can proceed. Work undertaken has included cultural mapping and management of cultural sites; intergenerational knowledge transfer; weed and feral animal control; monitoring and management of threatened species and their habitats and fire management.

3.4.4. Indigenous Carbon Farming Fund

In 2014, the Australian Government's Indigenous Carbon Farming Fund provided $4.2 million to help Indigenous Australians benefit from carbon farming opportunities (Figgis et al. 2005). Activities funded included education, consultation, feasibility assessments and development of methodologies applicable to Indigenous participants. Although $22.3m was committed over 5 years, no further funding rounds have been announced.

3.4.5 Indigenous Advancement Strategy

In 2014, the Australian Government developed a $4.9b Indigenous Advancement Strategy (IAS) to replace more than 150 different Indigenous programs[13]. Programs made redundant by this strategy include Indigenous Protected Areas, Community Development Employment Projects, Indigenous Carbon Farming Fund, and Indigenous Heritage Programme (DPMC 2015). Organisations previously funded under any of these programs must now apply under the six IAS programs. Five-year commitments made to continue Working on Country and the Remote Jobs and Communities Programme continue under the IAS.

The IAS includes the objective of increasing Indigenous employment and businesses engaging in land management. It also includes objectives relating to education and training and improving the safety and equity of remote communities.

Programs under this strategy that are relevant to Indigenous participation in the conservation economy are the $2.5b Jobs, Land and Economy Programme (Table) and the $240m Remote Australia Programme. The Jobs, Land and Economy programme commits to:

- Long-term Indigenous employment in land and sea management,
- Training and skill development to support long-term employment,
- Development of Indigenous businesses and community enterprises,
- Settlement of Land rights claims and changes in land tenure to facilitate economic development, and
- Building capacity of native title corporations to promote sustainable economic and social benefits, and meet their statutory obligations.

TABLE 12. FUNDING FOR THE JOBS, LAND AND ECONOMY PROGRAMME OF THE INDIGENOUS ADVANCEMENT STRATEGY

SOURCE: DPMC (2015)

	2014-15 ($m)	2015-16 ($m)	2016-17 ($m)	2017-18 ($m)	Total ($m)
Committed funding	513	491	480	466	1,949
Uncommitted funding	52	122	187	185	546
Total funding	565	613	667	651	2,495

Activities eligible for funding under this program include:

- Provision of jobs, particularly enduring jobs, in land management and other activities,
- Provision of employment, training and skill development for job seekers in remote Australia,
- Development of Indigenous businesses and community enterprises, and
- Various measures relating to lease negotiation, land tenure reform and Native Title claims.

The strategy's Remote Australia Programme focuses on home ownership and improving facilities, services and employment opportunities in remote Indigenous communities.

[13] www.dpmc.gov.au/indigenous-affairs/about/indigenous-advancement-strategy

The first funding round, announced in March 2015 and extended in May 2015, granted $1b to 996 organisations to deliver 1,350 projects.

3.4.6 National Landcare Programme, 20 Million Trees and Green Army

The focus of the National Landcare Programme on restoring degraded landscapes and increasing youth employment means its programs currently offer limited scope for biodiversity protection in Northern Australia. National Landcare Programme funding has been concentrated in the southern and eastern parts of Australia (Figure a). This geographic bias is even more pronounced for Green Army projects (b), which are concentrated in the most populous areas, and 20 Million Trees providers, which are concentrated in the most intensively developed areas requiring revegetation (c). The proportion of funding allocated to regional bodies has also declined since a peak in 2003-8, reducing the capacity of NRM groups to assist landholders' transition to the conservation economy[236].

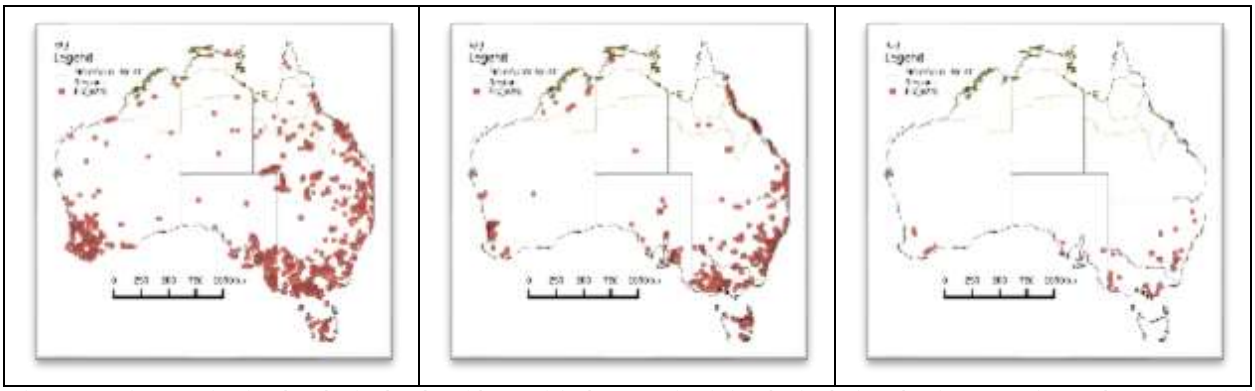


FIGURE 31. DISTRIBUTION OF (A) NATIONAL LANDCARE PROGRAMME PROJECTS (NATIONAL STREAM ONLY), (B) GREEN ARMY PROJECTS AND (C) 20 MILLION TREES SERVICE PROVIDERS IN RELATION TO THE MONSOONAL NORTH REGION

SOURCE: ***HTTPS://FIELDCAPTURE.ALA.ORG.AU/***

The Threatened Species Strategy commits to improve the conservation status of 20 mammal and 20 bird species by 2020. Of these priority species, only the Golden Bandicoot, Alligator Rivers Yellow Chat, and, possibly, the Night Parrot occur in Northern Australia. Given the restricted distribution of these species, this work is likely to involve only a small number of Traditional Owners, rangers and pastoral land managers. The commitments to control feral cats and improve habitat have the most potential for broad community involvement in the north, including through:

- Controlling feral cat eradication from Groote Eylandt,
- Protecting significant vegetation communities, wetlands and marine ecosystems,
- Re-establishing vegetation connectivity and natural pathways such as wildlife corridors,
- Revegetating riparian and coastal zones which link aquatic and terrestrial environments,
- Best practice management of our reserve system, and
- Broad landscape-scale revegetation and management of weeds.

3.5 Natural Resource Management in Queensland

The Queensland Government supports Indigenous cultural and natural resource management; conservation on private land; establishment of sustainable businesses based on natural resources; adoption of sustainable practices; and structural readjustment to improve sustainability of primary production. These initiatives are described below.

3.5.1 Department of Environment and Heritage Protection

The direction of the Queensland Department of Environment and Heritage Protection is set in its Strategic Plan. Great Barrier Reef water quality improvement is one of its highest priorities. Threatened species recovery, minimising environmental damage from development and sharing information with stakeholders also rate highly. There may appear to be less emphasis on capacity building through strategic partnerships than in other environmental or primary industry agencies. However, the department does provide funding for Indigenous ranger groups through a number of environmental grants programs (see Table 13 and 14) and uses environmental offsets to counterbalance unavoidable damage as a result of developments (see Environmental offsets programs).

TABLE 13. ELEMENTS OF THE QUEENSLAND DEPARTMENT OF ENVIRONMENT AND HERITAGE PROTECTION STRATEGIC PLAN RELATING TO THE CONSERVATION ECONOMY. SOURCE: QEHP (2015)

Priorities	
Goals	
Strategies	**Outcomes**
Conserving nature and heritage	
Enhance Queensland's ecosystems	
• Improve the water quality of Queensland's coast, waterways, catchments and wetlands • Protect and conserve Queensland's ecosystems and species, and increase the state's protected area estate • Minimise negative interactions between wildlife and communities	• Water quality improvement measured through performance scorecards and report cards, including Healthy Waterways and Gladstone Harbour • Improved results for threatened species through the Back on Track program • 17% of land gazetted as protected area estate by 2035
Protecting the Great Barrier Reef	
Protect the Great Barrier Reef	
• Provide clear accountability for the state's contribution to the Reef 2050 Long-Term Sustainability Plan • Establish and support a high-level taskforce providing advice on ways to protect the reef	Based on the 2009 baseline continued progress towards targets of: • Up to 80% reduction in nitrogen run-off from key catchments such as the Wet Tropics and the Burdekin by 2025 • Up to 50% reduction of sediment run-off from key catchments such as the Wet Tropics and the Burdekin by 2025
Conserving nature and heritage	
Protect significant heritage places	
• Promote the value and understanding of Queensland's heritage through programs and education initiatives • Regulate and support the management and protection of places with state heritage value	• The most significant places in Queensland accurately captured in the state's heritage registers
Enabling responsible development ***Stimulating economic growth and innovation*** ***Ensuring sustainable management of natural resources***	
Avoid, minimise or mitigate impacts on the environment	
• Regulate environmentally significant activities based on best practice project assessment and approval and a contemporary compliance framework that focuses on high-risk activities • Oversee the development and delivery of whole-of-government climate change mitigation and adaptation programs • Administer the environmental offsets framework to minimise impacts on the environment • Implement programs to reduce unlawful waste activities and promote increased re-use and recycling	• Improved environmental results for air quality and waste as shown through State of the Environment reporting and the annual State of Waste Report • 80% of environmental problem-solving projects completed and outcomes reported • 80% of Queensland coastal councils with Coastal Hazard Adaptation Strategies in place by 2019
Providing responsive and integrated government services	
Work collaboratively and productively with industry, business and community	
• Provide evidence behind decisions and greater access to performance data • Implement a 5 year science and research program to inform policy and monitor performance • Promote private sector investment in environment and heritage protection • Educate, and engage with, communities about the state's ecosystems and species	• 80% of EHP services and transactions available online by 2019 • 20% of departmental programs funded by private sector investment by 2025 • 5 year rolling science and research program developed by December 2015

TABLE 14. CURRENT AND PREVIOUS QUEENSLAND SOURCES OF FUNDING FOR UNDERTAKING CULTURAL AND NATURAL RESOURCE MANAGEMENT PROJECTS

SOURCES:1,HTTPS://ENVIRONMENT.EHP.QLD.GOV.AU/LAND-SEA-GRANTS/;
2, WWW.QLD.GOV.AU/ENVIRONMENT/POLLUTION/FUNDING/EVERYONES

N/A = NOT AVAILABLE

Scheme	Focus	Period	Budget	Grant limit	Monsoonal North		Source
					Projects (%)	Funds (%)	
Current							
Indigenous Land and Sea Ranger Program	Indigenous NRM	2014-15	$0.91 m	$100,000	27.3	28.3	1
Indigenous Land and Sea Ranger grants	Indigenous NRM	2013-15	$1.94 m	$100,000	27.3	28.3	1
Everyone's Environment Grant	• Conservation • Urban Wild Spaces Pilot Projects • Heritage • Research	2011-14	$12 m	$100,000	6.8	10.3	2
NatureAssist		N/A	N/A	N/A	N/A	N/A	
Previous							
Vegetation Incentives Program	Protect and manage high quality non-remnant vegetation in Queensland under a conservation covenant or agreement (delivered by Greening Australia)	2005-6	$12 m	$20,000	0	0	321
Indigenous Sea Country Management Grants	Develop sustainable management of dugong, turtles and other marine resources	2013	$1.96 m	$200,000	18.8	29.9	14

3.5.2 INDIGENOUS CULTURAL AND NATURAL RESOURCE MANAGEMENT

The objectives of the Queensland Aboriginal and Torres Strait Islander Economic Participation Action Plan (Department of Aboriginal and Torres Strait Islander and Multicultural Affairs 2014) include sustainable economic development in regional and remote communities. Strategies for achieving this objective include increasing the number of rangers employed in the Department of Environment and Heritage Protection (EHP) Indigenous Land and Sea Ranger Program; expanding this program through industry partnerships; and reforming tenure arrangement to improve Indigenous access to business finance.

In line with these objectives, in 2014, the $9.1m Indigenous Land and Sea Ranger Program provided full-time environmental management jobs for Indigenous people in host organisations (Hill et al. 2008). This includes 26 rangers in five ranger groups in the Monsoonal North (Figure). Activities undertaken by these rangers include:

- Preserving cultural sites and stories,
- Weed and feral animal management,
- Fire management,
- Biodiversity surveys on local species and habitats,
- Supporting disaster recovery efforts,
- Visitor management and education, and
- National parks management.

Alignment with the Economic Participation Action Plan would appear to ensure a long-term commitment to this program. In addition, EHP's Indigenous Land and Sea Ranger grant program[15] provided $500,000 for ranger groups to

[14] www.ehp.qld.gov.au/coastal/management/indigenous-sea-country-grants.html

[15] www.qld.gov.au/environment/plants-animals/community/grants-program

undertake cultural and natural resource management projects in 2014-15, with a subsequent funding round recently closed. Activities funded by these grants include:

- Cultural heritage site management (recording, protection and training),
- Protected species monitoring and conservation,
- Habitat restoration,
- Weed and feral animal management,
- Fire management,
- Erosion control, and
- Country planning.

FIGURE 32. QUEENSLAND INDIGENOUS LAND AND SEA MANAGEMENT RANGER GROUPS

SOURCE: ***HTTPS://ENVIRONMENT.EHP.QLD.GOV.AU/LAND-SEA-RANGERS/***

3.5.3 Nature Refuges and NatureAssist

Queensland landholders may enter into conservation agreements to reserve land on their properties as a Nature Refuge[16]. The aim of the Nature Refuge program in Queensland is to conserve and control the use of significant cultural and natural resources. However, it also allows for the interests of landholders, where these are compatible with conservation goals. For example, grazing may be allowed in some Nature Refuges, if this is not detrimental to the recognised conservation values of the Nature Refuge.

While any landholder can approach the Queensland Government with a proposal to establish a Nature Refuge, most effort will be invested in securing agreements in priority areas[17]. Formerly focusing on threatened species and communities, the priorities are currently being reviewed to maximise protection of significant conservation values, connectivity and resilience to predicted climate change. Considerable effort is being invested in identifying areas that both currently support highly biodiverse areas and have the highest likelihood of continuing to do so under a range of

[16] *Nature Conservation Act 1992* (Qld)

[17] No map of priority areas was publicly available at 5 September 2015

climate change projections. The protection of conservation values not already protected under the existing protected area estate will also be taken into account. There are likely to be several priority areas in the Monsoonal North region. Assessment of Nature Refuge proposals may be undertaken by the Department of Environment and Heritage Protection or outsourced to the Queensland Trust for Nature[18].

Queensland currently has 491 Nature Refuges[19], including 27 in the Northern Gulf region (representing 615,397ha of land). Nature Refuges protect 3.94 million ha of habitat across the State. Around half of the Nature Refuges in the Monsoonal North were signed up between 2007 and 2012, when landholders could receive an extension of 10 years in return for managing part of their property as a Nature Refuge under the repealed Delbessie agreement (DNRM 2007).

Queensland legislation requires that declaration of the Nature Refuge must specify the reason for its establishment and the period of its duration, and that the landholder must enter into a conservation agreement covering:

- Management responsibilities of the landholder and the Queensland Government,
- Any support (including financial assistance and technical advice) to be provided by the Queensland Government and specifying how any financial assistance is to be used,
- Land uses and management activities that are restricted, prohibited or require a permit, and
- Conditions that would result in the landholder being required to repay financial assistance or the conservation agreement being terminated.

There is no provision in the legislation for conservation agreements over land that is not protected as a Nature Refuge.

Subject to certain conditions, Nature Refuge boundaries may be changed; a Nature Refuge may be revoked; and conservation agreements may be altered or terminated. Compulsory declaration of a Nature Refuge may occur under special circumstances, in which case a conservation covenant will be prepared prescribing management and use. Nature Refuges and conservation agreements and covenants are generally binding on current and subsequent landholders and any other people with an interest in the land.

Nature Refuges do not provide protection from mining, and Queensland's environmental offsets legislation does not require damage to a Nature Refuge's environmental values caused by any development to be offset either on the Nature Refuge or in an equivalent environment[20]. However, offset arrangements may fund the establishment and management of Nature Refuges that protect or restore the conservation values affected by a development.

Government assistance is not available for Nature Refuges declared as a condition of a government-funded acquisition or licence. For other types of Nature Refuges in priority areas, funding may be available under NatureAssist for management actions such as fencing, soil stabilisation and management of weeds and pest animals and fire to protect conservation values[21]. The Queensland Government has committed $5 million over 2015-16 to continue securing and managing nature refuges under this program[22]. Funding under NatureAssist was originally awarded through a competitive tender process (Higgins et al. 2014). The restructured Nature Refuges program is likely to make strategic investments to maximise its conservation goals in priority areas. NatureAssist partners (Southern Gulf Catchments, Northern Gulf Resource Management Group, NQ Dry Tropics and AgForce) can assist landholders negotiate the establishment and management of a Nature Refuge.

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[18] www.qtfn.org.au/nature-refuge-assessments

[19] www.landmanagementonline.org.au/dehp/

[20] *Environment Protection Act 1994* (Qld)

[21] http://www.ehp.qld.gov.au/ecosystems/nature-refuges/natureassist

[22] http://statements.qld.gov.au/Statement/2015/7/14/funding-to-improve-great-barrier-reef-water-quality-and-address-climate-change

3.5.4 Department of Agriculture and Fisheries

The Department of Agriculture and Fisheries Strategic Plan sets the direction for assisting primary producers develop and manage sustainable production systems (Table). The plan also includes strategies and actions for improving Indigenous employment and business development, including through biosecurity surveillance.

TABLE 15. ELEMENTS OF THE QUEENSLAND DEPARTMENT OF AGRICULTURE AND FISHERIES STRATEGIC PLAN RELATING TO THE CONSERVATION ECONOMY

SOURCES: QDAF (2015). NB PRIORITIES SPECIFIC TO FORESTRY AND FISHERIES ARE NOT INCLUDED

Services	
Priorities	**Strategies**
	Connect industry to opportunity
Drive innovation and productivity through research, development and extension	• Improve the uptake of innovative technologies and practices • Partner with industry and research bodies to build research, development and extension capability across Queensland
Improve sustainability of agriculture	• Advocate for protection of agriculturally important land and water • Support producers to manage risks associated with extreme weather events, climate change and climate variability • Improve management practices to reduce the impacts of agriculture on the environment • Develop energy-, input- and resource-efficient food and fibre production systems
Support a modern and capable workforce	• Support industry to improve rural job services and skills development to meet rural workforce needs • Facilitate partnerships between training providers and universities to enhance skills-based training
	Manage biosecurity risks
Improve flexibility and adaptability of biosecurity service delivery	• Implement a risk-based investment strategy for biosecurity resources that aligns with state, national and international priorities • Benchmark service delivery against other jurisdictions
Expand shared responsibility and partnerships	• Develop state and local government weed and pest animal partnerships and frameworks to support shared decision-making and service delivery • Implement shared responsibility with other agencies, industries, businesses and individuals through co-investment, partnering, contracting and capability building
Improve biosecurity information management	• Develop the Biosecurity Information Management System
Continue to build biosecurity capability and emergency preparedness	• Review the state's biosecurity capability • Implement the Biosecurity Emergency Preparedness Program to improve the capability of biosecurity management and surveillance and detection systems to identify and respond quickly to threats and outbreaks • Expand partnerships with industry, local government, community and private providers to better manage pest and disease outbreaks
Enhance product value	• Manage agricultural chemical use and food contaminants, and ensure animal welfare standards meet community expectations

3.5.5 Sustainability Loans

The Queensland Rural Adjustment Authority provides low interest loans of up to $650,000 to primary producers to cover capital costs of improving the viability, environmental sustainability and climate resilience of their enterprises[23]. To be eligible for a loan, the primary producer must be employed full-time in their enterprise. They must demonstrate that they need financial assistance for the intended work, but not be financially over-extended. They must have the ability to repay the loan, and have sound prospects for commercial viability. The loans cannot be used for debt restructuring. A management plan must be submitted with the application explaining how the activities financed with

[23] http://www.qraa.qld.gov.au/current-programs/Productivity-Loans/sustainability-loan/Sustainability-Loan-Primary-producer

contribute to the intended outcomes. An enterprise that is already financially over-extended is not eligible for this or other assistance, such as drought relief loans. The relevance of these loans to the pastoral industry is discussed in the Sustainable Grazing section.

3.6 Environmental offset programs

Australian Government environmental legislation requires adverse impacts of development on significant environment assets to be avoided and minimised (mitigated), wherever possible (SEWPaC 2012). There is also provision for restoration after the development is completed. Damage that cannot be avoided, mitigated or restored is called residual damage (McKenney et al. 2010). Environmental offset schemes are designed to compensate for unavoidable, residual damage to environmental assets. Assets considered in Australian offset schemes include threatened species and communities as well as other environmental assets protected under international agreements (e.g. World Heritage Areas, significant wetlands and migratory species). While there are currently no formalised schemes covering greenhouse gas emissions, the Western Arnhem Land Fire Abatement project was essentially a carbon offset project developed through negotiations with the Northern Territory Government to deliver emission abatement and social benefits to an Indigenous community (Green et al. 2012; Whitehead et al. 2009).

The Australian Government (SEWPaC 2012) and the State of Queensland (State of Queensland 2014) have policies requiring residual environmental damage caused by development to be offset (see below). Each jurisdiction provides guidelines and tools to help the developer calculate the likely impact of their proposed development and formulate and cost a proportionate response to address the residual damage and to allow the government to assess the adequacy of the proposed offset actions. Queensland jurisdictions maintain offset registers in which offset areas and actions are recorded. Bilateral agreements between the Australian and State and Territory Governments should eventually result in all offset programs being delivered through State and Territory Governments (DoE 2015b). This is presently only the case for New South Wales.

Offset actions must maintain or improve the conservation of the affected asset, but developers are encouraged to contribute to overall environmental, economic and social wellbeing. Offset actions to protect or restore biodiversity assets are usually undertaken outside the area of the development, but in the same bioregion or subregion. Actions frequently involve protection and management or restoration of threatened community or threatened species habitat, but may also include land purchase and research to the benefit of the affected asset. Except where the environmental damage being offset is deemed to be only temporary, offset areas must be permanently protected and managed for conservation of the affected asset. Depending on the jurisdiction, developers may choose to undertake the offset activity themselves; contract a third party to do so; or pay the government an amount required to cover the cost of the offset activity. Payments vary depending on the costs involved and may cover land purchase, establishment costs, ongoing maintenance, administration as well as incentive payments. Duration and scheduling of payments also vary, but should continue as long as maintenance is required.

In Queensland, offset conditions imposed on permission to undertake proposed developments or actions that are likely to have an adverse residual environmental impact are regulated under Queensland's *Environment Offsets Act 2014* (*EOA 2014*). This legislation covers, but is not restricted to, the following environmental assets (called matters in the legislation):

- Nationally threatened species and ecosystems, migratory species, internationally important wetlands, a National Heritage place and World Heritage Areas,[24]
- Queensland protected plants, animals and areas,[25]

[24] *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)

[25] *Environment Protection Act 1994* (Qld). NB. Nature Refuges are excluded from many provisions of the Act.

- Queensland declared fish habitat,[26]
- Queensland marine conservation park zones,[27]
- The Great Barrier Reef Marine Park,[28]
- Declared areas of high nature conservation value and endangered regional ecosystems ,[29]
- High ecological value waters,[30]
- A water resource,[31] and
- Other environmental matters listed under a local planning scheme, policy or other instrument, such as a strategic environmental or cropping area, a priority living or agricultural area.[32]

[26] *Fisheries Act 1994* (Qld)

[27] *Marine Parks Act 2004* (Qld)

[28] *Great Barrier Reef Marine Park Act 1975* (Cwlth)

[29] *Vegetation Management Act 1999* (Qld)

[30] *Environmental Protection (Water) Policy 2009* (Qld)

[31] *Water Act 2007* (Cwlth)

[32] *Sustainable Planning Act 2009* (Qld) and *Regional Planning Interests Act 2014* (Qld)

Under *EOA* Project establishment, accounting and auditing procedures are complex and costly, so only projects that generate high numbers of ACCUs are likely to be financially viable (Dore et al 2014). An economic assessment of a range of sample carbon projects indicates that fire management projects have the highest net earning potential, followed by herd performance and managed regrowth (Table). Avoided clearing was not viable in the example given, and the viability of using nitrate licks instead of urea licks was questionable. The viability of soil carbon projects was not assessed.

There are several caveats to this economic assessment. First, economic viability depends on the level of emissions generated before project activities are undertaken (called the baseline) and the capacity for improvement. For example, a fire management project is unlikely to be viable on a property that already has effective fire management; and a herd management project is unlikely to be viable on a pastoral enterprise that is already following best practice management. Secondly, this assessment does not take into account brokerage or aggregation costs, which may be a set fee or a percentage of project income, or a combination of the two. Finally, it does not include cost savings that can be made from combining activities, such as coordinated fire management, across several properties into a single project. Conversely, it is important to note that savings cannot be made by combining activities from different methods within a single project area, as these must be accounted in separate projects.

2014, the proponent of any development or action likely to degrade an environmental asset may be required to offset this impact by undertaking or financing activities to restore the condition of that asset. They may also be required to provide "a social, cultural, economic or environmental benefit".

3.7 CARBON ECONOMY

As described earlier, there are several approved methods for deriving carbon credits from land or agricultural management (See Carbon). These methods allow income to be earned from storing carbon or reducing the emissions of greenhouse gases (carbon dioxide, methane and nitrous oxide) through Australia's Emission Reduction Fund (ERF) established under the *Carbon Credits (Carbon Farming Initiative) Act 2011* (Cwlth). ERF-approved projects generate Australian Carbon Credit Units (ACCUs) that can be sold or traded domestically or internationally. Projects must use ERF-approved methods, and the projects themselves must also be approved and audited to determine how many ACCUs have been earned. Once credits have been earned they can be sold through the government reverse auction (tender) process directly or to a third party, or to the voluntary market (Figure 33). For a project to be approved, the right to manage carbon and the right to undertake a project on the land must be established (Dore et al. 2014). This may require negotiation with Native Title owners, where they are not the project proponents. Ownership of carbon resources is approached differently in the different states and territories, and needs to be clearly defined before projects progress (Griffiths et al. 2007; Heckbert et al. 2009).

TABLE 16. ESTIMATED INCOME AND COSTS OF SAMPLE ERF CARBON PROJECTS ON PASTORAL PROPERTIES

SOURCE: COHN (2015)

Method	Project period	Annual income	Establishment cost			Periodic costs			Net annual income
Fire management 8,700-15,000 km² Gulf Savanna	25 years	$100-160k	$10k	$20-30k†	$11k	$3.5k	$9k	$1k	$88-150k
Herd performance 10,000-15,000 breeders Kimberley/Gulf Savanna	7 years	$300-600k	$10k	N/A	$13k	$3.5k	$9k	$1k	$27-70k
Managed regrowth 1,000 ha Cape York Peninsula	25 years	$50k	$10k	N/A	$10-15k	$3.5k	$9k	$1k	$34k
Nitrate licks 30,000 breeders	7 years	$18k	$10k	N/A	$13k	$3.5k	$9k	$1k	$4k
Avoided clearing* 1,000 ha Desert Channels	20 years	$6k	$10k	N/A	$10-15k	$3.5k	$9k	$1k	$0

CURRENTLY NO METHOD COVERS AVOIDED CLEARING IN QUEENSLAND, AS THE CURRENT METHOD REQUIRES A PERMIT FOR CLEARING TO HAVE BEEN ISSUED BEFORE 2010. †ADDITIONAL COST, NOT INCLUDED IN ORIGINAL PRESENTATION

The only ERF-registered projects in the Monsoonal North at the time of writing were fire management and soil carbon projects (Table). Carbon credits earned had been earned from several fire management projects. No credits had been earned from soil carbon, and the long-term prospect for doing so is uncertain (see Increasing soil carbon). There was also no registered project in which urea licks were to be replaced with nitrate licks, even though this method was originally approved in August 2014 (and amended in June 2015), or using the herd management method – but this method had been approved less than two weeks earlier. However, both herd management and developing dietary approaches are considered to have potential to reduce methane emissions from cattle while improving enterprise viability. These are described in more detail in the remainder of this section, along with the two other methods assessed as being viable in the Table – fire management and managed regrowth.

TABLE 17. NUMBER OF APPROVED CARBON PROJECTS AT 18 SEPTEMBER 2015

SOURCE: CLEAN ENERGY REGULATOR (WWW.CLEANENERGYREGULATOR.GOV.AU)

	Monsoonal North					Other	Total
	Kimberley	Top End	Gulf Savanna	Northern Gulf	Burdekin Dry Tropics		
Land or agricultural management							
Fire management	6	7	3	12		20	48
Soil carbon			1		1	8	10
Avoided deforestation						55	55
Tree planting						192	192
Reforestation/regrowth						32	32
Herd management							0
Other							
Piggeries						10	10
Waste		1			3	104	108
Transport & fuel						6	6
Urban/Commercial						3	3
Grand Total	**6**	**8**	**4**	**12**	**4**	**430**	**464**

Carbon policy is yet to settle, with policy moving from Labor Government's 2011 Clean Energy Future program (with carbon trading and the Carbon Farming Initiative) to the Coalition Government's 2014 Direct Action program (with the Emission Reduction Fund)[12]. So far both versions have provided opportunities for the land management sector to store carbon and reduce greenhouse gas emissions, but lack of bipartisan support for the Emissions Reduction Fund[33] and the Labor Party's plan to reinstate an emissions trading scheme[34] leaves land managers with uncertainty about the future.

3.7.1 FIRE MANAGEMENT TO ABATE NITROUS OXIDE AND METHANE

Bushfire smoke emits 2-3.5 billion tonnes CO_2-e globally each year (van der Werf et al. 2006) , and produces about 1.5% of Australia's greenhouse gas emissions, the majority of which comes from Northern Australia (DoE 2015a). Bushfire emissions contain methane and nitrous oxide, which remain in the atmosphere for many years, and carbon dioxide (CO_2), which is assumed to be reabsorbed when the plants regrow, so is not counted as a greenhouse gas (Russell-Smith and Whitehead 2015). However, bushfires emissions of methane and nitrous oxide alone have a significant impact on global warming (Russell-Smith et al. 2013).

Savanna Fire Management (or Savanna Burning)[35] projects reduce the amount of methane and nitrous oxide lost to the environment through the strategic use of fire in the early dry season (before August) to reduce the spread of late dry season fires. Part of the emission reduction is gained from the reduced extent of fires and part from the more patchy and less intense nature of early dry season fires compared with late dry season fires. Establishing a Savanna Fire Management project involves:

- Defining a project area and demonstrating that you have the right to undertake a project in this area;
- Assessing the extent of fires and calculating average annual emissions over a 10 year baseline period in the high rainfall zone and a 15 year period in the low rainfall zone to determine if the project is viable;
- Registering the project with the Clean Energy Regulator (CER);
- Creating and verifying a base map for the eligible fuel types in the project area;

[33] http://www.abc.net.au/news/6696666

[34] http://www.abc.net.au/news/6621198

[35] Emission reduction fund methodologies: Savanna Burning (repealed), Savanna Fire Management

- Developing a plan for reducing extent of late dry season fires, that must include using early dry season burning;
- Getting the project audited and approved by the CER;
- Undertaking fire management, and recording management and fuel use as required;
- Assessing the extent of early and late dry season fires, calculating emissions and comparing with baseline, subtracting emissions from fossil fuels used in project management;
- Generating an offsets report and submitting it to CER;
- Submitting to audits as periodically required; and
- Accruing carbon credits for emissions reduced.

Savanna Fire Management has rapidly become the most lucrative form of payment for environmental services in Northern Australia. By 18 September 2015, 1.3 million credits had been derived from fire management projects in the Monsoonal North from a total of 16.4 million credits accrued from land sector activities across Australia. The original Savanna Burning methodology only applied in areas receiving at least 1,000mm average annual rainfall, so most registered projects have been in this zone (Figure). With the release of the Savanna Fire Management method in March 2015, projects can now be established in areas receiving 600-1,000mm annual average rainfall, and two projects have been established in this zone. There is considerable scope to increase the number of projects in the Monsoonal North, particularly in the low rainfall zone. There is also the capacity to increase the number of carbon credits being generated from Savanna Fire Management projects through a new methodology being developed that improves accounting for carbon sequestration in fine fuel and woody debris. Under current ERF rules, it is not clear whether existing projects will be able to transfer to this methodology without establishing a new baseline.

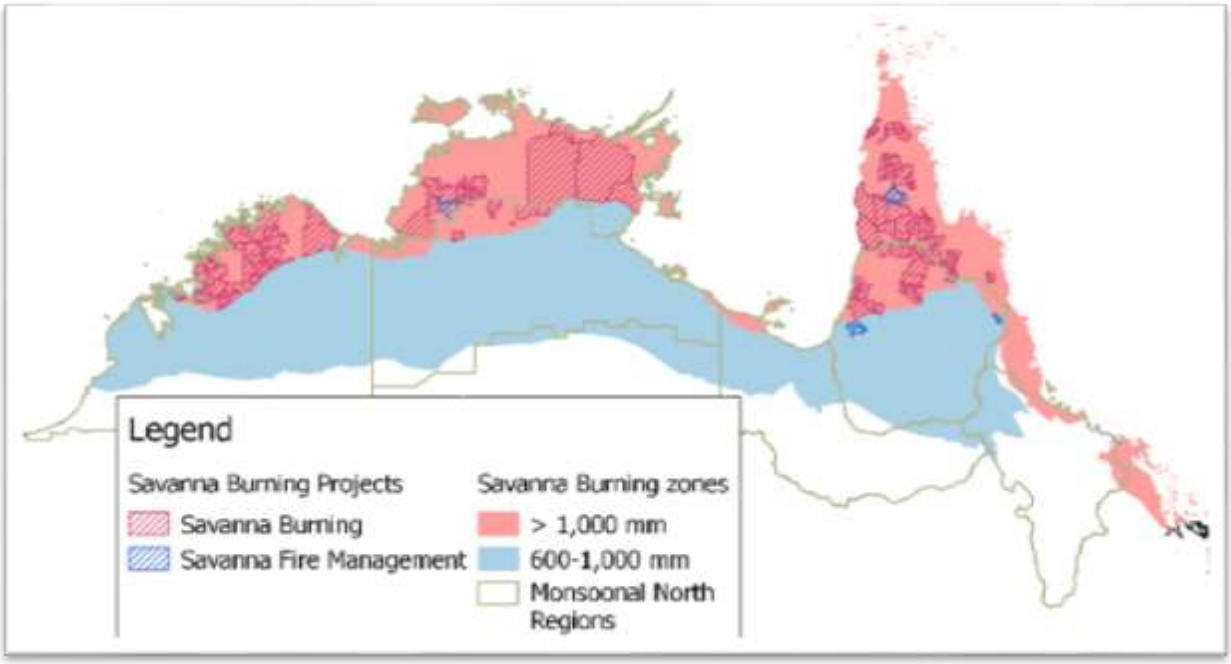

FIGURE 34. SAVANNA BURNING AND FIRE MANAGEMENT PROJECTS REGISTERED BY 18 SEPTEMBER 2015 IN RELATION TO RAINFALL ZONES

SOURCE: CLEAN ENERGY REGULATOR (WWW.CLEANENERGYREGULATOR.GOV.AU/ERF/EMISSIONS-REDUCTION-FUND-PROJECT-REGISTER)

Figure 44 indicates that where as previously only the North West corner of the Northern Gulf region qualified for Savanna burning, now the 600-1000mm methodology has been introduced, almost all of the region now has the opportunity to participate in the carbon economy through savanna burning.

3.7.2 Adjusting cattle diets to reduce methane emissions

As described earlier, methane emissions from cattle are a significant source of GHG emissions, accounting for 66% of Australia's agricultural emissions, and around 10% of Australia's total emissions (DoE 2015). There are several potential options for reducing methane emissions from cattle without reducing production (Table). While replacing urea lick blocks with nitrate ones is approved, its economic viability is questionable[36]. The most promising options, for which the development of a methodology appears promising, are feeding cattle marine algae and including Leucaena in the forage system. Planting Leucaena as a forage has the added benefit of increasing production. However, as it has weed potential, Leucaena should be used according to the Leucaena Network's Code of Practice (Leucaena Network 2014).

TABLE 18. OPTIONS FOR REDUCING METHANE EMISSIONS FROM NORTHERN BEEF CATTLE THROUGH DIETARY ADJUSTMENT

SOURCE OF ASSESSMENT: MLA (2015)

Practice	Production increase	Potential emission reduction		Method prospect	Literature
		Enterprise	National		
	(%)	(%)	(T CO_2-e)		
Replacing urea lick with nitrate	0	6	363,000	Approved	Callaghan, M.J., et al. 2014
Marine red algae	8	60	3,296,000	Promising	Machado, L., et al. 2014, *Journal of Applied Phycology*; Machado, L., et al. 2014 *PLoS ONE*
Leucaena	22	20	112,000	Promising	Harrison, M.T., et al. 2015
Bioactive compounds from plants	3.5	25	1,373,000	Moderate	Durmic, Z., et al. (2014)
Grape marc fed to feedlot cattle	0	10	145,000	Poor	Beauchemin, K.A., et al. (2008), Cotter, J., et al. (2015)

3.7.3 Improving herd genetics and management to reduce methane emissions

Other approaches to reducing methane emissions from cattle are genetic improvement of the herd and improving herd management to reduce the number of cattle required to produce each kilogram of beef and the time each animal spends in the grazing system (Table). Improved herd management makes a modest contribution to emissions reduction, but has long-term profitability benefits, and has an approved ERF methodology[37]. Genetic modification of the herd is more problematic, as selection for reduced emissions can select for animals with other undesirable traits, such as low growth rates, and the required genes may not be passed down the generations or may take several generations to

[36] Emission Reduction Fund method: Reducing greenhouse gas emissions in beef cattle through feeding nitrate containing supplements

[37] Emission Reduction Fund method: Beef cattle herd management

infiltrate the entire herd (Hegarty 2007). However, research into this area is ongoing, and a suitable method may eventually be developed.

TABLE 19. OPTIONS FOR REDUCING METHANE EMISSIONS FROM NORTHERN BEEF CATTLE THROUGH HERD MANAGEMENT

SOURCE OF ASSESSMENT: MLA (2015)

Practice	Production increase	Potential emission reduction		Method prospect	Literature
		Enterprise	National		
	(%)	(%)	(T CO_2-e)		
Best management practices for reproductive performance and feed utilisation	20	3	286,000	Approved	Wiedemann, S.G., et al. (2015), Bentley et al 2008, Bell, A.W. and P.L. Greenwood (2012)
Genetic improvement	0.8	6	487,000	Poor	Hegarty, R.S., et al. (2007)

Improving herd management involves adopting a range of best management practices that have been proven to improve reproductive performance, reduce the proportion of reproducing animals in a herd and increasing growth rates (Table). One of the confounding effects is that that emissions reduced through improved performance may be offset if it also increases the volume of meat being produced. This is accounted for by basing emission calculations on the entire herd.

TABLE 20. EXAMPLES OF HERD MANAGEMENT FOR REDUCING METHANE EMISSIONS FROM NORTHERN BEEF CATTLE

SOURCE: (WIEDEMANN 2015; WIEDEMANN ET AL. 2015)

Practice	Impact on productivity
Fencing and additional water points	• Allows introduction of herd segregation and priority feeding of some herd classes • Reduces overgrazing near water points and improves access to better quality pasture, improving condition scores, pregnancy rates and weaning weights
Rotational grazing	• Improves feed quality for breeding cattle with the aim of increasing condition scores, pregnancy rates and weaning weights
Herd segregation / supplementation	• Allows targeted supplementation of second calving heifers • Reduces handling of herds with young calves at foot, reducing the incidence of mis-mothering and mortality in calves prior to weaning
Irrigation or forage cropping	• Cropping and/or irrigation will: increase growth rates of steers, and reduce stocking pressure on rangeland areas, improving breeder herd performance
Increased selection pressure, culling and reduced breeder numbers	• Culling unproductive animals should result in higher feed availability for the remaining herd and may contribute to higher fertility over time, resulting in higher pregnancy rates and higher growth rates in calves prior to weaning.

The steps involved in undertaking a herd management project include:

- Demonstrating that you have the right to undertake a project in this area, and that the land has not been cleared of native vegetation for the purpose of the project;
- Deciding on the management actions you wish to adopt;

- Calculating baseline emissions (using three years of positive liveweight gain within the seven-year period before start of project) using the Beef Herd Management Calculator[38] by entering information about:
    - herd numbers and composition
    - liveweight gain
    - cattle diet
    - birth and purchase of new cattle
    - sale and destination of cattle and average weight at sale
    - diet (for years in which this is an identified activity)
- Identifying the project activities you intend to undertake each year of the seven-year project;
- Registering the project with the Clean Energy Regulator (CER);
- Getting the project audited and approved by the CER;
- Undertaking the management improvement and keeping records of herd composition and management as required;
- Calculating emissions each year and comparing with baseline, subtracting emissions from fossil fuels used in project management;
- Generating an offsets report and submitting it to CER;
- Submitting to audits as periodically required; and
- Accruing carbon credits for emissions reduced.

Pilot studies have indicated that profits made through improving herd management can increase revenue of a large cattle enterprise by 6-10% (Cohn 2015; Wiedemann 2015). By the end of September 2015, there were no ERF projects registered using this method, which had only been available in the previous month. The cost of changing management, requirements for detailed record and resistance to practice change may be the biggest impediments to uptake of this method (Cary et al. 2011; Greiner et al. 2008b; Pahl et al. 2007).

3.7.4 Managed regrowth

Allowing vegetation to regrow increases the amount of carbon stored in the trees and shrubs. The amount of carbon stored at each site will depend on the type of the original vegetation, and the soil and climate of the site. The steps involved in a Managed Regrowth project include:

- Defining a project area and demonstrating that you have the right to undertake a project in this area,
- Demonstrating that the land has previously been cleared of native vegetation for pastoral use,
- Calculating baseline emissions using FullCAM[39] by entering information about the size and location of the site and its previous management,
- Preparing a site management plan (e.g. fencing to control stock grazing pressure, weeding) to demonstrate that regrowth will occur,
- Registering the project with the Clean Energy Regulator (CER),
- Getting the project audited and approved by the CER,
- Undertaking and keeping records of necessary management as required,
- Calculating emissions each year and comparing with baseline, subtracting emissions from fossil fuels used in project management,
- Generating an offsets report and submitting it to CER,
- Submitting to audits as periodically required, and
- Accruing carbon credits for emissions reduced.

[38] www.environment.gov.au/climate-change/emissions-reduction-fund/methods/beef-cattle-herd-management

[39] Full Carbon Accounting Model www.environment.gov.au/climate-change/greenhouse-gas-measurement/land-sector

Assisting natural regrowth to occur is more economically viable than tree planting is, but in most areas will require a carbon price that is more than twice the current $13.95/t (Comerford et al. 2015; Evans et al. 2015). A hypothetical regrowth project undertaken at Laura in the Cook shire, just outside the Northern Gulf, was assessed as profitable (Cohn 2015). However, a Queensland-wide assessment found that regrowth projects become profitable in Cook Shire only once the carbon price reaches $30/t, but that it will not be profitable in the Queensland section of the Monsoonal North (Comerford et al. 2015).. This is not too problematic as limited vegetation clearance means the Monsoon North is not a priority for regrowth projects.

3.8 ECOTOURISM

Cultural and nature-based tourism is a well-developed aspect of the conservation economy. It is applicable to both Indigenous communities and pastoral enterprises in the Monsoonal North, as well as to independent operators (Altman 2001; Ferguson 2012; Fuller et al. 2005; Moskwa 2010). In total, tourism contributes between 3-7% to the Northern Australian economy (Tourism Research Australia 2011), with little growth since 1999, and the market for cultural and nature-based tourism is only a small section of the market (Prideaux 2013) [365]. Fewer than 10% of visitors to Darwin in 2000-2002 participated in Aboriginal cultural activities or went on guided tours and the percentage was even lower in 2010-12 (Carson 2013). However, a higher proportion of visitors venturing away from major cities are interested in nature-based – particularly adventure-based – tourism, and there is potential to grow this small market (Ryan et al. 2000).

Ecotourism is a risky business. Both Indigenous and non-Indigenous micro-businesses in the Top End have a high failure rate (Fuller et al. 2005). Tourism is particularly vulnerable to global economic changes and bad weather (Prideaux 2013). Tourism can have both positive and negative impacts on Indigenous communities (Dyer et al. 2003; Ryan et al. 2005; Scherrer et al. 2013; Smith et al. 2009). As well as the economic benefits of income and employment, benefits of well-designed tourism ventures include strengthening culture, increased cultural coherence and increased cross-cultural understanding. There is also the potential for tourists to contribute to communities through volunteerism, with many "grey nomads" being prepared to spend time in communities on capacity building projects (Leonard et al. 2009). Disadvantages of poorly designed tourism enterprises can include damage to cultural sites and inappropriate site visits, limited engagement between tourists and the Indigenous community, degradation of culture, and exploitation. Unplanned tourism can also be a drain on the economy and cause environmental degradation (Greiner 2010; Greiner et al. 2010; Stoeckl et al. 2006).

Growth of ecotourism to benefit regional economies will require appropriate policy settings, collaborative governance arrangements and tourism products based on consumer demand, along with significant investment in associated facilities (Blanch 2008; Prideaux 2013; Whitford et al. 2010). Appropriately managed tourism ventures can receive recognition from accreditation schemes, such as that run by Ecotourism Australia[40].

[40] www.ecotourism.org.au

3.9 Non-Government Organisations

Historically, NGOs have a history of supporting state-based preservation of land, which has often had the effect of disenfranchising Indigenous Australians (Holmes 2011; Moorcroft et al. 2012). However, it is no longer the case of the major NGOs supporting conservation in Northern Australia. In line with priorities identified above, the majority of NGO financial assistance is provided to Indigenous organisations through partnership arrangements to establish Protected Areas and undertake and implement management plans. Non-Government Organisations are most active in the Kimberley and Top End. There is very little NGO activity in the Queensland sections of the Monsoonal North, although several groups invest in Cape York Peninsula.

Bush Heritage Australia (BHA) has identified priority areas in the Monsoonal North region. Australian Wildlife Conservancy owns Brooklyn Sanctuary in the upper Mitchell River catchment in the Northern Gulf, on which it also coordinates multi-tenure fire management. The Wildlife Land Trust[41] provides non-financial support for wildlife sanctuaries on private land, but currently lists no sanctuaries in the Monsoonal North. No evidence was found of conservation NGOs investing in conservation on other forms of private land. A search of conservation economy funding opportunities showed that this pattern of investment was typical across Australia and worldwide.

FIGURE 35 AUSTRALIAN WILDLIFE CONSERVANCY SANCTUARIES

SOURCE: AUSTRALIAN WILDLIFE CONSERVANCY[42]

[41] www.wildlifelandtrust.org.au

[42] http://www.australianwildlife.org/sanctuaries.aspx

3.10 INDIGENOUS NATURAL RESOURCE MANAGEMENT

Before contact with Europeans, Indigenous Australians lived a form of conservation economy based on sustainable management of Australia's land and seas. Indigenous people continue to have high levels of participation in a range of conservation economy activities (Altman 1987, 2003; Altman 2012). Previous sections of this report have described a range of activities undertaken by Indigenous people in the Monsoonal North, including proclaiming and managing Indigenous Protected Areas on their own land and working as rangers to undertake cultural mapping and Indigenous NRM. Indigenous Australians are also the principle suppliers of remote biosecurity surveillance and removal of ghost nets from the Gulf of Carpentaria, and undertake substantial emission reductions through Savanna Burning projects (see below). Ecotourism is also a growing part of the Indigenous conservation economy, but will not be explored further in this section (See Ecotourism).

Indigenous cultural and natural resource management, hunting, fishing and other cultural activities have demonstrated health, cultural, economic and environmental benefits (Altman 2012; Burgess et al. 2005; Weir et al. 2011). Participation and related health benefits are highest among Indigenous people living in remote areas (Altman et al. 2012). This argues for the support of homelands, and the provision of employment and training that is accessible by people living in homelands (Altman et al. 2012). However, the concentration of services in a few regional locations in the Northern Territory and Western Australia has been controversial, and does not appear to provide equitable access to resources to remote communities (Markham et al. 2015).

www.environment.gov.au/indigenous/workingoncountry/

www.qld.gov.au/environment/plants-animals/community/about-rangers/

www.dpaw.wa.gov.au/about-us/working-at-dpaw

3.10.2 INDIGENOUS CARBON PROJECTS

Savanna Burning – emission abatement through early dry season burning – was pioneered on Indigenous lands in Arnhem Land through a collaboration between Indigenous elders and rangers and western scientists (Dore et al. 2014; Fitzsimons et al. 2012b; Russell-Smith et al. 2015; Yibarbuk et al. 2001). Currently, at least one-third of Savanna Burning/Fire Management projects are being undertaken by Indigenous organisations[43]. These projects are responsible for close to three-quarters of the carbon credits generated from Savanna Burning so far. This work has provided funds required for the purchase of land by Indigenous people (Fitzsimons et al. 2012a), and contributes to the employment and resourcing of many Indigenous rangers. Incomes may be increased further once the savanna burning/carbon sequestration method comes on stream.

The Aboriginal Carbon Fund[44] has assessed other options for Indigenous people to earn income through carbon management. The most promising for the Monsoonal North is Savanna Enrichment, which involves under-planting native vegetation with bush foods, such as Gubinge (*Terminalia ferdinandiana*) or Pindan Walnut (*Terminalia cunninghamii*), to increase carbon stocks. This would provide Kyoto-compliant carbon credits that could be sold both through the Clean Energy Regulator and on the voluntary market. Other options are less certain, partly because CER-approved methods are unavailable, as these are restricted to forms of carbon storage and abatement recognised under the Kyoto Protocol.

TABLE 21. ASSESSMENT OF POTENTIAL EMISSION REDUCTION METHODS RELEVANT TO INDIGENOUS LAND IN THE MONSOONAL NORTH

SOURCE: ABORIGINAL CARBON FUND (HTTP://ABORIGINALCARBONFUND.COM.AU/BLUE-CARBON)

Method	Description	Assessment	Kyoto compliant
Savanna enrichment	Increasing carbon stocks with plantations of bush foods	Methodology under development	Yes
Blue carbon	Increasing carbon stocks in marine habitats such as mangroves or seagrass	Method approved overseas but requires research and development in Australia	No
Feral animal control	Reduces methane emissions by reducing the lifespan of animals	Method developed but rejected by Clean Energy Regulator	No
Rangeland management	Increasing carbon stocks by managing livestock, feral animals and fire	Method approved overseas but requires research and development in Australia	Unclear

[43] Clean Energy Regulator www.cleanenergyregulator.gov.au

[44] http://aboriginalcarbonfund.com.au

3.10.3 SUSTAINABLE USE OF WILDLIFE

Hunting and harvesting of wildlife is an important, and perhaps undervalued, aspect of Indigenous economies (Altman 1987, 2003; Altman 2012; Davies et al. 1999). Use of wildlife for personal, domestic or non-commercial communal purposes is enshrined in Native Title legislation[45], and permitted under legislation in all three jurisdictions[46]. Commercial use of wildlife is a high priority for Indigenous people (Zander et al. 2014), and activities such as harvesting crocodile eggs and mustering water buffalo and have made a significant contribution to the income of some Indigenous communities for well over a decade (Altman et al. 2005; Austin et al. 2012). However, commercial use of wildlife is prohibited in all three jurisdictions without specific approval, and faces opposition from conservation activists and the broader community (Lunney 2012; Northfield et al. 2010). It is prohibited by the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) where it involves nationally listed threatened species, unless included in a management plan that has been approved by the Commonwealth Minister for the Environment. Crocodile management plans that included harvesting of eggs and safari hunting were submitted to the Commonwealth by the Northern Territory Government in 2005, 2009 and 2014 (DLRM 2014; Leach et al. 2009, 2012). On each occasion, the collection of eggs was approved, but safari hunting was prohibited (DLRM 2014). No decision appears to have been made on proposed amendments submitted in 2012[47].

Facing minimal community opposition and no legislative barriers, commercial use of feral animals is less problematic (Davies et al. 1999). Feral animal control has the potential to contribute significantly to the economies of Indigenous communities through both sale of product and delivery of an environmental service (Austin et al. 2011; Gorman et al. 2008).

[45] *Native Title Act 1993* (Cwlth)

[46] Conservation and Land Management Act 1984 (WA); Territory Parks and Wildlife Conservation Act (NT); Nature Conservation Act 1992 – Nature Conservation (Wildlife Management) Regulation 2006 (Qld)

[47] www.environment.gov.au/consultation/proposed-management-program-saltwater-crocodile-northern-territory-australia-2012-2014;

3.10.4 BIOSECURITY SURVEILLANCE

Australia invests in biosecurity work on the Australian mainland, at ports and in neighbouring countries (Black et al. 2008). However, invasion threats across the vast northern coastline make threat detection difficult (Figure). Indigenous ranger groups and other land managers in remote Northern Australia are ideally placed to detect and monitor these risks (Maclean et al. 2014; Marley et al. 2006). Until 2006, Indigenous rangers undertook unpaid surveillance of fishing vessels across the Northern Territory coast (Muller 2008). In May 2006, $6.9m was allocated by the Australian Quarantine Inspection Service (AQIS) to engage Indigenous community groups in monitoring bio-security risks from illegal foreign fishing vessels over a four-year period (Law et al. 2007; Muller 2008). Since 2010, about 40 Indigenous ranger groups have been funded to undertake biosecurity surveillance under contractual and fee-for-service arrangements through the AQIS Northern Australia Quarantine Strategy (NAQS) (DoA 2014; Greiner et al. 2013). These rangers assist in monitoring new weed occurrences, mapping host plant for foreign pest and diseases, trapping and examining feral pig for diseases, managing sentinel herds, mapping bat colonies, monitoring marine debris, trapping mosquitoes for disease vector detection and raising public awareness (Greiner et al. 2013; Joint Committee of Public Accounts and Audit 2012; Muller 2008). On 8 July 2015, the Australian Ministers for Agriculture and Indigenous Affairs announced $12.4m to continue and extend this program as part of a $200m commitment to improving Australia's biosecurity[48].

[48] www.agriculturemeinister.gov.au/pages/media-releases/12-4-million-for-indigenous-rangers.aspx

3.11 SUSTAINABLE GRAZING

The most extensive land use in the Monsoonal North is grazing, which occurs across both Indigenous and non-Indigenous lands, so sustainable conservation of grazing lands has the potential to contribute to the environmental health of the region. There are also many opportunities for grazing enterprises to benefit financially from participating in the conservation economy. Improving herd and land management and reducing runoff and sediment loss can reap financial gain as well as provide environmental benefits. Carbon emission reduction through land and herd management can also be profitable. Financial support may also be gained for dedicated biodiversity conservation in priority areas. There are also several extension programs that will help pastoralists identify and adopt the best practices for their circumstances, and financial support may be available to underwrite the cost of this transition. Ecotourism is also a growing part of the pastoral conservation economy, but will not be explored further in this section (See Ecotourism).

3.11.1 GRAZING LAND STEWARDSHIP

Practices needed to protect and restore Grazing lands in Northern Australia are well understood, and include both land management and herd management. Many of these practices also have biodiversity benefits. Stewardship payments recognise the public benefit of protecting and restoring agricultural land condition (Attwood et al. 2009; Dobbs et al. 2008; Scherr et al. 2008). Stewardship payments are well-established across Europe the under the European Union Common Agricultural Policy (Courtney et al. 2013; Dobbs et al. 2008; Keenleyside et al. 2011). They were first instituted in Australia in 1994 to subsidise management of salinity (Maraseni et al. 2013). From 2008 to 2012, the Australian Government provided stewardship payments to undertake conservation management in threatened ecological communities for up to 15 years (Coggan et al. 2013; Rigsby 1981; Zammit 2013). An assessment of 152 properties participating in stewardship of box gum grassy woodland – including nine properties in Queensland – showed paddocks under stewardship management were in better condition than were matched reference paddocks on the same property, with better perennial grass cover and greater richness of ground cover species and birds and less weed cover (Kay et al. 2013). The program also successfully engaged landholders who had no prior interest or experience with environmental programs; was viewed favourably by participants; and promoted an improved conservation ethic (Coggan et al. 2013). Stewardship payments to improve grazing management practices were similarly trialled for a two-year period in the Desert Uplands, Queensland, in 2006-7 (Windle et al. 2009). While the auctioning system was considered a success, no assessment of environmental outcomes has been published.

Many pastoral managers in Northern Australia have indicated their willingness to enter into stewardship arrangements to undertake paid conservation (over and above that already undertaken for pastoral management) (Adams et al. 2012, 2014; Greiner 2014b; Greiner 2015a), including management to address weed, fire, pest animal and erosion issues for conservation. Payments for such management averaged $2/ha/year in the Desert Uplands trial and were also estimated to cost an average of $2/ha/year in the Daly River catchment of the Northern Territory (Adams et al. 2012). Daly River managers prefer to be paid or supplied with fencing and other materials necessary for undertaking conservation management than to be allowed increases in permitted area of clearing, or provided with conservation certification or labour to do the work.

So far, stewardship schemes applicable to Northern Australia have been short-lived, and no schemes are currently operational. One reason is likely to be the high perceived private benefit, as sustainable management of rangelands is the most profitable form of pastoral management (Donaghy et al. 2010; Higgins et al. 2007; MacLeod et al. 2004; O'Reagain et al. 2011; O'Reagain et al. 2011). Another is that philanthropic organisations investing in environmental service delivery prioritise poverty alleviation, especially in developing world (see Prioritisation of conservation investment). In Australia, philanthropic organisations largely focus on Indigenous economic development along and/or biodiversity conservation. It is important, therefore, that anyone designing a future grazing land stewardship scheme be aware of funding insecurity, and ensure legacy outcomes for both providers and investors through an enduring change in management ethic or by financing transitional arrangements required to support long-term sustainable management (e.g. paddock-spelling). In addition, conditions of stewardship need to be well-structured, contracts binding and obligations monitored (Dobbs et al. 2004). Payments and conditions also need to be consistent with international trade obligations, which means that they need to focus on landscape condition, rather than increased

production (Dobbs et al. 2004). At present, the best option for receiving payments for improving grazing practices may be through adjusting herd management to reduce methane emissions (see below).

3.11.2 Carbon economy

The various options for pastoral enterprises to earn income from GHG emission reduction were described earlier (see Carbon economy). The most relevant of the approved methods are:

- Savanna Fire management
- Best management practices for reproductive performance and feed utilisation.

The most promising methods yet to be approved involve supplementing cattle diets with marine red algae (Machado et al. 2014) or inclusion of Leucaena in the grazing system (Harrison et al. 2015). Adoption of practices to reduce emissions has the benefit of providing both a public benefit and improving the productivity and resilience of grazing enterprises.

3.11.3 Biodiversity conservation

In most respects, biodiversity benefits from best practice grazing management (Fisher et al. 2006), but other measures are required to manage land specifically for biodiversity conservation on all or part of a grazing property. Because these actions are additional to those required for pastoral production, they are more likely to attract funding than grazing land stewardship is. Many pastoral landholders have already entered into conservation agreements for biodiversity conservation, including through establishment of Nature Refuges or conservation covenants (Greiner et al. 2008a; Moon et al. 2011) (see Biodiversity conservation), or have expressed a willingness to participate in paid biodiversity conservation schemes (Greiner 2014b; Greiner 2015a; Moon et al. 2011).

As described earlier, State and Commonwealth funding has been the main source of funds for such efforts, and is likely to continue to be so. The most promising source of funds to support long-term management in priority areas, such as those identified in Figure , is offset payment schemes, where funding is available for the management of a specific threatened species or community, or other listed environmental asset, that is being affected by a development in a nearby area, rather than for restoration of general biodiversity condition. In Queensland at least, the restructured Nature Refuge/NatureAssist program aims to fill this latter function. The type of work likely to be supported includes fencing of high conservation value areas. However, as with previous schemes, funding availability is likely to vary as Government policy focus shifts from time to time.

3.11.4 Financial assistance

In Queensland, pastoralists wishing to improve the viability, environmental sustainability and climate resilience of their enterprises may be eligible for a sustainability loan (see Sustainability loans). Eligible activities include:

- Fencing to separate land types and exclude stock
- Prevention and reclamation of land degradation (e.g. erosion and salinisation)
- Pest plant and animal control
- Tree planting and biodiversity conservation
- Purchase of plant and machinery for land-care purposes
- Effluent and waste control and disposal
- Water quality protection
- Development of water supplies (dam construction, water points, irrigation systems).

Eligible activities to improve climate resilience include:

- Construction or improvement of storage facilities for fodder and other commodities
- Adoption of cropping or grazing best management practice to minimise climate change impact

- Improve and maintain water supplies and improve water use efficiency
- Alternative energy generation systems.

The loans can also cover business restructuring and purchase of livestock and machinery.

Sustainability Loans can be used to establish plantations for carbon sequestration. While no specific mention is made of using sustainability loans to cover the costs of establishing a Herd Management project under the Emission Reduction Fund, some of the actions needed (e.g. fencing and livestock replacement) are listed as eligible. An assessment of return on investment, included in the selection criteria, will be essential to ensure that taking out a sustainability loan does not result in an unsustainable debt burden.

An enterprise that is already financially over-extended is not eligible for a sustainability loan. However, those already burdened with crippling debt have the greatest difficulty in adopting sustainable practices as they feel pressured to increase stocking rates to meet debt repayments (Greiner et al. 2006). Many landholders in Northern Australia are under financial stress resulting from static cattle prices and increasing costs increase, falling equity as a result of the collapse in land prices in 2008; and the resultant increased cost of servicing over-extended debt (ABARES 2014c; McLean et al. 2014). One impact of escalating debt is that it can drive land managers to increase their grazing pressure as they try to service debt payments (Greiner et al. 2006). Cancellation of portion of national debt has been used to secure an increase in the area protected for biodiversity conservation in developing countries (Büge et al. 2015; Gockel et al. 2011). Cancellation of portions of farm debt have also been used to secure on-farm conservation in the United States. Exploring the potential for such a scheme in Northern Australia, Greiner et al. (2007a) found a significant percentage of pastoralists in debt were interested in converting a portion of their land from pastoral to conservation use in return for debt-cancellation (Greiner et al. 2007). The payments landholders expected for participating in such a scheme ($40-$1,364/ha) were mostly higher than the cost of outright purchase ($200/ha). Additional issues identified included the need to secure conservation agreements in the long-term; the cost and difficulty of enforcing management conditions on the sacrificed land; and the potential for grazing pressure to be increased on other parts of the property to compensate for lost pasture. Moreover, while a number of funding sources for the scheme were identified (government, banks, NGOs), no organisation is volunteering to invest in such a scheme. Rather, donors show a preference for investing in long-term biodiversity conservation linked to social justice in developing countries (Martin 2013).

There are other financial instruments to assist farmers out of debt, mostly based on developing world poverty alleviation and/or conservation efforts. These include aggregation of debt across several enterprises, which reduces transaction costs and increases purchasing power (Sahoo 2005) and loan guarantees (Büge et al. 2015; IFAD 2014; Marley et al. 2006; Moritz et al. 2013; Northfield et al. 2010; Sahoo 2005), in which a third party (such as a government or a conservation NGO) guarantees part of the loan required for the producer to transition to financial and environmental sustainability (Davies et al. 2013; IFAD 2014). Such arrangements may need to be conditional on a mandated commitment to practice improvement.

3.11.5 Market access and accreditation

Consumers are sometimes willing to pay extra for products that they perceive to be sustainably produced, especially if this means the product is better quality, more sustainable, or healthier than the standard fare (Bauman et al. 2007; de Haes et al. 2010; Loureiro et al. 2000). Demand for ecologically produced food is growing in China and India (Driver et al. 2011; Paull 2008). Producers benefit from eco-labelling and marketing only if it provides price premiums or market access and security. The challenge of a labelling system is traceability through the supply chain (Pahl 2007). The Australian beef supply chain, for example, is complex, with little direct contact between producer and consumer (Figure).

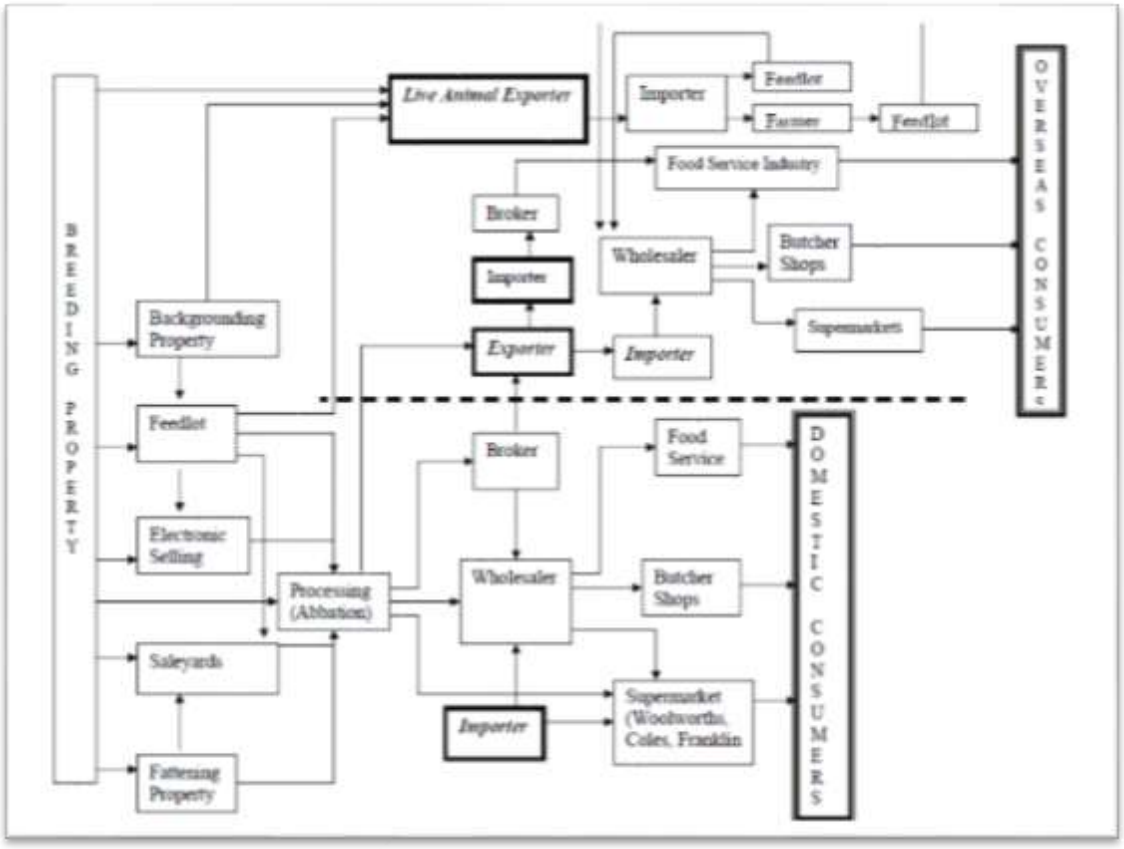

FIGURE 36. AUSTRALIAN BEEF SUPPLY CHAIN

SOURCE: JIE ET AL. (2007)

Northern beef is sold through three main methods: saleyard auctions, over-the-hook sales to abattoirs and paddock sales, principally supplying the live-export market (Figure). The most common method – saleyard auction – provides little opportunity for assessment of meat quality before sale or to attract a price premium for sustainably-produced cattle (Mulley et al. 2014). There are a few Australian paddock-to-plate operations that deliver branded, high quality, sustainably produced beef at a premium price, but the market niche is currently small and the costs high (Mulley et al. 2014).

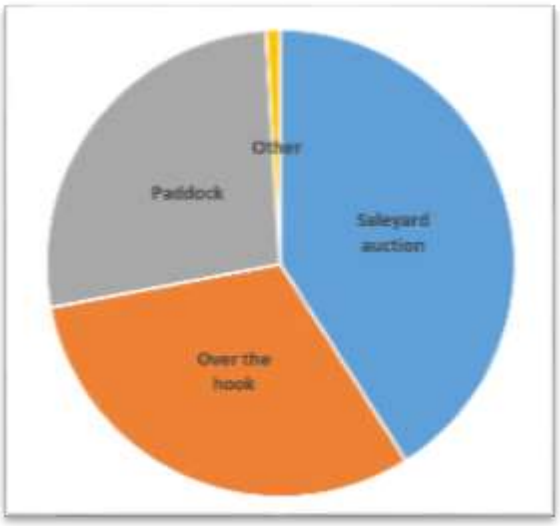

FIGURE 37. METHOD OF SALE OF NORTHERN BEEF CATTLE IN 2011-12 (B)

SOURCE: THOMPSON ET AL. (2014)

The best way to ensure cattle attract a price premium through the general market is to ensure good body condition and meat quality (Mulley et al 2014). Meat Standards Australia grades meat quality at the abattoir based on various carcass characteristics. In 2013-14, producers of MSA-graded beef received an average price premium of 29c/kg (MLA 2014). Certain criteria must be met before a carcass is eligible for MSA grading, including limited stress though mustering, handling and transport. Many producers in the remote parts of Northern Australia cannot meet these requirements (QDAFF 2012). Also, tropical breeds start with a lower meat quality than British breeds, but can be improved through good management, particularly by reducing stress and increasing growth rates through improved herd management, as described above (MLA 2011), and may be expected to attract a price premium of up to $100 a head. Increased growth rates also mean that cattle can be sold at a heavier weight and at a younger age than they otherwise would, and so have access to a more profitable section of the market (Figure). This would not require specific labelling.

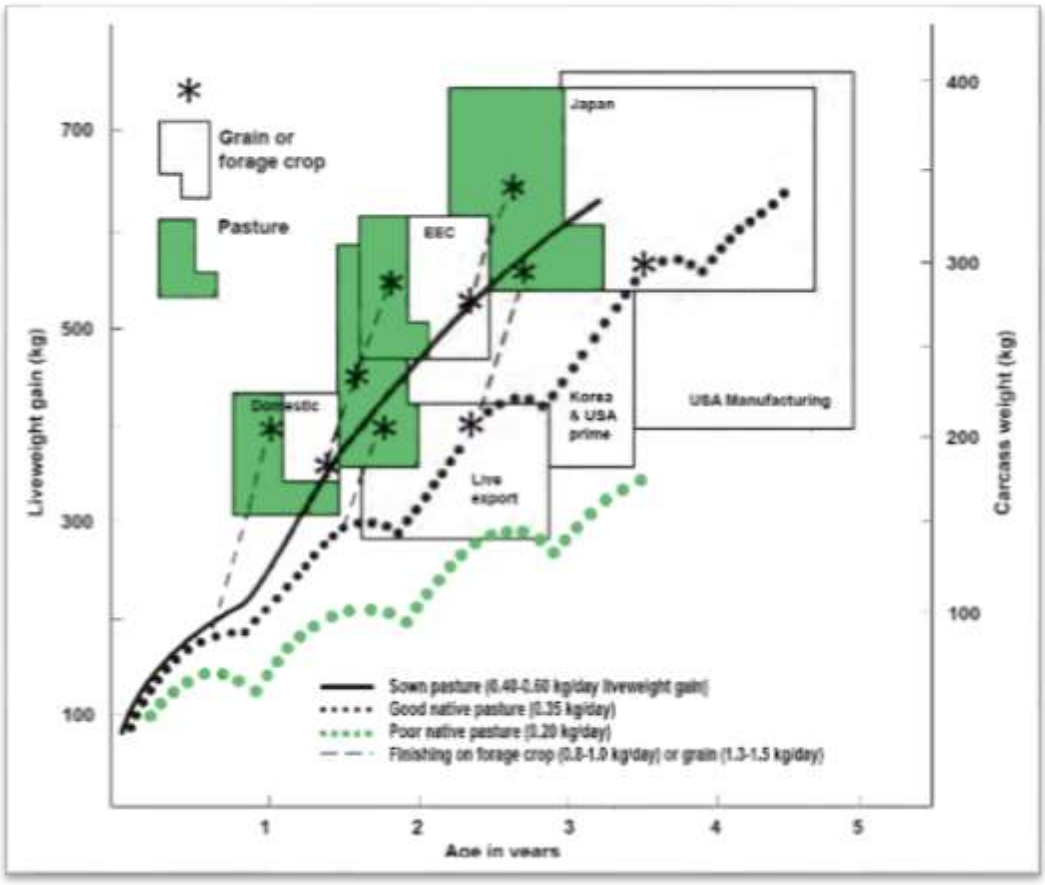

FIGURE 38. MARKET SUITABILITY OF NORTHERN AUSTRALIAN CATTLE GROWN ON DIFFERENT FEED REGIMES

SOURCE: REDRAWN FROM [468] BASED ON [469]

Another approach to rewarding beef producers for sustainable production is through improving the reputation of the beef industry, such as through the Target100 initiative[49]. This initiative is part of a strategy to communicate efforts to improve industry practices to the public through education programs, and conventional and social media (MLA 2014).

In conclusion, there may be limited and expensive opportunities for producers to benefit from eco-labelling schemes. However, producers who improve their herd management to improve environmental sustainability and reduce GHG emissions should reap the benefits through improved productivity and product pricing and market access, regardless of specific labelling schemes. Access to MSA grading would provide an additional price premium for sustainably produced cattle, where this can be achieved. Finally, industry-wide efforts to improve the environmental credentials of the beef industry will benefit individual producers through greater consumer confidence in their product.

[49] An initiative of Meat & Livestock Australia and industry representative bodies, including the Cattle Council of Australia, Australian Meat Industry Council, Australian Lot Feeders Association, Australian Meat Processing Corporation www.target100.com.au/About

3.11.6 Extension and adoption

Entering the conservation economy requires adjustment of pastoral operations. Sustainable and profitable practices are well known and well-documented, but adoption rates are low. Extension services are essential to support uptake. The Productivity Commission recognised the importance of government support for farmers to improve their business management skills and build self-reliance through research, development, extension, training and professional advice (Productivity Commission 2009). Pastoralists are well-served in this area by programs such as Grazing Land Management, Cash Cow (McGowan et al. 2014; NT et al. 2002), BreedPlan[50] and $avannaPlan-Beef$ense[51]. State Governments, State Farm Organisations and NRM groups are all involved in programs to facilitate practice improvement. This includes running land and business management courses and Best Practice frameworks, as well as managing devolved grants to support adoption of specific technologies or land management practices.

Low uptake indicates that pastoralists have either low motivation or significant barriers to adopting sustainable practices (Rogers 2003, Weatherley 2013). Improved profitability alone is not sufficient to drive practice change, but pastoralists under financial pressure are often driven to overstocking or have difficulty making practice changes as they are spending time working off the property to make ends meet (ABARES 2011, 2014c; Greiner 2009; Martin et al. 2014; Nason 2014; Pahl 2007; Pahl et al. 2007). Addressing such issues requires assisting pastoralists improve their financial literacy and manage debt (McLean et al. 2014). This includes helping pastoralists understand the profit drivers in their business, and to place more value on the amount of beef they produce than on the number of cattle they carry.

3.12 Conclusions

The conservation economy is operating in Northern Australia and is likely to grow, but also be subject to variation with shifting Government policy. Growth is most likely to be driven by the international priorities of conservation of listed threatened species, protection of World Heritage values, establishment of a protected area estate and alleviation of poverty among Indigenous people and in the developing world, adherence to sustainable development goals and mitigation of climate change. These priorities are likely to inform investments by governments, NGOs and private donors.

The principle opportunities for growth in the conservation economy in the Monsoonal North are:

- Greenhouse gas abatement activities (e.g. Savanna Burning, Methane emission reduction),
- Indigenous Land and Sea Management supported by governments and NGOs,
- Protection of high priority biodiversity on private or leasehold land funded through development offsets, and (to a limited extent) through government-funded programs, and
- Taking advantage of the inherent financial benefits of herd management to improve animal performance and land condition.

[50] http://breedplan.une.edu.au/

[51] https://futurebeef.com.au/avannaplan-beefense/

4. Grazing Lands Natural Resource Management Plan

4.1 Land Survey

4.1.1 Assets

4.1.1.1 Land condition in the Northern Gulf Grazing Lands

Good land condition (a healthy cover of perennial grasses, and minimal weeds or bare ground) provides good quality forage to cattle through the year, and is therefore essential for profitable enterprises (Roth 2004). Persistent overstocking causes land degradation, eliminating perennial grasses, exposing bare ground and increasing run-off and soil erosion. Maintaining ground cover is important for minimising soil loss from the paddock, but a good cover of deep-rooted perennial grasses is needed to minimise the runoff responsible for gully and bank erosion (AHA 2008).

The remote and expansive nature of the Northern Gulf region limits the ability for land managers to monitor change in land condition over vast areas, and the use of remote sensing technologies has become a valuable tool in land condition assessments. Determining land condition in Australian rangelands relies on a range of methods. These include permanent photo monitoring points, a plot-based assessment of vegetation cover, composition and soil-surface condition (ABCD method), and the use of satellite imagery for condition assessments over large spatial areas (Vanderduys et al. 2011).

ABCD land condition classification (Chilcott et al. 2003)

'The ABCD is a framework that classes grazing land in four condition classes (A, B, C or D), from good (A) to very poor (D). The description for each class is summarized below:

- 'A' condition (good): good coverage of perennial grasses for that land type, less than 30% bare ground, no erosion, good soil surface condition,
- 'B' condition (fair): has one or more of the following – some decline in 3P grasses, increase in other species (less favoured grasses, weeds), bare ground (>30%, <60%), some decline in soil condition, some signs of previous erosion or susceptibility to erosion,
- 'C' condition (poor): has one or more of the following – decline in 3P grasses, large amounts of less favoured species, bare ground >60%, obvious signs of past erosion or high susceptibility to erosion,

'D' condition (very poor): has one or more of the following – lack of any perennial grasses or forbs, severe erosion or scalding, resultant hostile environment for plant growth'.

Gobius (2012) provides the most recent assessment of land health in the Northern Gulf region, however the author highlights the paucity of information available for a comprehensive monitoring system. These eco-accounts used a range of datasets (both spatial and on-ground) as environmental indicators to assess the health of the land in the Northern Gulf and Cape York region. The combined land health for the Northern Gulf and Cape York region was classified as "Moderate" 79 out of 100. Of the 25 IBRA sub regions twelve were classified as in "Good" land health and 12 were classified as in "Moderate" health, while one was classified as in "Poor" health (Gobius 2012).

The Karumba Plains, Claraville Plains, Woondoola Plains and Donors Plateau IBRA sub regions consistently appeared in the poorest health (Gobius 2012). Further, fertile soils tended to have pasture composition problems and less fertile soils had problems with woodland thickening (J Rolfe 2015, pers. comm., 22 April).

Regions considered to be in better health had less cattle, more area per beast. They also had greater return of dollar per beast, higher returns per hectare from livestock and from agricultural production, and higher total gross value of agricultural production ($/ha). However, these regions also had less total income from livestock, which

suggests they were not solely reliant on livestock and were therefore less likely to overstock pastures (Gobius 2012).

A total of 258 survey sites will be revisited at the end of 2015 so that further land condition data can be collected (J Rolfe 2015, pers. comm., 22 April). This data can be used to measure trends in land condition and indicate if land condition is progressing towards regional objectives.

Land condition assessment of the Northern Gulf Region (Shaw et al. 2007)

'The land condition of fourteen grazing land types were assessed by using scores of soil condition, pasture composition and woodland density. The total scores were categorised as: A (100% of original carrying capacity), B (75%), C (45%) or D (20%) condition. In 2007 the condition of 260 sites were assessed to provide a benchmark for current land condition'.

'Across all land types, 47% of sites were in A condition, 34% in B condition, 17% in C condition and only 2% in D condition. Seventy-five percent of land types with grazing values greater than 5 were in A or B condition, compared with 88% for those with grazing values less than or equal to 5. For Georgetown granites, only 27% of sites were in A or B condition, with values for other land types being: alluvials 59%, black soils 64% and red duplex soils 57%, suggesting that improving management of these land types is a priority. On land types with high grazing value, the major discounting factor was pasture composition (72% of sites discounted), while increasing woodland density was the main discount (73% of sites discounted) on low grazing value land types'.

'Black soils and black basalts have high grazing value, but usually occupy low-lying areas. Seasonal inundation offers some protection to these soils, with stock not grazing these areas until they have dried out. Nevertheless, only 64% of these soil types were in A or B condition and, like the alluvial soils, were discounted on pasture composition and weed invasion. While marine plains were poorly represented in this survey, experience indicates that these pasture lands are in good condition and are expected to remain in this condition. This situation arises from the long periods of inundation experienced by this land type each wet season, which results in a natural annual wet season spelling program'.

'Red basaltic soils were generally in very good condition with 88% of assessments in A condition and the remaining 12% in B condition. They are recognised as heavy grass country and have a relatively high grazing value. Historically, cattle productivity has been poor on this land type owing to deficiencies of salt and sulphur (Hunter et al. 1979) and sparse water supplies. As a result, stocking rates have not matched typical potential pasture yields. In more recent times, water supplies have been improved and mineral supplements are fed, so productivity has improved and the potential for overuse has increased. However, this has not yet been reflected in a drop in land condition'.

'Higher grazing value land types should be a priority for investment in management change in the Northern Gulf region. They have contributed greatly to nutrient and sediment flows, and returning them to good (A or B) land condition would have positive production and environmental benefits. Options available to graziers to rehabilitate degraded land will revolve around combinations of rotational, wet season pasture spelling to restore 3P pasture composition and strategic burning for managing woody vegetation'.

Invertebrates and land condition (Andersen et al. 2004b)

The colonisation of ant communities can inform researchers of the condition of the soil and change in ecological condition of a field site. Ant community composition has been clearly correlated with those of other invertebrate groups and ant species richness has been found to be highly correlated with soil microbial biomass.

Using ants as bio-indicators is time-efficient and cost-effective and can be applied to a wide range of land-use situations such as off-site mining impacts, forest management, conservation assessment, re-vegetation programs and grazing impacts. The data collected can be used to determine suitable management at the local scale or larger regional scales. Using ants as bio-indicators provides comparable data to using birds and vastly better data than for other terrestrial vertebrates.

There are numerous ant species that have been identified as consistent increasers or decreasers in relation to disturbance. A global model has been developed of ant community dynamics based on functional groups in relation to environmental stress and disturbance. There are also well-developed protocols for comprehensive ant survey, making this survey method useful and achievable.

INVERTEBRATES AND LAND CONDITION (ANDERSEN & MAJER 2004)

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4.1.1.2 Soil Health

Soils form the basis of both the natural and production systems in the region; therefore their sustainability is reliant on soil health. Soil condition is difficult to measure at scales other than the site or paddock scale. Consequently, much of the data for overall condition of soil for the region is reliant on the monitoring of soil by individual land managers. However, to assist in collection of data over larger areas, efforts are being made toward the development of remote sensing techniques, which can aid in the assessment of soil condition and trends in land condition (e.g. (Karfs et al. 2000; Knight et al. 2007).Karfs et al 2000; Knight et al 2007). Again, remote sensing approaches offer the best prospect for broad scale monitoring of soil and land condition, particularly if it can be linked to the various on-ground monitoring efforts.

The use of remote sensing technology should also be used at the property-scale for grazing land management. This appears to be a high priority for ongoing research (Brooks et al. 2008b).(Brooks et al 2008). Although remote sensing has many technical limitations, the technology continues to be improved. Remote sensing still provides the most viable means of monitoring change over extensive, remote areas over time.

Effective management of the landscape requires an understanding of the climatic, biophysical and human induced changes. However, in a region as vast and remote as the Northern Gulf, monitoring change over time is difficult and cost prohibitive without the use of remote sensing technology and spatial analysis. The Landsat archive provides the longest historical record, ranging from 1972 through to 2005. The Gilbert and Mitchell catchments of the Northern Gulf region have been interpreted over a 17 year period using this technology for degree of vegetation and land cover change (Brooks et al. 2008aBrooks, A. et al 2008; Brooks , AP et al. 2008b 2008).

MONITORING IN REMOTE AREAS, MITCHELL RIVER EXAMPLE (KNIGHT ET AL. 2007)

'Research has been constrained by the scale of Australia's tropical rivers, by remoteness and by the lack of infrastructure. For example, the Mitchell River catchment is 72,000 km^2 in area, with headwaters near Cairns in the east flowing more than 600 km northwest into the Gulf of Carpentaria. There are few roads (most are unsealed and completely impassable in the wet) and ground access to rivers is difficult. A remote sensing-based mapping approach is the only practical method for mapping features and processes over inaccessible, large areas (such as catchments >10,000 km^2). However there are a number of unique issues that have to be addressed when undertaking remote sensing over large areas that are not evident when mapping over small areas. For example, when dealing with relatively high resolution imagery (such as Landsat or Aster imagery) mosaic files can be very large (>10Gb), comprised of numerous (50 or more individual satellite image scenes), most of which have been acquired at different times (at different seasons and years). As a result the remote sensing process becomes more complicated and cumbersome requiring considerable processing power and data storage resources'.

4.1.1.3 Grazing Land Soils

Soil types of the Northern Gulf Grazing lands include: black soils/black basalts, alluvial soils, Georgetown granites, red duplex, red earths, yellow earths, sandy soils and range soils in inland areas; and vertisols, rudosols, tenosols, hydrosols and sodosols in floodplain and coastal areas. Soils in the Grazing lands are typically phosphorus deficient which impedes both weight gain and reproductive productivity of beef cattle (Jackson et al 2012 in Crowley 2015). The black soils/black basalts, alluvial country, Georgetown granites and red duplex soils have high value for grazing country (NGRMG 2008). Of these the alluvial soils are considered the most fertile in the Northern Gulf Grazing lands and are considered to be the best country for grazing. Alluvial land needs to be fenced to control stock access or overgrazing will result, however if stock are removed the country can recover relatively quickly in comparison to other land types (Clark 1996).

4.1.1.4 SOILS FOR IRRIGATED AGRICULTURE IN THE GILBERT CATCHMENT

More than 2 million hectares of the Gilbert catchment are at least moderately suitable (class 3 or above) for cropping production. The soils however, do have considerable limitations that lower production potential and require careful management (Petheram et al 2013 [Flinders]; Petheram et al 2013 [Gilbert]).

Soil mapping has been undertaken by the Department of Natural Resources to determine the suitability of soils in the Gilbert River (between Chadshunt Station and Green Hills Station) for irrigated agriculture. Of the 108,000 hectares of land mapped, 20,894.2 hectares was identified as arable land that is highly suitable for irrigated agriculture with very minor limitations. Another 7,580.3 hectares was identified as arable that is moderately suitable for agriculture for moderate limitations. CSIRO have undertaken a more comprehensive survey of the soils in the Gilbert catchment and found the potential to be between 20,000 to 30,000 hectares that will support year-round mixed irrigated and dryland cropping. The precise area under irrigation will vary year to year depending on factors such as irrigation efficiency, water availability, crop choice and risk (CSIRO 2013).

The soils that are most suitable for irrigated agriculture in the Gilbert catchment are the recent alluvial soils adjacent to the Gilbert and Einasleigh rivers upstream of their confluence; elsewhere the agricultural potential is low (Petheram et al 2013 [Flinders]; Petheram et al 2013 [Gilbert]) A brief overview of soil genetic group classes of the Gilbert catchment adapted from Petheram et al. (2013) is provided below (Table 22). The most limiting attributes of the soil in the Gilbert River are soil moisture holding capacity/moisture availability on the sandier soils, erosion potential on the sloping soils, and low fertility on soils other than the recent alluvials. The land has potential for the sustainable production of a wide range of irrigated land uses climatically suited to the area with low risks of degradation (GDS 2009).

TABLE 22: **SOIL GENETIC GROUP CLASSES OF THE GILBERT CATCHMENT AND THEIR SUITABILITY FOR AGRICULTURE ADAPTED FROM PETHERAM ET AL. 2013.**

Soil generic group description	Occurrence (%)	Agricultural suitability	Major management considerations
Sand or loam over friable earth clay	27%	Potentially suitable	Steep slopes, small isolated areas, erosion, shallow soil and rock may limit development in uplands
Friable non-cracking clay or clay loam soils	24%	Generally high potential because of good structure, chemical fertility and water holding capacity	Soil on young basalt landscapes in the catchment are frequently shallow and rocky, uplands may have some steep slopes
Seasonally wet soils	2%	Generally unsuitable for crop development.	Acid sulfate soils and salinity are associated problems in some areas
Red, yellow or grey loamy soils	10%	Moderate to high potential when spray or trickle irrigation is applied due to their good drainage	Low to moderate water holding capacity, often hard setting, low soil nutrients
Deep sandy soils	0.5%	Low potential due to excessive draining and poor water holding capacity	Low soil nutrients, subject to wind erosion
Shallow sandy/stony soils	24%	Negligible potential due to lack of soil depth and presence of rock	Often steep slopes, prone to erosion
Sand or loam over sodic/intractable clay	4%	Generally low potential due to restricted drainage, poor root penetration and susceptibility to gully and tunnel erosion	Those with thick to very thick A horizons are favoured. Sandy surfaced soils have low soil water holding capacity.
Cracking clay soils	8.5%	Moderate to high potential	The flooding limitation will need to be assessed locally. Most soils are high in salt which limits crop rooting depth and moderate to

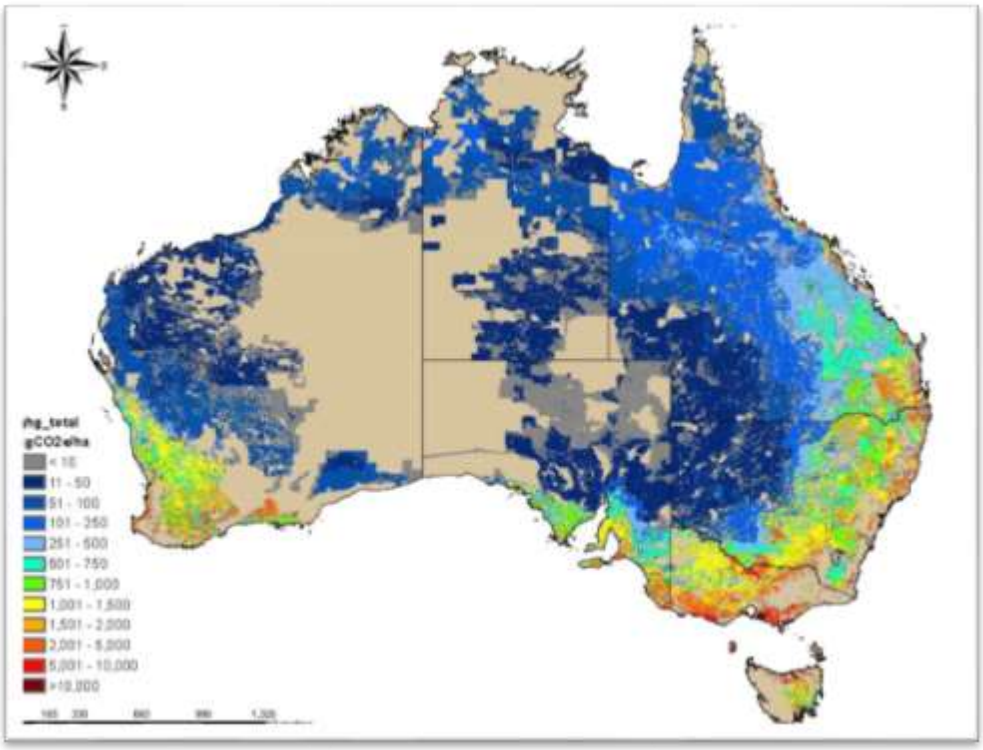
	moderately high water holding capacity.

4.1.1.5 GREENHOUSE GAS BUDGETS

Agriculture produces around 13.5% of global greenhouse gas (GHG) emissions (Fensham 2006) and 16% of emissions generated in Australia[52]. However, agriculture is not currently included in emission reduction targets at a national or global level, so farmers are not required to reduce their emissions (Edwards and Russell-Smith 2009), although this reprieve may be short-lived (Williams et al 2002). It has been estimated that mitigation actions could reduce emissions from Australian agriculture by around 126 Mt CO_2-e per year (Woinarski et al 20014).

Beef cattle produced about 6.8% of the Australia's greenhouse gas (GHG) emissions in 2012[53] and 10-12% of global emissions (Preece, N.D. (2007). As well as methane produced from enteric fermentation, pastoral operations generate significant GHG emissions through electricity and fuel consumption (Greiner et al 2003). Global demand for beef is therefore an important driver of GHG emissions (Greiner et al 2007). So it is important that beef is produced as efficiently as possible to minimise contribution to climate change, with emphasis being on production efficiency (i.e. carbon-equivalent units per kilogram of meat, rather than total GHG emissions) (Bentley et al. 2008).

Livestock grazing is the only agricultural land use that can be undertaken sustainably on savanna grasslands and open woodlands while maintaining its ecological values (Wahlquist 2013). GHG emissions from grassfed beef production in Australia has been estimated and 12 CO_2-e/kg meat produced, which is low relative to world standards (Peters et al. 2010), and agricultural emissions per unit of land in the Monsoonal North are amongst the lowest in the country (**Error! Reference source not found.**).



[52] http://ageis.climatechange.gov.au/#

[53] Beef cattle were estimated to produce 1.8 Mt CH_4 in 2012, with 0.06% generated by manure management and the remainder from enteric fermentation(DoE 2014b). This constitutes 42.5% of Australia's agricultural GHG emissions, which is in turn 16.1% of Australia's total GHG emissions(DoE 2014a). Beef cattle were estimated to produce 1.8 Mt CH_4 in 2012, with 0.06% generated by manure management and the remainder from enteric fermentation[370]. This constitutes 42.5% of Australia's agricultural GHG emissions, which is in turn 16.1% of Australia's total GHG emissions[371].

Even though cattle producers are not required to reduce their carbon footprint, the industry is cognisant of the need to reduce emissions (Williams et al. 2002). Improvements to energy use, animal husbandry and land management have been identified as ways to achieve emission reduction and many are already being implemented (see Table 23). In summary, management practices that improve herd performance, including through improved land condition, breeding rates and liveweight gain, all decrease the carbon input required to produce a kilogram of meat. Furthermore, of the diversification options identified in the next section, forage cropping and savanna burning can also improve the carbon budget at an enterprise level.

TABLE 23 STRATEGIES TO IMPROVE GREENHOUSE GAS FOOTPRINT OF PASTORAL PROPERTIES

* = ***CARBON FARMING/ EMISSION REDUCTION FUND METHODOLOGY APPROVED***

Strategy	Sources
Energy consumption and production	
Switch to renewable energy	(Bentley et al. 2008)
Produce biofuel crops	Woinarski et al 2004
Improve feed conversion efficiency	
Genetic selection of livestock	Williams et al 2002, 2008),(Rolfe 2010),(Basarab et al. 2006)
Nitrogen and phosphorus supplements, especially in the wet season*	(Hennessy et al. 2000)
Phosphorus supplements, especially in the wet season	(Bray et al. 2013)
Improved feed-base	(Bentley et al. 2008)
Dietary additives e.g. Saponins	(Guo et al. 2008)
Reduce ruminant protozoa	(Clemens et al. 2001)
Improve feed quality	
Moderating stocking rate to improve pasture quality	Williams et al 2002, al 2004
Grain-based feed-lotting	(Bentley et al. 2008),(Hegarty et al. 2008),(McCrabb et al. 1999)
Improve herd management and growth rates	
Genetic selection of livestock	(McCrabb et al. 1999)
Herd management (e.g. Improve reproductive performance, Culling infertile cows, Early joining)*	375,384,388
Property infrastructure	(Bentley et al. 2008)
Sequester carbon	
Restore native tree cover through planting and/or regrowth*	Woinarski et al 2004, Wahlquist 2013
Improve soil carbon (e.g. by promoting deep-rooted perennial grasses)*	Woinarski et al 2004
Abate GHG emissions	
Fire management to reduce extent of late dry season fires (Savanna Burning/Fire management)*	Woinarski et al 2014)

4.1.1.6 CLIMATE CHANGE ADAPTATION

While the extent of the projected impacts of climate change on the northern pastoral industry could be seen as dispiriting, options have been identified for providing resilience for the industry to weather these impacts. Most of the enterprise-level options (see Table 24) are consistent with current best practice and are already incorporated into extension programs. Industry resilience will therefore benefit from continued support for extension programs and best-practice frameworks.

TABLE 24. ENTERPRISE-LEVEL OPTIONS TO FACILITATE CLIMATE CHANGE ADAPTATION

SOURCE: HOWDEN ET AL. (2008)

Options
Pasture productivity and grazing pressure
Select sown pastures and forage crops adapted to higher temperatures and water constraints
Revise fertiliser management through sown legumes and phosphate fertilisation where appropriate
Provide urea and phosphates directly to stock via reticulation and use effective supplementary feeding strategies
Increase use of strategic spelling
Use fire to control woody weeds
Use responsive stocking rate and rotation strategies based on seasonal climate forecasting, alter crop/livestock mix
Develop regional safe carrying capacities i.e. constant conservative stocking rate
Where appropriate, develop software to assist pro-active decision making at the on-farm scale
Improve water management, particularly for pasture irrigation
Pests, disease and weeds
Increase use of biological and other controls (cautiously)
Increase use of insect traps for sentinel monitoring and for population control
Adopt alternative chemical and mechanical methods for reducing woody weeds
Use pest predictive tools and indicators
Use quantitative modelling of individual pests to identify most appropriate time to introduce controls
Animal husbandry and health
Select animal lines that are resistant to higher temperatures but maintain production
Modify timing of mating based on seasonal conditions
Modify timing of supplementation and weaning
Construct shading and spraying facilities to reduce heat stress
Increase use of trees to provide shade and reduce wind erosion

4.1.2 THREATS

4.1.2.1 GRAZING PRESSURES

Northern Gulf beef cattle herd

Cattle grazing is the principal land use (92%) across the Northern Gulf region with a total herd size of approximately 800,000 to 900,000 head (Cummings 2008) (MLA 2012). There has been a long-term growth trend of cattle numbers across the region since the 1960s. In the Etheridge Shire cattle numbers have increased from 113,000 in 1969 to 315,000 in 2005/06 (a long-term trend average of approximately 3% per annum). Numbers across the Northern Gulf region have increased from 548,000 in 1983 to 630,000 in 2006/07 and further increased to 933,292 in 2011 (Cummings 2008; MLA 2012). Government projections for the northern Australian beef industry show by 2040 a predicted increase in Queensland cattle numbers from 12.2 million in 2013 to 16.8 million in 2040 (Chilcott et al. 2014).

There are approximately 160 grazing properties, covering an area of approximately 17 million hectares. These enterprises rely principally on native pastures to turn off about 200,000 cattle per year. The range of markets targeted for cattle sales includes the retail food market and the US grinding beef trade, live export, and some transfer of weaners to finishing properties in central and southern Queensland (Shaw et al. 2007).

Growth in stock numbers has been influenced by factors that have reduced previously high mortality rates, in part made possible by improved road access, introduction of drought and tick resistant breeds, better disease management, improved herd management through fencing and more water points, and increased use of hays and supplements (Ash et al. 1997). Licks have enabled graziers to run more cattle, rather than be used for their intended purpose, which is to increase production rates (Clark 1996). These production advancements, together with a beef price slump in the 1970s, have resulted in a marked increase in cattle numbers since the 1960s (Ash et al 1997).

Higher stocking densities causes increased grazing pressure on the natural environment which has lead to reduced land condition and a widespread decline in the density of perennial tussock grasses over the past 30 to 40 years (Ash et al 1997). The problem appears to be more widespread in the north-east (Tothill et al. 1992) as a failure to adjust stock numbers during a decade (1980s-1990s) of generally below average wet season rainfall has resulted in persistently high grazing pressures (Ash et al 1997).

Grazing properties are large and rely on native grasses and vegetation for productivity and long-term viability (Cummings 2008). While there are minor areas of improved pasture in the tropical savannas of Northern Australia, these account for a very low total area. The largest area is 5% of the Claraville Plains sub region of the Gulf Plains, followed by some areas in the Undara Basalts sub region of the Einasleigh Uplands (Fisher et al. 2004). The loss of land condition and productive grasses can be detrimental to beef cattle enterprises, therefore managing these resources is of highest importance to maintaining the beef cattle industry in Northern Gulf.

Grazing impacts on land condition

Much of the land in the Northern Gulf Grazing lands has poor soil fertility and therefore lower stocking rates are recommended for maintaining good land condition. The great variety of soil types in the region results in highly variable quality in grazing country. Lower quality land is generally used for breeding cattle for low value live export or for fattening and finishing elsewhere (Crowley 2015). Tableland grazing properties however, are more suited to fattening cattle and most producers either buy cattle for fattening or have breeders and fatten their progeny (Clark 1996).

Although the original condition of the native understory is unknown, vegetation surveys strongly suggest that a major cattle-driven transformation has taken place in the landscape (Foran 1980). High grazing pressure has been sustained over decades, resulting in a significant loss of desirable perennial grasses over large parts of the region. Infertile soils, with their low productivity and nutritive value together with limited property infrastructure and development, have resulted in comparatively low stocking rates, meaning these areas have not been impacted as much as higher value grazing lands. However, with increasing numbers of live cattle being shipped from ports adjacent to the monsoonal grasslands (Stewart 1996), it is likely these pasture communities will come under increasing pressure (Ash et al. 1998b).

Unsustainable grazing practices threaten the functioning of ecosystems and the survival of many native species. In combination with climate variability, maintaining high numbers of cattle has led to the loss of ground cover in some land types. This lack of ground cover has resulted in a loss of nutrients, topsoil and water through run-off and soil erosion. High value grazing land types such as the Georgetown granites have experienced a loss of condition in more than 70% of its extent in the region (Shaw et al. 2007).

Typically, grazing management involves set-stocking based on the rated carrying capacity of land systems or pasture types (Table 25), however in Queensland, the industry has a long history of stocking above the recommended carrying capacity (Tothill et al. 1992). Some land managers use variable stocking rates based on fixed utilisation and seasonal forecasting, although currently many graziers have limited capacity to implement this due to high debts. In some parts of the region, particularly in areas of relatively high productivity, there are moves towards pastoral intensification through further water-point development and reduction in paddock size (Fisher et al. 2004). This grazing strategy aims to create even distribution in grazing pressure; however, the long-term impacts remain unproven. The grazing ratio between grazing land and water points (for effective grazing cover) is below the recommended level in the Gulf savanna, being half the recommended number at one point for every 66 km^2 (Crowley 2015). Strategic placement of new watering points would allow more of each property to be grazed (Crowley 2015). Reducing paddock size by fencing is another strategy that can be used to encourage even grazing distribution. Although more costly than increasing the number of watering points, increased sub-division can have benefits such as providing better animal control, better management of grazing pressure, herd segregation and resting strategies, more flexibility to use fire as a management strategy and potentially lower mustering costs. Alternative grazing strategies such as wet season spelling and rotational grazing are rarely used (A Taylor 2014, pers. comm., 15 June), however, more recently adoption rates have been higher (Bortolussi et al. 2005).

4.1.2.2 LAND CONDITION AND ECONOMIC RETURNS

A long-term study at Wambiana, near Charters Towers, Queensland, demonstrated that adjusting stocking rates in response to variation in climate (Herczeg and Love 2007, Australian Government 2009) not only increased profitability (O'Reagain et al 2014, O'Reagain et al 2011), but both protects the grazing resource in the long-term (DoW WA 2013) and improves conditions for biodiversity (Cook et al 2010). Adjusting stocking rates to carrying capacity requires an assessment of forage availability (Roth 2004).

Adjusting stocking rate is most easily done on backgrounding properties, where weaner steers are purchased and grown for sale to feedlots (McClelland Rural Services Pty Ltd 2014, Australian Government 2009). Stocking rates can be adjusted on such properties by reducing the number of animals purchased and increasing the number sold. However, breeding properties are dependent on their reproductive stock to produce weaners for sale, so have less capacity to reduce numbers, as this also reduces capacity to re-build the herd when conditions improve. Nevertheless, modelling has also shown varying stock number in response to seasonal condition can also be profitable on breeding-finishing properties (EPA WA 2015).

Resting pastures is important to allow recovery of perennial grasses (Roth 2004). In the Monsoonal North, the most effective form of resting pastures is periodic wet season spelling. This requires the property to be divided into enough paddocks to allow stock to be removed from one paddock and distributed across the remaining paddocks. A large number of paddocks will allow rotational grazing, which will be most effective when paddocks are locked up for an entire wet season. Another option is to burn parts of a paddock to attract cattle to the new growth that follows, thereby resting the unburnt areas (Marsh and Pannell 2000) . Surveys indicate that use of spelling has increased in the regions from less than one half of enterprises in 1994-1997[54] to in excess of 60% of enterprises across Northern Australia in 2010-12[55].

TABLE 25: **LAND TYPES RECOGNISED ACROSS THE NORTHERN GULF REGION AND GRAZING VALUE OF EACH TYPE IN GOOD CONDITION. THE HIGHEST VALUE LAND IS RATED 10 AND OTHER LAND TYPES RATED AS A FRACTION OF THE BEST TYPE.**

Land Type	Grazing Value	Carrying Cap in A and 100% access Ha/AE	Land Type	Grazing Value	Carrying Cap in A and 100% access Ha/AE
Alluvial Soils	10	4	Old Alluvial	6	8
Black soil/Black basalt	9	4	Red earth	5	10
Marine Plain	8	6	Yellow earth	3	12
Red basalt	7	6	Sandy Forest	1	20
Red duplex	7	6	Sand ridge	1	20
Georgetown Granite	6	8	Range soil	1	20

[54] Spelling rates in Dalrymple region: 1994: 27%; 2004: spelling 43% (Head 1999) Spelling rates in 1996/7: North-western Western Australia: 28%; Northern Territory: 44%; Queensland Gulf: 24%;
Queensland Mitchell Grass: 32%; North Queensland: 45% (CSIRO 2013).

[55] Kimberley (2010): spelling 61%, rotational grazing 23% (McGowan 2014, Mifsud 2013) Northern Territory (2011-12): spelling 61%, rotational grazing 23% (DEEDI 2010) Burdekin Dry Tropics (2008-10): spelling: 92%; wet season spelling of at least 25% of the property: 75%; rotational grazing or cell grazing (Hughes 2004, AHA 2014)

Other Granites	6	9	Lancewood	0.5	40
Bluegrass/Coolibah	8	7			

Northern Gulf Region Grazing Land Management (GLM) Land Types

Fencing by land type and managing these as separate units could improve overall land management in the Northern Gulf. Subdivision fencing enables better control of stock access and grazing pressure by breaking down paddocks into sub-management units (Department of Agriculture 2013b). Each paddock can be grazed according to the recommended carrying capacity which can help ensure land condition is not reduced in fragile or preferred land types. Although fencing to land type is considered an effective land management tool, it is not always practical or cost-effective. In these situations, rotational grazing, spelling, location of watering points and supplement feeding sites, temporary fencing (eg. Low cost electric fencing) and fire can be used to even out grazing pressure and improve the condition of deteriorating land (DAFF 2013).

Future Beef provide fact sheets on land types in the Northern Gulf region. These fact sheets provide land use and management recommendations for best management of each GLM type. The fact sheets are available at http://futurebeef.com.au/topics/grazing-land-management/land-types-of-queensland/northern-gulf/.

NGRMG mapping extension officers work with land managers to develop property maps which include land type mapping, fencing, water planning and infrastructure, fire and flood management and soil carbon sequestration. These maps can assist land managers to effectively manage their properties to improve planning, increase productivity and sustain good land condition.

Fencing by land type is only part of a suite of considerations needed for optimum grazing land management. Effective pasture utilisation using well-spaced watering points plays a major role in more even grazing coverage and better overall land condition (Smith 2000).

Natural resource management objectives on pastoral lands aim to retain sufficient vegetative cover to protect the soil from erosion, and therefore maintain the productive capacity. However, natural resource management occurs within the context of achieving adequate levels of animal production (and income) to meet short-term economic needs. In practice, these two objectives do not always converge.

The adoption of improved management and innovative technologies by producers in the Northern Australian cattle industry is limited by the inability to predict how changes in practices and combinations of practices affect production and resource condition (Hunt et al. 2014; A Taylor 2015, pers. comm., 10 January). Further, the education level of some property managers would somewhat limit the understanding of and therefore adoption of practices that are innovative and research based (A Taylor 2015, pers. Comm., 10 January). High debt levels and high operating costs also inhibit changes that are likely to improve land condition and provide long term better financial productivity, and instead overstocking may be practiced in an effort to 'make ends meet' in the short-term. Rising operating costs, low beef prices and current drought conditions (which have caused a drop in profitability) has resulted in debt per business in the Northern Gulf in excess of $3.8 million (Rolfe et al. 2014).

Decisions about stocking rates are often based on the condition of the cattle and the pastures at the end of the wet season; and stocking numbers may be reduced if there is not full ground cover. Profitability issues and debt servicing pressures impact on stocking rates and grazing land management across the region with many producers running unsustainable numbers or delaying their destocking strategies (Rolfe et al 2014). Further, small property sizes limit the capacity of some landholders to reduce stocking rates to below the minimum needed to remain viable. Many properties have been able to increase stocking rates by providing a phosphorous supplement over the wet season, and urea based licks during the dry season. Some properties aim to spell country regularly, though this is only possible if properties are large enough, and adequately fenced (Fisher et al. 2004).

Good land condition, with a healthy cover of perennial grasses and minimal weeds or bare ground is crucial for providing good quality forage to cattle through the year and hence benefits enterprise productivity (Hunt et al.

2014). Long-term safe stocking rates have been found to increase live weight gains, breeder performance, weaning efficiency, and reduce the need to drought feed (Smith 2000). Improvements to land condition from lowering stocking rates can take several years (Smith 2000), particularly if land condition has been reduced due to previously high stocking rates (Hunt et al 2014).

4.1.2.3 Profitability of the northern beef industry

'Profitability of the northern cattle industry has not improved over the last 30 years and has declined for the best performing enterprises. This is because costs of cattle production have increased thirty-fold since 1950 (or stayed level in real terms) compared to an eight-fold increase in income (or a 60% decrease in real terms) (McLean et al 2014 in Crowley 2015). Indeed, after interest payments have been made, most cattle businesses made losses and are deemed to be unsustainable (McLean et al 2014 in Crowley 2015). Direct costs of producing a 400 kg steer (labour, supplements and fodder, agistment, animal health and freight and selling) rose by 150% between 2001 and 2008, while total costs of production has increased by 54% (McCosker et al 2010 in Crowley 2015). These estimates do not account for lost production as a result of Weeds (ca $1,000 million/year), Pest animals (ca $36 million/year) and Disease and parasites (ca $390 million)– for which costings are not available. In addition, cattle theft has been estimated to cost the industry between $1.5 and $2 million a year in Queensland alone'.

'While there is marked variation in enterprise performance across the region, the majority of northern beef enterprises are not considered viable in the long term. Over 2001-2012, the top performing 25% of enterprises averaged a profit of $66 per head of cattle sold compared to an industry average of $6 per head (McLean et al 2014 in Crowley 2015). Performance was found to be related to good management rather than constrained by environmental factors. Top performance was characterised by higher reproductive rates, lower mortality rates and better sale weights relative to industry averages. Therefore adoption of management practices to improve herd performance should flow through to improved enterprise profitability'.

Maintaining good ground cover is important for minimising soil loss from the paddock, and good cover of deep rooted perennial grasses is needed to minimise runoff responsible for gully and bank erosion (Bartley et al. 2014). Studies have shown that either conservative stocking with year-round grazing or a grazing system that includes some wet season resting will help maintain land in a desirable state for sustainable pastoral production or facilitate the transition from a less ecologically desirable state (Ash et al. 2011). Conversely in a set stocking situation, Walker et al. (1997) report that the selective elimination of 90% of the existing grass layer for three consecutive years in an Australian tropical savanna was sufficient to reduce the most palatable perennial grass species beyond the threshold of natural recovery (Sharp et al. 2003).

Spelling of pasture may be most practically achieved on a rotational basis where paddocks are rested for the entire wet season. At least 5% of a property should be spelled every year (A Taylor 2014, pers. comm., 15 June). In good seasons where there is above average pasture growth, spelled paddocks may not need to be grazed at all, thereby increasing the opportunity to use fire for pasture, woody weed and tree/shrub management. Spelling also has the advantage that the whole paddock is rested rather than reducing stocking rates. Reducing stocking relieves grazing pressure on less preferred parts of a paddock, however, this management activity may have little impact in areas most preferred by cattle (Ash et al. 1997).

Controlled breeding, including pregnancy diagnosis and foetal ageing, may be a way of reducing the impacts of overgrazing by targeting births to the season of highest forage availability (Williams 2008). This method not only reduces overgrazing but also improves the profitability of grazing enterprises and the fertility of cows. Reproductive performance can also be improved by culling infertile cows and sub-fertile bulls, early weaning and segregating pregnant and lactating cows younger than five years for preferential nutritional management (Burns et al 2010; Holroyd & McGowan in Crowley 2015). Early weaning at the end of the pasture growth season and segregating a different classes of animal allow producers to maintain a cows in good condition, maximising the number that conceive for the next breeding round (Perkins et al 2010; Holroyd & McGowan 2014; McGowan et al 2014 in Crowley 2015).

4.1.2.4 Grazing Best Management Practice (GBMP)

Grazing best management practice (GBMP) is about managing the pastures and the number, type and location of grazing animals on a property to optimize pasture growth and composition and animal production. GBMP aims to reduce threats posed by land degradation, erosion, weeds and pest animals as well as safe-guarding and enhancing biodiversity. Monitoring land condition over time will reveal how the management strategies are contributing to land improvement or degradation.

GBMP covers six key areas which include:

1. Maps and property information - maps and property information can assist managers in making decisions on the property scale;
2. Land capability and condition – Land types inform landowners about an area's capability in terms of its potential productivity, limitations and vulnerabilities. Land type mapping enables producers to identify areas of land that differ in their capability and to determine how these differences will affect productivity and influence management decisions. The indicators used to assess land condition are, perennial, productive and palatable (3P) grasses, ground cover, soil condition, presence of weeds and woodland thickening;
3. Managing the land resource – includes land type fencing and water distribution for better management of stock access and grazing pressure, managing frontages and wetlands to reduce land use impacts on the aquatic environment, protecting and improving biodiversity, managing the tree-grass balance and planning for and using fire for management of pastures;
4. Managing grazing pressure - includes understanding pasture growth, setting sustainable stocking rates and adjusting stocking rates based on assessments of forage quantity and quality, pasture composition, residual feed and ground cover, timing livestock management such as calving and weaning, managing allocation of grazing to paddocks and managing for even pasture use;
5. Improved pastures and forage crops – these can be used to significantly improve production by providing extra feed, improving diet quality, providing alternative forage, providing forage for specific purposes and restoring land condition especially where little or no native pasture exists;
6. Managing weeds and pest animals – including identifying weed incursions, controlling weeds, preventing weeds and controlling pest animals.

CATTLE GRAZING IMPACTS ON SOIL BIOLOGY (ASH ET AL. 1997)

'Bacterial and fungal microflora, arthropod detritivores and termites are important in the tropical tall grass rangelands for nutrient cycling (Mott ***et*** *al.* 1985 in (Ash et al. 1997)). In north-east Queensland heavy grazing reduced termite diversity from six species (mainly grass feeders) to one species (a wood feeder) at a high fertility site while at a moderate fertility site species diversity was reduced from six to two (Holt ***et*** *al.* 1996a in (Ash et al. 1997)). Soil microbial biomass also varies in response to changes in grass type and soil cover. At three sites in north-east Queensland (low, moderate and high fertility soils), microbial biomass in bare patches was approximately 30% of that recorded in perennial grass patches while bare patches had approximately 65% of the microbial biomass found in perennial grass areas (Holt ***et*** *al.* 1996b in (Ash et al. 1997). A reduction in soil microbial biomass will result in lower mineralisation rates and lower levels of plant available nutrients, both of which may cause a reduction in herbage growth (Ash et al. 1997)'.

Palatable, **P**roductive, **P**erennial (3P) Grasses

Grasses that are palatable, productive and perennial (3P) are an important resource for the grazing industry in Northern Gulf. Perennial grasses are not only an important forage resource for cattle but have a vital role in protecting and stabilising the soil, trapping and retaining litter, sediment and nutrients and providing habitat for native fauna (Hunt et al. 2014). Maintaining the health and productivity of 3P grasses is therefore an essential part of good land management.

Studies have shown that long-term set-stocking leads to gradual deterioration of the more palatable pasture species (3P grasses) and spelling pastures is necessary to maintain desirable pasture composition. According to Tothill et al. (1992), good pasture management involves:

- Long-term safe stocking rates that will maintain the pasture resource in a desirable and productive condition;
- Strategic management of the grazing resource to counter either the overuse of the resource which is inevitable at times or any gradual erosion of the desirable pasture composition; and
- Strategic management of the resource to enable the implementation of livestock husbandry practices which will improve the efficiency of livestock output. Production per head, rather than per hectare, may actually improve the per-hectare results.

4.1.2.5 SOIL DEGRADATION AND GRAZING MANAGEMENT

The impact of grazing animals is not limited to the direct effects of grazing on vegetation communities. Grazing impacts on soil health by trampling which causes compaction and a reduction of ground cover. This causes greater exposure of the soil to the erosive effects of rainfall and wind. Exposure of the soil alters landscape function through modification in surface hydrology, nutrient dynamics and plant growth potential. Therefore, the management and monitoring of the impact on soils is as critical as managing and monitoring the impact on plants (Fisher et al. 2004).

Soils in the grazing lands of the Monsoonal North are typically phosphorus-deficient (Figure). This impedes both weight gain and reproductive productivity (Etheridge et al 1996). Phosphorus supplements are therefore important for maintaining the nutritional health and productivity of cattle, particularly in the wet season, when grass contains high levels of protein needed for animal production (CLC et al 2003, NABRC 2012, Huang et al 2000). Phosphorus supplementation is of particular interest because of the poor performance of cattle on most performance measures when compared with other parts of northern Australia where phosphorus availability is higher (Productivity Commission 2009).

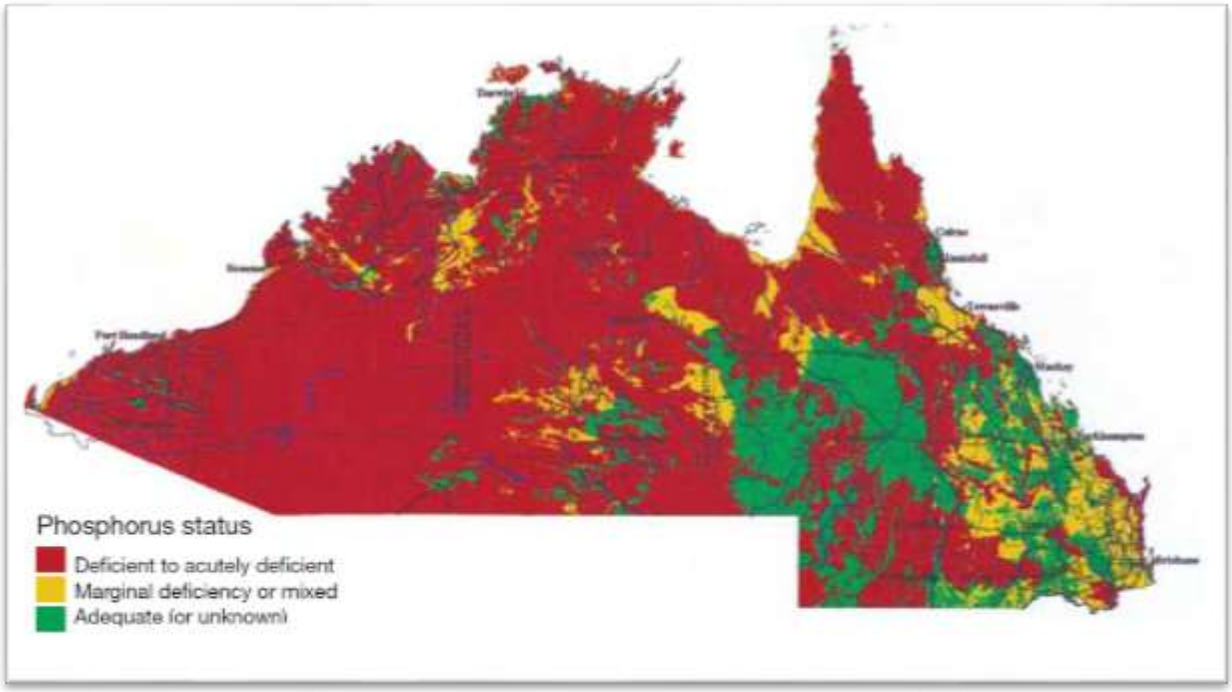


FIGURE 40. SOIL PHOSPHORUS STATUS ACROSS NORTHERN AUSTRALIA

SOURCE: JACKSON ET AL. (2012) (QUERY: ETHERIDGE ET AL 1996) IS #331) ADAPTED FROM MCCOSKER AND WINKS (1994) (QUERY: MANN ET AL 1998 IS #333) (MCCOSKER ET AL. 1994)

Improved pastures

Cattle raised on introduced grasses with either legumes or nitrogen supplements may perform better than do animals raised on native pastures, allowing them to be sold at a premium into high value markets (Winter et al 1991; Petty et al 1998; Burrow 2014 in Crowley 2015). Although these species may benefit some beef production enterprises, several exotic pastures have had adverse impacts on the natural environment, as has the associated tree clearing (Lonsdale 1994; Cook & Dias 2006 in Crowley 2015). Exotic grasses are also discussed in section 2.2.3.

4.1.2.6 MINING

Current mining operations across the Northern Gulf region include many small scale as well as two large operations (Mt Carbine and Red Dome mines). Throughout the region, numerous abandoned mine sites exist and are the focus of this section of the plan (as current operations are controlled under State legislation). Abandoned mines and mine workings threaten the health of soils, riparian areas and adjacent aquatic habitats. One of the most historically significant alluvial gold mines in Georgetown region was at Kidston, near Einasleigh where 588.3kg (18,976 oz) of gold were produced between 1907 and 1910 (Development 2014)(GSD 2014).

TABLE 26. ECONOMICALLY VIABLE MINERAL DEPOSITS IN THE MONSOONAL NORTH

SOURCE: (GEOSCIENCE AUSTRALIA AND BREE 2012, GEOSCIENCE AUSTRALIA (2004)

Commodity	Kimberley	Top End	Gulf Savanna	Southern Gulf	Northern Gulf	Burdekin Dry Tropics
Bauxite	+					
Coal						+
Coal seam gas						+
Cobalt	+	+				
Copper	+	+		+		+
Diamond	+		+			
Gold	+	+	+	+	+	+
Iron	+	+				
Lead	+	+	+	+	+	
Magnesite		+				
Manganese		+				
Molybdenum						+
Nickel	+	+				+
Niobium	+					
Phosphate			+	+		
Platinum group elements	+					
Rare earths	+					
Silver	+	+		+	+	
Tantalum	+	+				
Tin		+			+	
Tungsten						
Uranium		+		+		+
Zinc	+	+	+	+	+	
Zirconium	+					

In comparison to neighbouring regions across the dry tropical savanna of Northern Australia, the Northern Gulf region does not have many large mineral deposits (as per Table above)..

The major impacts of mines result from clearing, excavating and waste disposal (Knight 1998). While the area of land affected by the minerals industry is relatively small, the magnitude of the impact can go far beyond the footprint of the mine itself. Seepage of contaminated leachate from waste rock piles and tailings dams is a significant cause of surface and groundwater pollution in many mining areas. This form of contamination can arise while the mine is operational and without remedial action, can persist long after site operations cease. In some cases, previously innocuous mine waste deposits have suddenly begun to generate acidic and/or metalliferous leachates many years after they have been re-vegetated and left unattended (Butler et al. 2006).

The clearing of vegetation is one of the most significant terrestrial impacts of mining, which will vary according to the type of mineral extracted and the methods employed. Sub-surface mining causes far less vegetation disturbance than surface mining such as strip mining and dredging. Vegetation clearing is also required for haul routes as well as the mine itself. Waste dumps may be situated within the mineral lease or remotely in industrial areas. Slime dams, slurry ponds and similar impoundments are formed when the residues from ore processing are deposited in artificially dammed areas (Lloyd et al. 2002).

Under modern legislation (Mineral Resources Act 1989), the industry generally conforms to the environmental management requirements of regulatory authorities (e.g. Environmental Protection Act 1994). However, while some contamination may be derived from sites with current mining activities, many of the sites in the Northern Gulf with potential to release contaminants into the environment were abandoned prior to the introduction of this legislation

and are presently in a derelict state. The greatest sources of contamination are old and abandoned mines developed when mine site rehabilitation and mitigation were neglected (Taylor 1996).

In Queensland there is an active process of identifying mines that pose the most serious threat to the environment, local biodiversity and human health. The sites are then prioritised according to the level of risk they pose, and are progressively rehabilitated, usually at public expense. However, the remoteness of many abandoned mines complicates the rehabilitation strategies. Remediation of sites will involve considerable expense and resources so that sites considered most at risk to the local community and environment receive the highest priority. Despite being littered with thousands of abandoned mine sites, remote areas such as most of the mine sites in Northern Gulf rarely get attention, and the ongoing impacts on the wider environment are largely unknown (Lloyd et al. 2002).

The development of an abandoned mine rehabilitation and awareness program should receive urgent attention. High variability in the types and concentrations of heavy metals which contaminate the areas around the abandoned mine survey sites indicates that remediation may require a detailed study of individual sites (Jardine et al. 2012).

4.1.2.7 Climate change and drought resilience

Beef production is highly dependent on seasonal conditions, with droughts leading to destocking and years of good rainfall allowing restocking. Increasing rainfall can assist in pasture recovery, improve land condition and increase the potential carrying capacity and stocking rates. However, extended periods of elevated rainfall can lead to unrealistic expectations of long-term carrying capacity and can lead to over stocking and therefore loss of land condition (Department of Agriculture 2013b). Recent drought in 2013 prompted large numbers of properties in the Northern Gulf to destock (Mifsud 2013 in Crowley 2015). To combat the impacts of climate change on land condition in the Northern Gulf, variable stocking rates in response to environmental conditions may be a more viable option than set stocking rates. Further, with higher variability in the amount and timing of rainfall, wet season spelling to rest pastures and have feed reserves is critical for natural resource management (Rolfe et al. 2014).

Many of the adaptation practices identified for improving resilience are consistent with existing best practice recommendations aimed at improving productivity and sustainability. Droughts are a natural process that can cause some degradation of production resources such as pasture and soil. The recuperative processes following drought events must be clearly understood to enable the development of suitable property management actions. The grazing industry is driven primarily by rainfall and therefore stocking should be dictated by predicted rainfall or drought events. Climate and pasture growth prediction tools can be used by graziers to better manage their stock and avoid further losses to land condition. Many land managers however, do not adequately prepare for drought events and manage their stock once drought conditions have been established. The establishment of better predictions of future and interpretation of past drought events could assist property managers to establish management actions in preparation of drought events, and therefore reduce impacts on the environment (Tothill et al. 1992).

In 1997, a large cattle grazing trial was initiated in northern Queensland to quantify the relative performance of a range of grazing strategies in a variable climate. This study demonstrated that managers who overstock and/or only respond to droughts in a delayed, reactive fashion can also suffer significant financial losses through the costs of drought feeding, forced sale of poor condition cattle and animal mortality. These losses can seriously affect long-term business performance, and ultimately jeopardise the survival of the enterprise (O'Reagain et al. 2011).These results challenge the assertion that sustainable management is not profitable and the perception that 'more cattle equals more money' (Stockwell et al. 1991).

This study provided the first long-term evidence that recommended grazing strategies such as moderate or variable stocking can be just as, if not considerably more, profitable than heavy stocking. Varying stocking rates with changing seasonal conditions ensured that grazing enterprises were far more profitable over the longer term than constant heavy stocking (O'Reagain et al. 2011). High stocking rates in the variable strategies leading into the dry years significantly damaged pasture condition due to overgrazing, this resource degradation also leads to financial losses. As noted by Higgins et al. (2007), while variable or opportunistic strategies are 'intuitively appealing', they are not necessarily optimal relative to more conservative strategies such as constant moderate stocking (O'Reagain et al 2011).

Carbon dioxide enrichment alone may also have positive and negative effects, forage production increased through increased growth rates and improved water-use efficiency (end-of-century projected CO_2 increases modelled as causing a 26% increase in production) (McKeon et al 1998). However, as woody plants (C3) respond more vigorously to CO_2 enrichment, increased forage production is likely to be offset by woody thickening (McKeon et al 1998). Moreover, forage quality is likely to decline (Crimp et al 2002) and with it animal growth rates, and enterprise production and profitability (Howden et al 2008, Cobon, D.H., et al 2009).

In most scenarios, whether rainfall remains roughly the same or decreases, pasture growth and safe stocking rates are expected to decrease, with the worst scenarios predicting decreases in pasture growth and safe stocking rates approximating 50% and 60% respectively in both central Queensland and the Victoria River District of the Northern Territory (Whish et al 2014).

Climate change impacts on the production environment will filter through to enterprise and industry viability (Table). But each level of the supply chain will also be directly affected. Effects will extend from increasingly stressful operating conditions to damage caused by floods and cyclones. One example was the impact of Cyclone Marcia, which not only cut communications in the Rockhampton region in February 2015[56] but closed the abattoir for at least six weeks because of power disruption and damage to buildings[57]. This closure affected cattle sales and prices throughout north Queensland[58]. Unfortunately, very few of the projected impacts of climate change are expected to yield positive effects on the northern beef industry. Similarly, in March 2015, Gunbalanya Meatworks had to stop killing and freeze packed meat when Cyclone Nathan delayed transportation for a week[59]. These sort of impacts should be anticipated on the Northern Gulf beef industry, under current climate projections of increased intensity of tropical cyclones.

CLIMATE CHANGE RISK FOR THE GRAZING INDUSTRY OF NORTHERN AUSTRALIA (COBON ET AL. 2009)

'By 2030, some areas of Northern Australia are predicted to experience increased numbers of droughts and lower summer rainfall. This poses a serious threat to the rangelands. Although the impacts and adaptive responses will vary between ecological and geographic systems, climate change is expected to have noticeable detrimental effects on the grazing industry. Climate change is predicted to reduce pasture growth and surface water availability, increase woodland thickening (which decreases the productivity of the land and increases the cost of mustering) and decrease the production per head and gross margin. Further research and development is needed to identify the most vulnerable regions and to inform policy in time to facilitate transitional change by land managers'.

'The amount of surface cover on the soil is a useful indicator of rangeland condition (Tothill et al. 1992) and together with pasture tussock health drives recovery in good seasons. More droughts, lower summer rainfall, higher evaporation and temperature, more wildfires and higher peak wind speeds are likely to drive greater exposure of the soil surface. Low surface cover exposes the soil to water and wind erosion and reduces water infiltration and soil moisture content. Loss of topsoil reduces vegetation growth and increases sediment loads in watercourses. Existing adaptive responses such as adjusting stock numbers to feed reserves, early destocking, and managing total grazing pressure, use of climate forecasts and erosion mitigation strategies will help maintain surface cover and improve the sustainability of cattle production systems throughout the region'.

[56] www.abc.net.au/news/6217420

[57] www.abc.net.au/news/6285738; www.themorningbulletin.com.au/news/meatworks-to-open-in-four-weeks/2566697/

[58] www.abc.net.au/news/6268850; www.mla.com.au/Prices-and-markets/Market-news/QLD-weekly-cattle-summary-26022015; www.mla.com.au/Prices-and-markets/Market-news/QLD-weekly-cattle-summary-05032015

[59] www.abc.net.au/news/6345286

TABLE 27. CASCADING EFFECTS OF CLIMATE CHANGE CONSEQUENCES FOR BEEF PRODUCTION IN NORTHERN AUSTRALIA

SOURCES: 1, (MCKEON ET AL 1998); 2, (HOWDEN ET AL 2008); 3, (COBON ET AL 2009); 4, (WHISH ET AL 2014); 5, (KRITICOS ET AL 2003); 6, (TURTON 2012); 7, (FRASER ET AL 2005); 8, (KENT AND ALSTON 2008); 9, (CSIRO ET AL 2007); 10, (STEVENS 2008)

NB: THIS TABLE ONLY CONSIDERS CLIMATE CHANGE SCENARIOS PROJECTED WITH MEDIUM TO VERY HIGH CONFIDENCE (SEE TABLE 3 OF THE INTRODUCTION).

Variable	Positive drivers	Negative drivers	Projected overall outcome	Sources
Environmental factors				
Surface water		Increased temperatures	Reduced water availability	2
Soil stability		Increased rainfall intensity Increased cyclone intensity	Increased soil erosion	2,3
Ground cover	CO_2 fertilisation Increased temperatures	Increased heatwave conditions Increased wildfire extent Increased soil erosion	Reduced ground cover	3
Soil carbon		Increased temperatures	Reduced soil carbon	2
Cattle ticks		Increased temperatures	Increased numbers and expanded distribution	2,4
Weed spread and water use		Increased temperatures Increased cyclonic disturbance	Increase weed burden	3,5,6
Pasture and feed production				
Woody thickening	More severe wildfires	CO_2 fertilisation	Uncertain	2
Forage production	CO_2 fertilisation Longer growing season Decreased woody thickening	Reduced ground cover Shorter wet season Higher temperatures Increased evaporation Increased woody thickening	Reduced forage production	1,2,3,4
Forage quality		CO_2 fertilisation	Reduced forage quality	2

…/continued

TABLE 27. CONTINUED

Variable	Positive drivers	Negative drivers	Projected overall outcome	Sources
Grain for feed		Increased competition for agricultural land Increased demand for grain for biofuel	Reduced availability and increased cost	2
Animal production				
Animal heat stress and water requirements		Increased temperatures Increased evaporation More heatwave conditions	Increased heat stress and water requirements	2
Animal liveweight gain		More cattle ticks Reduced forage production and quality Increased heat stress	Reduced liveweight gain	2
Reproductive rates		Reduced forage production and quality More heat stress	Reduced reproductive rates	2
Animal mortality		Reduced forage production and quality More heat stress Reduced water availability Increased wildfires	Increased mortality rates	2,3
Animal production		Reduced liveweight gain Reduced reproduction	Reduced animal production	2
Enterprise viability				
On property - infrastructure		Increased heat stress Increase water needs Reduced water availability Increased cyclonic severity Increased wildfires	Increased need for shade, cooling sprays and watering points and replacement of damaged infrastructure	2
Profitability		Reduced animal production Increased infrastructure and pest and weed management costs Increased cost of grain	Reduced income, gross margins and hence profitability	2,3
Social outcomes				
Emotional stress		Reduced income, gross margins and profitability		7,8

…/continued

TABLE 27. CONTINUED

Variable	Positive drivers	Negative drivers	Projected overall outcome	Sources
Infrastructure				
Water storage and distribution		Accelerated degradation	Interruptions to supply Increased maintenance costs	9
Road transport		Temporary or permanent road closure necessitating re-routing (where possible) Increased road maintenance costs Increased risk from road damage	Reduced access to properties Reduced ability to get cattle to market Increased transport costs Increased insurance costs Potential increased cattle mortality	9
Rail transport		Temporary closure from submergence or buckling of tracks Damage to signals and electrical systems Damage to rail foundations	Reduced ability to get cattle to market Increased transport costs Increased insurance costs Potential increased cattle mortality	9
Ports		Increased corrosion Storm damage Inundation	Increased frequency and duration of port closures Shipping delays Increased transport costs Increased insurance costs Potential increased cattle mortality	9
Power generation		Increased power disruption Accelerated degradation	Potential interruptions to operation of meatworks	9,10
Communications		Increased frequency and duration of network outages	Disruption of communication services	9,10
Buildings		Significant damage to, and accelerated deterioration of buildings	Disruption of lives and business operations	9

4.2 FLORA

4.2.1 ASSETS

The Northern Gulf grazing lands occur within the Carpentaria and Karumba basins (Smart et al. 1980). The climate is tropical and characterised by hot wet summers and drier winter months. Annual rainfall varies across the region from the drier south west, such as 744 mm per annum at Croydon.

The wide range in climate and landform is reflected in the diverse range of vegetation types and flora. The vegetation varies across the region however, in the Grazing lands it is dominated by eucalypt woodlands, extensive floodplains and grasslands which are mainly situated in the far west of the region (Gulf Plains) (Figures 1 & 2).

The Queensland herbarium has identified 14 Broad Vegetation Groups (BVG) within the region (at 1:5 million scale). The BVG's comprise 499 separate regional ecosystems (REs); 41 of these are listed as 'endangered' and 161 as 'of concern' according to the EHP biodiversity status. There are a total of 397 REs in the Grazing lands, of these 10 are listed as 'endangered' and 119 'of concern' according to the EHP biodiversity status. The vegetation types reflect the region's diversity of landforms, geology, soil types, climatic variation and fire history (NGRMG 2008). A comprehensive list of endangered regional ecosystems in the Northern Gulf and their threats can be found in Appendix 1.

The most distinctive vegetation communities found in the Northern Gulf grazing lands are:

- Eucalypt (*Eucalyptus* and *Corymbia* spp) woodlands with a grassy understorey.
- Tea tree (*Melaleuca viridiflora*) woodlands across floodplains;
- Lancewood (*Acacia shirleyi*) scrubs on gravelly ridges;
- Grasslands on clay and alluvial plains - dominated by bluegrasses (*Dichanthium* and *Bothriochloa* spp) and Mitchell grasses (*Astrebla* spp);
- Freshwater wetlands, both permanent and seasonal;
- Salt marsh, mudflats, mangrove and sand dune communities in a broad coastal band;
- Vine forest (e.g. Forty Mile Scrub); and
- Riparian woodland and forest that occur along the more permanent watercourses.

The flora of the region is distinctly tropical. The eucalypt woodlands, which dominate the region, contain a variety of shrubs, such as wattles (*Acacia* spp.) and currant bush (*Carissa lanceolata*). The ground layer is typically dominated by a range of native grasses including wire grasses (*Aristida* spp), blue grasses (*Bothriochloa ewartiana* and *Dichanthium sericeum*), black spear grass (*Heteropogon contortus*), kangaroo grass (*Themeda triandra*). A few eucalypt woodlands have a spinifex (*Triodia* spp.) grass layer. Introduced grasses include Indian bluegrass (*Bothriochloa pertusa*), buffel grass (*Cenchrus ciliaris*) and urochloa (*Urochloa mosambicensis*). Forbs include native legumes (*Desmodium* spp, *Glycine* spp, *Indigofera* spp.) and introduced pasture legumes (e.g. stylos, *Stylosanthes* spp).

FIGURE 41: VARIATION IN EUCALYPT ECOSYSTEMS, FROM TALL ROSE GUM FORESTS IN THE WET TROPICS (TOP) TO IRONBARK (MIDDLE) AND COOLABAH WOODLANDS (BOTTOM).

FIGURE 42: NON-EUCALYPT ECOSYSTEMS OF THE REGION INCLUDE SEDGELANDS, TEA TREE WOODLANDS AND GRASSLANDS.

4.2.1.1 Vegetation condition and change in recent decades

Native vegetation is a critical element in biodiversity conservation and may be instrumental in facilitating vertebrate and invertebrate species adaptation to climate change. Assessment of the extent and condition of native vegetation is important in determining the health of landscapes for biodiversity. The Northern Gulf Grazing lands retain most of their remnant vegetation, with minimal vegetation clearing having occurred (99% remaining remnant vegetation; and low 0.001% recent clearing; eg: [Accad et al. 2013; DEWHA 2009; Morgan 2001]). However the vegetation has been affected by cattle grazing, especially exotic pasture development, woody weeds, mining, changed fire regimes and the localised impacts of infrastructure development.

Vegetation structure across the region has remained broadly stable over recent decades. However, thickening of native shrubs and saplings of trees (i.e. woody thickening) have occurred, however there is debate about the scale and degree of thickening in various locations (Fensham et al. 2007a).

The composition of the grass layer of many woodlands has altered with the expansion of introduced grasses, including valued pasture species (e.g. buffel grass, *Cenchrus ciliaris)* and also less palatable species, e.g. grader (*Themeda quadrivalvis*) and rat's tail (*Sporobolus* spp) grasses. A decline in the diversity and abundance of some native grasses and forbs is linked to the increase in exotic plants (jackson 2005; Kutt et al. 2012b).

From a pasture perspective, 81% of grazing sites surveyed across the Northern Gulf Grazing lands were considered to be in a good condition, being ≥ 75% of the original carrying capacity (Shaw et al. 2007). A high proportion of the grazing sites in poorer condition were in land types of lower soil fertility, e.g. Georgetown granites. Shaw et al (2007) considered improving management of alluvial, black soil and granite land types a priority, with pasture composition and increased woody thickening a particular issue for fertile land types.

In areas where vegetation has not been extensively cleared but is in poor condition (such as heavily grazed areas with little understory structure and low plant recruitment) biodiversity may be depleted (DEWHA 2009). The Landscape Health in Australia report (Morgan 2001) found that the Northern Gulf region was scored in the middle stress category. A more recent assessment of vegetation condition across Northern Gulf and Cape York Peninsula gave the condition of native vegetation a score of 79 out of 100. Kutt (2008) considered some wetland vegetation, e.g. Macaroni Swamp south of Staaten River, were in fair to good condition. However, riparian vegetation (i.e. along rivers and significant creeks) was considered to be declining in condition, especially in the Gulf Plains bioregion. The paucity of data regarding native flora across the Grazing lands, has been repeatedly emphasized and may reduce the accuracy of these assessments (Gobius 2012; Kutt 2008; NLWRA 2002).

4.2.1.2 Threatened ecological communities

A number of regional ecosystems across the Northern Gulf grazing lands have an 'endangered' or 'of concern' biodiversity status due to limited natural distribution. For example, RE 9.7.6 woodland of flaky-bark (*Eucalyptus chartaboma*), Clarkson's bloodwood (*Corymbia clarksoniana*) with lancewood (*Acacia shirleyi*) to the east of Mount Surprise. Other ecosystems are threatened by woody thickening, weed, fire and grazing management issues, or erosion impacts for example, RE 2.3.9 Coolabah (*Eucalyptus microtheca*) and Bauhinia (*Lysiphyllum cunninghamii*) low open woodlands on floodplains along the Mitchell River (threatened by high total grazing pressure); and bloodwoods (*Corymbia* spp.) woodland on floodplains north of Georgetown (threatened by weeds, such as rubbervine).

There are two federally listed threatened ecological communities (TEC) in the Northern Gulf region. Of these, the communities of native species dependent on natural discharge of groundwater from the Great Artesian Basin are found within the Grazing lands, especially to the north-west of Chillagoe and south of Croydon (Fensham et al. 2010). In addition to potential impacts on the aquifer from bores, mining and excavation, threats to these springs include invasion by weeds such as para grass (*Urochloa mutica*) and olive hymenachne (*Hymenachne amplexicaulis*), grazing and trampling by stock and feral animals (Fensham et al 2010).

4.2.1.3 Threatened Flora

There are 95 plants known to occur within the region that have a 'near threatened', 'vulnerable' or endangered' (or presumed extinct) status under the Queensland *Nature Conservation Act 1992* (Figure 3, Queensland Herbarium Herbrecs data, accessed February 2015; Appendix 2). Of these, 39 are found within the Grazing lands. The

majority of threatened flora across the Grazing lands are grasses, forbs and shrubs, which can be particularly impacted by weeds, high grazing pressure and altered fire regimes.

Little ecological research has been undertaken on the majority of the 95 threatened species in the region. Therefore, there is little knowledge of specific threats and management requirements. Many of those with an EPBC status have some details on threats. These are typically relating to maintaining fire management appropriate to the species ecology, and limiting weed and clearing impacts. One species, the wetland forb *Eriocaulon carsonii*, grows amongst springs linked to the Great Artesian Basin. It is threatened by overuse of the water source as well as grazing and weed impacts.

Climate change has the potential to influence these threatened species through potential erratic rainfall and extreme weather events. These could impact on the survival of mature plants (e.g. droughts killing plants), or impact on germination or seeding events.

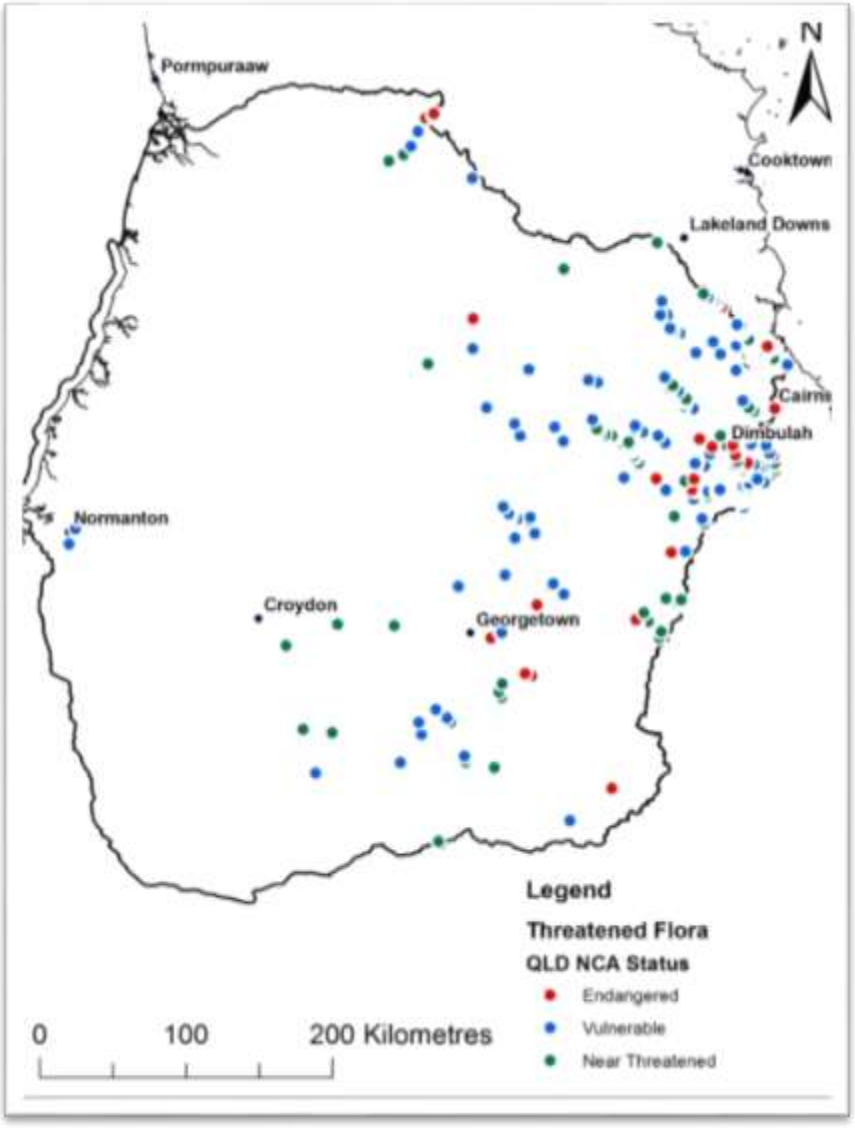


FIGURE 43: THE KNOWN LOCATIONS OF THREATENED FLORA IN THE NORTHERN GULF. DATA FROM THE QUEENSLAND HERBARIUM (HERBRECS SEARCH FEBRUARY 2015)

4.2.2 Threats to Flora

The principal threats to the flora across Northern Australian Grazing lands appear to be land degradation caused by inappropriate management, such as overgrazing (Lorimer 1998); and a reduction in landscape variability, especially in relation to pasture composition and mosaic fire management (Woinarski 1999). Although varying in specifics between ecosystems, there are many common issues including pest species, fire and grazing pressure and the management of canopy and ground layer habitats in general.

The common threats to the vegetation of the Northern Gulf Grazing lands include inappropriate fire and grazing management, weed invasion, feral animals, artificial water extraction and timber harvesting. Although much of the tree cover vegetation of the Northern Gulf appears relatively intact, landscape connectivity has been impacted in the understory and grass layer through disturbances from high grazing pressure, high densities of weeds and/or feral animals (Morgan 2001). Key threats that can be managed are considered below.

4.2.2.1 Woody thickening

FIGURE 44: WOODY THICKENING OF GUTTA PERCHA (EXCOECARIA PARVIFOLIA) NEAR NORMANTON

The term "woody thickening" refers to an increase in the density of native shrubs, saplings and trees (Figure 44). There is considerable evidence that woody thickening has occurred within eucalypt forests, woodlands and grasslands across Northern Australia, including the Northern Gulf region, for at least the last few decades (Crowley et al 2009; Scanlan et al 1996; Stanton et al 2014). For example, over half (58%) of sites surveyed during land condition assessments showed evidence of woody thickening (Rolfe et al 2004).

It is apparent that thickening has not been universal across all woodlands or locations, and the degree to which vegetation has thickened is subject to debate (e.g. (Fensham 2008; Fensham et al. 2007a). Severe droughts have had a balancing effect on woody structure of woodlands, as a consequence of extensive tree deaths (Fensham et al. 2009).

The most common vegetation types of the region that have suffered from woody thickening are grasslands, eucalypt woodlands (especially in the Gulf) (Burrows et al 2002; Crowley et al 2009; Stanton et al 2014). Common trees and shrubs that have increased in abundance in these ecosystems are gutta percha (*Excoecaria parvifolia*), breadfruit (*Gardenia vilhelmii*), currant bush (*Carissa ovata* and *C. lanceolata*), tea tree (*Melaleuca viridiflora*), various wattles (*Acacia* spp) and eucalypts.

Woodland thickening impacts on grazing productivity by inhibiting pasture growth and increasing mustering costs (Kernot et al. 2008; Rolfe et al. 2004). Woody thickening can also have biodiversity impacts, such as where rainforest expansion has significantly reduced the extent of grassy tall eucalypt forests (Stanton et al. 2014; Williams et al. 2012).

There is evidence that in dry tropical woodlands, woody thickening is influenced by a combination of factors including intensification of grazing, reduced fire frequency and/or intensity, and increases in atmospheric CO_2 (Fensham et al. 2009; Scholes et al. 1997; Van Auken 2000). However, the mechanisms driving woody thickening are complex and appear to differ between land types and among the woody species involved.

Grazing may suppress the growth of some woody species through browsing (Scanlan et al. 1996), yet stock grazing reduces grass biomass, which is important for inhibiting the growth of woody vegetation (Harrington 1991;

MOST COMMON SPECIES ASSOCIATED WITH WOODLAND THICKENING IN THE NORTHERN GULF REGION: A LAND MANAGER'S

This study documented observations from individual land managers (including Traditional Owners) with regard to woody vegetation change in the Northern Gulf region. Information was collected through 14 semi-structured interviews with 22 respondents (including two Traditional Owners) from 17 properties. By interviewing long-term land managers from a variety of properties across Northern Gulf the study was able to provide data on woodland thickening on a number of different land and vegetation types.

The study found that breadfruit (*Gardenia vilhelmii*), *Eucalyptus spp.*, *Corymbia spp.* and gutta percha (*Excoecaria parvifolia*) appeared to have higher association with thickening in the region. Most land managers considered breadfruit to be thickening over a range of land and vegetation types, predominantly those continually stocked and rarely burnt areas. The Eucalypt species most commonly considered to be thickening were ironbark and coolabah (*Eucalyptus microtheca*). Ironbarks appeared to have thickened in lightly grazed paddocks with poor soil types, along open ridges and slopes, and also along river frontages. Coolabah appeared to have thickened in open woodland in the Normanton area. All land managers interviewed in the Normanton area said that gutta percha had significantly thickened on open plain and woodland areas. Other species that appeared to be associated with thickening include wattle (*Acacia spp.*), quinine (*Petalostigma spp.*), tea tree (*Melaleuca spp.*), pear tree (*Terminalia subacroptera*), yellow wood (*Terminalia spp.*), rubber vine (*Cryptostegia grandiflora*), mimosa (*Mimosa pigra*), ironwood (*Erythrophleumchlorostachys*), poison heartleaf (*Gastrolobium grandflorum*) and white wood (*Atalaya hemiglauca*).

Land managers began noticing vegetation thickening across the Northern Gulf approximately 15 to 30 years ago. All land managers in the Normanton area had observed gutta percha and coolabah trees thicken since the 1974 floods. Over half the land managers also believed that grazing management practices had contributed to vegetation thickening. Practices that were considered responsible for woody thickening were overgrazing facilitated by the use of phosphate licks; changing the soil environment; changed fire regimes, and introducing legumes into pasture. Some landholders believed that woodland thickening was a combination of all the above factors.

Van Auken 2000). The reduced grass biomass, as a consequence of heavy grazing pressure, also reduces the ability to implement fire programs.

Reductions in frequent, moderately intense fires have been linked to woody thickening (Crowley et al. 2009; Stanton et al. 2014). This is because regular fires of sufficient intensity to scorch the shrub and sapling layer are thought to inhibit, or reduce woody thickening through several mechanisms (Hunt et al. 2014; Williams et al. 2012). Crown scorch reduces most shrubs and eucalypt saplings <2m tall, to ground level coppice shoots from buds protected below to soil surface. Therefore, regular fires of this intensity can repeatedly prune the lower strata before it grows into large trees and shrubs, allowing grasses and herbs to maintain vigor. Regular fires are important for reducing the establishment of new woody seedlings. As germination events for savanna eucalypts is erratic and typically linked to high rainfall years (Williams 2009a), burning following good wet seasons is important for reducing the number of newly recruited woody seedlings.

The potential of increased numbers of severe droughts and perhaps more intense rainfall events will potentially impact on woody thickening. The germination of new woody plants most commonly occurs during high rainfall periods (Williams 2009a), and wet conditions will probably promote growth of existing saplings. Any increase in woody thickening due to high rainfall events can be managed using regular fire. Drought is known to cause the die back of canopy trees, which may balance woody thickening over a decadal scale (Fensham et al. 2009).

The interaction between grazing and fire management is crucial. The removal of grass biomass by high grazing pressure removes the fuel required to implement fires. Post-fire spelling is also important as it allows grasses to re-establish to maintain competition with woody saplings (Hunt et al. 2014).

The use of regular fire appears to be the most cost-effective option available to land managers on extensive grazing properties in the Northern Gulf region (Cowley et al. 2014; Kernot et al. 2008). Issues to consider when using fire to manage woody thickening include the density and extent of woody thickening and current weather conditions. An indication of woody thickening is where the mid layer of the vegetation (i.e. in the 2 to 5 m range) is becoming difficult to see through, especially where it was more open in the past (QPWS 2013). Priority should be given to maintaining fairly open woodlands and grasslands with limited thickening because it should require less resources to maintain vegetation in good condition compared to restoring unhealthy communities. Vegetation with limited or early stages of woody thickening are likely to be maintained through the use of moderately regular fire, focused in wetter years and seasons, of the intensity to scorch the tops of the crowns of the shrubs and saplings that are causing the thickening. The frequency of the fires should be flexible to incorporate issues such as wet season rainfall (i.e. burning mostly in wet years rather than dry years), and the rate of sapling regrowth (i.e. timing a second fire before the saplings and shrubs return to near their pre-fire height).

Where woody thickening is already dense over a large area, the success from burning may need to occur over stages, with initial fires producing the best results on the edges of thickets and subsequent fires burning more successfully further within the thicket. Where woody thickening is dense and extensive, fire intensity may need to be higher than in more open woodlands. The more intense fires implemented in the late dry season have a greater effect on woody thickening control than lower intensity early dry season fires (Cowley et al. 2014; Dyer et al. 2001). However greater preparation and management is required to contain late dry season fires and if limited rain falls after these fires, pastures may need considerable post-fire spelling to allow grass regeneration.

The aim of burning dense thickets is to scorch the tops of crowns of the thickening shrubs and saplings to produce some mortality and reduce others to ground level coppice shoots. This allows grasses and herbs to regenerate. Some species are more susceptible to being killed by crown scorching fires (e.g. rubbervine, *Cryptostegia grandiflora* and breadfruit, *Gardenia vilhelmii*) than others (e.g. tea tree, *Melaleuca* spp. and eucalypts [Dyer et al 2001; Kernot and English 2008; Williams 2009a]). All actions, whether burning, controlling weeds or promoting useful significant species, should include an element of assessment to ensure refinement of the program to its greatest potential. In regards to burning for woody thickening management, photo points and notes on observations of the reduction of woody thickening are important.

4.2.2.2 WEEDS

FIGURE 45: GAMBA GRASS INVADED WOODLAND WITH EUCALYPTS KILLED BY ELEVATED FIRE INTENSITY.

The negative impact of weeds results from their ability to out compete native flora and preferred pasture species, alters natural fire regimes and limits human use of an area, reducing access, recreational use and economic gains. Economically, weeds may impact directly on grazing land production systems, for example through reducing productivity of grazing lands or through material and labour costs for their control (Council 2007)(NRMMC 2007).

Dense weed invasion reduces floristic diversity and pasture quality. Weeds that remain in low densities with little biomass may provide little problem other than a reduction in the pristine nature of a habitat, whereas those that invade in high densities with a large biomass replace native plants and alter the resources available to fauna.

Weeds establish in new areas through the spread of seeds, or vegetative material, and opportunities for recruitment, usually through soil disturbance. Weed seed spread occurs through:

- Wind borne seeds;
- Water borne seeds in rivers and floods;
- Explosive seed pods;
- Animal transport including ants, wildlife (birds and mammals) and introduced herbivores;
- Graders and roadside machinery;

- Tractors, cars and farm implements;
- Transported materials, soils, sand, mulch and hay; and
- Deliberate introductions by gardeners and graziers.

Activities that increase soil disturbance and provide suitable environments for weeds to establish include:

- Inappropriately managed fire that changes vegetation composition, providing bare areas for weeds to invade;
- Clearing of ground for agriculture;
- Overgrazing that leaves bare ground or reduced grass cover;
- Selective grazing reducing desirable species giving weedy species a selective advantage;
- Soil disturbance by machinery or cattle; and
- Introduction of weed seeds to new areas by transport or machinery (Alden 2014).

The most appropriate way to prioritise weed control actions is to consider the weed's current and potential extent and impact. This prioritisation needs to be done at a property and a regional scale. All land holders have responsibility for managing weeds on their property. Weeds that are a priority for a particular property may not be a priority at a regional extent due to a weed's distribution and the larger number of weeds that must be prioritised across the region.

Significant weed management actions at a property and regional scale involve:

- Weed seed hygiene to prevent new weeds from entering an area and exist weeds spreading;
- Keeping transport corridors clear of weeds to reduce their spread;
- Mapping the extent and abundance of weeds;
- Prioritising weed species and locations for control;
- Focusing control efforts on small outlier infestations and scattered plants and working back from the edges of larger infestations;
- Using the most appropriate control actions for the right weed, in the correct location, using safe methods. These control actions will typically involve a combination of the following, where appropriate: biocontrol where available, fire, mechanical and/or herbicide;
- Coordinated weed control amongst neighbours; and
- Assessment of the success of control actions and updated weed distribution information (Alden 2014).

Weeds of concern to the Northern Gulf region

There are around 350 exotic plants currently known to have self-supporting populations within the region (Herbrecs 2015). Clearly some of these introduced plants have more of an impact and are of higher priority for management than others. An understanding of the existing weed management priorities and actions across the region was determined through discussions with people involved with weed management; a review of the pest management plans of the Shires of Etheridge, Cook, Croydon, Carpentaria, Tablelands and Mareeba; and information received from the Far North Queensland Regional Organisation of Councils (FNQROC) and the Cape York Weeds and Ferals Program (council 2010a; Council 2011a; Council 2012; Council 2011b; Council 2010b; Council 2013; FNQROC 2011; Program 2006).

Each shire council in the Northern Gulf region has their own weed management priorities which reflect problem weeds in their geographic area and land holder preferences, which are expressed in their weeds and pest management plans. Rather than duplicating these plans, which express shire scale, this review has focused on determining the priority weeds and actions that will provide a strategic regional response. This involves providing support and assistance for the management of the highest priority weeds identified in various council plans, while

taking on the role of ensuring highly aggressive weeds not currently present in the region (or only present in isolated areas) do not take a hold.

The following looks at local weeds declared under the Queensland legislation, key weeds identified by councils of the region and priority weeds and actions that Northern Gulf can focus on to provide a strategic contribution to weed management in the region.

DECLARED WEEDS OF THE REGION

Many of the significant weeds of the region are declared under legislation, Queensland *Land Protection (Pest and Stock Route Management) Act* 2002. This act has the following three categories for declared weeds and feral animals:

Class	Definition (Biosecurity Qld)	Current Class 1 weeds in the grazing lands of the Northern Gulf region.	Class 1 weeds near to the grazing lands of the Northern Gulf region, which could potentially enter if left unmanaged.
Class 1 weeds	Pest that has the potential to become a very serious pest in Queensland in the future. All landholders are required by law to keep their land free of Class 1 pests. It is a serious offence to introduce, keep, release or sell Class 1 pests without a permit.	There are currently no Class 1 weeds known to occur within the grazing lands. Both of the two Class 1 weeds found in the Northern Gulf region, Koster's curse (*Clidemia hirta*) and Siam Weed (*Chromolaena odorata*), are found on the Northern tablelands.	• Koster's curse (*Cildemia hirta*) • Siam Weed (*Chromolaena odorata*) • Limnocharis or yellow burrhead (*Limnocharis flava*) • Miconia (*Miconia* spp.) • Mikania vine (*Mikania* spp.) • Fragrant thunbergia (*Thunbergia fragrans*) • Laurel clockvine (*Thunbergia laurifolia*)
Class 2 weeds	Pest that has already spread over substantial areas of Queensland, but its impact is so serious that we need to try and control it and avoid further spread onto properties that are still free of the pest. By law, all landholders must try to keep their land free of Class 2 pests and it is an offence to possess, sell or release these pests without a permit.	• Bellyache bush (*Jatropha gossypiifolia* and hybrids) • Chinee apple (*Ziziphus mauritiana*) • Gamba grass (*Andropogon gayanus*) • Giant sensitive plant (*Mimosa diplotricha* var. *diplotricha*) • Mesquite (*Prosopis pallida*) • Olive hymenachne (*Hymenachne amplexicaulis*) • Parkinsonia (*Parkinsonia aculeata*) • Parthenium (*Parthenium hysterophorus*) • Prickly acacia (*Vachellia nilotica*) • Rat's tail grasses (*Sporobolus fertilis*, *S. jacquemontii*, *S. natalensis* and *S. pyramidalis*) • Sicklepod (*Senna obtusifolia* and *S. tora*) • Rubber vine (*Cryptostegia grandiflora*) • Water hyacinth (*Eichhornia crassipes*)	• Cabomba (*Cabomba caroliniana*)

Class 3 weeds	Pest that is commonly established in parts of Queensland. Landholders are not required to control a Class 3 declared pest plant on their land unless a pest control notice is issued by a local government because the pest is causing or has potential to cause an negative impact on an adjacent environmentally significant area. It is an offence to supply a Class 3 pest. A permit for specific purposes may be issued by Biosecurity Queensland	• Athel pine (*Tamarix aphylla*). Athel pine is also a Weed of National Significance. • Broadleaved pepper tree (*Schinus terebinthifolius*) • Camphor laurel (*Cinnamomum camphora*) • Captain Cook tree or yellow oleander (*Cascabela thevetia* syn. *Thevetia peruviana*) • Lantana or common lantana (*Lantana camara*) • Madeira vine (*Anredera cordifolia*) • Singapore daisy (*Sphagneticola trilobata*; syn. *Wedelia trilobata*)	• African tulip tree (*Spathodea campanulata*) • Cat's claw creeper (*Macfadyena unguis-cati*) • Chinese celtis (*Celtis sinensis*) • Broad leaf privet or tree privet (*Ligustrum lucidum*) • Small leaf privet or Chinese privet (*L. sinense*)

Source: Department of Agriculture, Fisheries and Forestry Biosecurity Queensland

Environmental and pasture weeds

Many significant weeds have no legal requirements for control (i.e. are not declared Class 1, 2 or 3 under the Queensland Land Protection Act), but have a significant impact on the conservation values of a native ecosystem and can reduce pasture quality. These include exotic grasses, which outcompete native grass layer species. The diversity of eucalypt woodlands is primarily found in the abundant grasses and herbs, and therefore large biomass exotic grasses, such as Gamba grass, buffel grass, can dramatically reduce the diversity of native flora.

It should be noted that the mention of these weeds here does not suggest that they be actively controlled in every location. Some, such as Buffel grass, are widespread across Northern Australia and are considered to have some grazing value. Examples are:

- Buffel grass (*Cenchrus ciliaris*) also valued as a pasture species
- Leucaena (*Leucaena leucocephala*)
- Mimosa bush (*Vachellia farnesiana - was called Acacia farnesiana*)
- Neem (*Azadirachta indica*)
- Noogoora burr (*Xanthium occidentale*)

Priority weeds in various council plans

Over recent years, councils across the region, supported by FNQROC, have undertaken thorough land holder consultation and pest prioritisation procedures. Naturally priority weeds vary between councils, based on the issues reflected in their landscape features and the geographic distribution of the weeds.

Priorities for a strategic approach to weed management across the region

This weed prioritisation process used a standard risk analysis, based on the combination of the impact of each weed, its legal status, its current and potential distribution and rate of spread. The weed distribution information was based on advice collated from consultation with local weed practitioners, well as maps from Queensland Herbarium data (Herbrecs) and Queensland Department of Agriculture, Fisheries and Forestry.

These priorities do not encompass all priority weeds identified by the various councils across the region, but focus on providing the best support at a regional level. The highest priority is given to highly damaging weeds with relatively limited regional distribution or species that are not currently present but have a high probably of being spread into the region. Key locations for some widely distributed weeds, such as rubbervine in the upper Gilbert River catchment, are also seen as regional priorities.

Following the risk and priority evaluation process, the weeds considered to have high and the highest priority in the Northern Gulf region, through landholder awareness, training and funding programs, are outlined below.

Weeds considered the highest priority:

1. Gamba grass, Andropogon gayanus, a Class 2 weed, is considered one of highest priority weeds in the region because of the relatively limited regional distribution (currently restricted the Mareeba, Undara, and Peninsula road areas) and the extreme effects on ecosystems and pasture conditions.
2. Koster's curse Clidemia hirta. This Class 1 weed can spread very rapidly and causing considerable pasture and environmental damage due to its ability to develop into dense smothering thickets. It is currently known, and being managed on the tablelands by the Mareeba Shire Council, in the Julatten area and creeks upstream from the Mitchell River.
3. Olive Hymenachne, Hymenachne amplexicaulis. This Class 2 weed is known from near Mareeba and Mt Molloy areas, and also north of Normanton.
4. Parthenium, Parthenium hysterophorus. This Class 2 weed is known from Mareeba and Tolga areas, and may be within the edge of the grazing lands. Ongoing vigilance is required because of the likelihood of repeated seed sources arriving in stock feed and on vehicles from outside the region.
5. Siam weed, Chromolaena odorata. This is a Class 1 weed that has undergone considerable control effort in the Wet Tropics. It is known from the Irvinebank area and has yet to become established in the grazing lands.
6. Water hyacinth, Eichhornia crassipes. This Class 2 weed is known from the Kowanyama area and also to the east of the region, north of Cairns.

Weeds considered a high priority:

1. Bellyache bush, Jatropha gossypiifolia
2. Giant rats tail grass, Sporobolus fertilis and S. pyramidalis
3. Giant sensitive plant, Mimosa diplotricha
4. Grader grass, Themeda quadrivalvis
5. Leucaena, Leucaena leucucephala
6. Mesquite, Prosopis pallida
7. Neem, Azadirachta indica
8. Physic nut, Jatropha curcas
9. Prickly acacia, Acacia nilotica
10. Rubbervine, Cryptostegia grandiflora; in specific locations only, e.g. upper reaches of Gilbert River
11. Salvinia, Salvinia molesta

Weeds not yet known in the region, but considered to be on the highest priority watch list for public awareness and immediate control:

1. Chilean Needle grass, *Nassella neesiana*; currently present in the Toowoomba region, but is likely to grow in this region and the flow of vehicles between regions makes it possible it could establish in the Northern Gulf.
2. Candy leaf, *Stevia ovata*, is a tall perennial herb, currently known from very recent collections near Herberton and Ravenshoe (i.e. adjacent to this region).
3. Fire weed, *Senecio madagascariensis*; currently known in the Wondecla district.
4. Fragrant thunbergia *Thunbergia fragrans*; currently known in the Wet Tropics.
5. Laurel clockvine *Thunbergia laurifolia*; currently known in the Wet Tropics.
6. Limnocharis or yellow burrhead *Limnocharis flava*; currently known in the Wet Tropics and Townsville district.
7. Mexican feathertop, *Nasella tenuissima*; currently present in the Longreach region.
8. Miconia, *Miconia* spp.; currently known in the Wet Tropics.
9. Mikania vine *Mikania micrantha*; currently known in the Wet Tropics.
10. Mimosa, *Mimosa pigra*; currently present in the Northern Territory and Prosperine.
11. Pond apple, *Annona glabra*, is a shrub of wetlands, which is a problem in adjacent Wet Tropics areas.

High priority weed profiles

Gamba grass, *Andropogon gayanus*. This Class 2 weed greatly increases fire intensity and smoothers out other flora, due to its high biomass. It is crucial to stop it spreading into the Gulf region, and important to contain it in the Mareeba to Lakeland Downs corridor.

FIGURE 47: RED DOTS INDICATE THE LOCATIONS OF GAMBA GRASS (ANDROPOGON GAYANUS) SPECIMENS SUBMITTED TO THE QUEENSLAND HERBARIUM (SOURCE: QUEENSLAND HERBARIUM HERBRECS). THE NORTHERN GULF NRM REGIONAL BOUNDARY IS INDICATED BY THE BLACK LINE.

Key locations for containment and/or control of Gamba grass:

1. Mulligan Highway between Mareeba and Lakeland Downs.
2. Walkamin - Mareeba district, especially near roads and the Mareeba wetlands.
3. Along the Gulf Development road, near Undara National Park.

Critical actions:

1. Focus land holder awareness information towards people in the key locations identified above.
2. Promote the values of vehicle and machinery wash down. The Mt Surprise public wash down facility is a critical location to reducing the threat of spreading Gamba grass into the gulf by vehicles.
3. Support finding proposals for control of gamba grass, especially in to the south and west of Mareeba, such as the Gulf and Burke Development roads, to reduce the risk of spread to the gulf district.

Olive Hymenachne (*Hymenachne amplexicaulis* cv. Olive) is a class 2 declared weed that smothers wetlands and is currently fairly limited in distribution across the region.

FIGURE 48: RED DOTS INDICATE THE LOCATIONS OF OLIVE HYMENACHNE (HYMENACHNE AMPLEXICAULIS CV. OLIVE) SPECIMENS SUBMITTED TO THE QUEENSLAND HERBARIUM (SOURCE: QUEENSLAND HERBARIUM HERBRECS). THE NGRMG BOUNDARY IS INDICATED BY THE BLACK LINE. THIS REGION IS STRATEGIC IN SPANNING THE NATIONAL OLIVE HYMENACHNE CONTAINMENT ZONE (MOST OF REGION) AND HIGH RISK PREVENTION ZONE (THE GULF SOUTH OF NORMANTON).

Key locations for containment and / or control of Olive Hymenachne:

1. Mt Molloy to Julatten district.
2. The Mareeba district.
3. North-east of Normanton.

Critical actions:

1. Focus land holder awareness information towards people in the key locations identified above.
2. Promote the values of boat, vehicle and machinery wash down.
3. Support finding proposals for control of Olive Hymenachne in the key locations, especially around Normanton, to reduce the risk of spread to the gulf district.

Climate change and weeds

Climate change may have a broad effect on weed abundance and distribution. Some researchers predict climate change could have a number of influences on weed distribution and abundance, including (Hilbert et al. 2014)(from Hilbert *et al.* 2014):

- The suitable climatic space for most invasive species may expand towards the south and east coast. This would mean that dry-land weeds such as exotic grasses could colonise country further south and east than currently distributed. Wet Tropics weeds will contract eastwards as areas to the west become drier.

- Changes in habitat that may follow climate change could give opportunities for weeds and exotics to replace natives as the conditions become less than ideal.
- Severe cyclones, which may increase in frequency with climate change, provide increased opportunities for the recruitment of invasive weeds. Suitable niches open with large-scale disturbance and wind and flood increase propagule distribution.
- Dispersal opportunities for invasive species are likely to increase due to extreme rainfall events.
- The spread of high biomass invasive grasses will transform savanna ecosystems into those dominated by exotic grass. Climatic change may be more conducive to exotic grass growth.
- Seasonally inundated waterholes in the dry tropics may be increasingly impacted by invasive animals, increasing the spread of weeds and impacting on native vegetation.

Appendix 2 lists 24 priority weeds for the Grazing lands and their predicted response to the climate change predictions for the Monsoonal North.

4.2.2.3 Grazing impacts on vegetation communities

Livestock grazing is the primary land use across the region. It is typically sympathetic to many requirements of the native fauna and flora. Many local graziers are attuned to the land forms and common plants and animals on their land. The use of woodlands and grasslands across the region for grazing, without extensive modification, can maintain the land in good condition and provide habitat for a wide variety of native fauna and flora.

Future changes in climate may include severe droughts with occasional highly intense wet periods which would have a serious impact on grazing enterprises. The possibility of increased droughts and intense wet rain events over the next few decades will have a significant impact on the grazing industry across the region, through its influence on pasture abundance and quality (Cobon et al. 2009; Crowley et al. 2015). Managing for this scenario requires good grazing practices that lead to improvements in productivity and sustainability, such as the management of water points, wet season spelling and total stocking rates (Bray et al. 2014).

Issues that need addressing for the maximum land condition and biodiversity benefits include improving our understanding of the carrying capacity of different land types to reduce excessive grazing pressure and the maintenance of fine scale variability within habitats.

Total grazing pressure results from the combined grazing of feral animals, stock and native herbivores, such as kangaroos. Excessive grazing pressure can cause a reduction in ground cover, changes in pasture composition and the potential for soil erosion.

Stock are selective in their choice of feed and therefore pasture composition is influenced by grazing management. Both the intensity and season of grazing affect pasture composition, with wet season grazing (or wet season spelling) having the highest impact on pasture composition (Ash et al. 1998b). Some native plants, such as kangaroo grass (*Themeda triandra*) and the legume *Vigna lanceolata*, decline markedly with increased grazing pressure, while other native grasses, such as the annual bottlewasher grass (*Enneapogon polyphyllus*), increase with stocking rate (McIvor 1998).

The influence of grazing on pasture composition can also depend on the dominant grasses in a paddock. Where paddocks are dominated by palatable native perennial grasses, low to intermediate grazing levels can result in increased pasture diversity, probably due to the competitive release provided to sub-dominant species by selective grazing of the dominant grasses (Calvert 2001). Conversely, a decrease in diversity has been documented in paddocks dominated by less palatable grasses (such as Indian couch and old, rank stands of buffel grass).

Grazing potentially influences the conservation of a wide number of flora species across the Northern Gulf region. Across Northern Australia, the decline in the density of perennial tussock grasses and some forbs has been associated with increased grazing pressure (Ash et al 2011; Ash et al 1997; Fensham and Skull 1999; Scanlan et al 1996). Species most at risk of decreases in distribution and abundance from high grazing pressure are palatable species, especially native perennial grasses. These grasses are particularly sensitive to grazing during the wet season (Ash et al. 1998a; Mott et al. 1992). Low stocking rates during the wet season have been found to provide perennial grasses with enough growth opportunity to withstand higher levels of stocking for the remainder of the year (Ash et al. 2011). If species composition is to be maintained in these grasslands stocking rates must be set at low levels to cope with the combined effect of under-compensation in response to defoliation in the wet season and strong dietary preferences for grazing sensitive species (Ash et al. 1998b). Fences should be positioned so as to enclose similar vegetation types in the one paddock to minimise the risk of animals concentrating on preferred vegetation or land types (Fisher et al. 2004).

In addition to directly reducing the density of perennial grass species, introduced herbivores can also indirectly alter grass species composition by facilitating the spread of introduced grass species that compete with native grasses. Cattle may also facilitate the spread and establishment of weeds by dispersing seeds or through disturbance to native vegetation caused by over grazing and trampling (Burrows 2000).

Regular monitoring of pasture availability through "Grasscheck" or similar monitoring programs, and appropriate variation in stocking rates is recommended. This is particularly important during climatic extremes such as drought. Consideration may be given to practices such as rotational grazing, spelling and controlled burning (as stipulated in a formal fire plan) (Greiner 2009).

Cattle raised on introduced grasses with either legumes or nitrogen supplements outperform animals raised on native pastures, allowing them to be sold at a premium into high value markets (McKeon et al 1998, Whish, G.L., et al 2014, Cobon et al 2009). Concerted efforts have therefore been made to find exotic plants that will reliably boost cattle production. Through the course of the 20th century, CSIRO introduced at least 2,250 grasses and 2,691 legume species, mostly for assessing their grazing potential (Crimp et al 2002). Several exotic pasture have had adverse impacts on the natural environment, as has the tree clearing that is often required to establish introduced pastures (Crimp et al 2002, Turton 2012). In Northern Australia, the most vigorous introduced grasses – Gamba Grass (*Andropogon gayanus*), Para Grass (*Urochloa mutica*), Olive Hymenachne (*Hymenachne amplexicaulis*), Aleman Grass (*Echinochloa polystachya*), Buffel Grass (*Cenchrus ciliaris* or *Pennisetum ciliare*) and Mission Grass (*Pennisetum polystachion* and *P. pedicellatum*) – are called "transformer" species or "green bulldozers"[60] because they exclude other species and the increased fuel loads they produce can cause fires of sufficient intensity to destroy canopy trees (Fraser et al 2005, Kent and Alston 2008, CSIRO et al 2007, Stevens 2008, Bernstein et al 1999). Five of these grasses have been identified as key threats to biodiversity conservation (Bolin 1998). Gamba Grass is a Weed of National Significance[61], and a management plan has been prepared for its containment and control in the Northern Territory (Crowley 2007). Buffel Grass has become invasive to the detriment of biodiversity in both central Australia and Queensland sections of the Monsoonal North (CSIRO et al 2007, Newman and Head 2015, Peel 2013, Roelfsema, M., et al 2014, Caripis et al 2011, Crowley 2012), but has not been identified as an issue in the Top End or Gulf Savanna. Some pastoralists are also concerned about their ability to control the spread of Gamba Grass, Wynn Cassia, Leucaena (*Leucaena leucocephala*), Mission Grass, *Stylosanthes* spp. and Indian Blue Grass (*Bothriochloa pertusa*) (Petheram et al 2013, Heckbert et al 2009).

Despite adverse biodiversity effects, introduced pastures continue to be an important part of productivity improvement. In the Northern Territory, exotic pasture species are used on most Top End Properties and around half the properties in the Gulf Savanna (Katherine Pastoral region), but only cover a small proportion of each region (Top End: 3%, Gulf Savanna 4.8%) (DEEDI 2010). The main species used in the Top End are Jarra Grass (*Digitaria milanjiana*); Tully Grass, (*Brachiaria humidicola*), Seca Stylo (*Stylosanthes scabra*) and Wynn Cassia (*Chamaechrista rotundifolia*); and in the Gulf Savanna are Buffel Grass, Nixon Sabi Grass (*Urochloa mosambicensis*), Seca Stylo and Verano (*Stylosanthes hamata*). The most common use of exotic pasture species is to over-sow native pastures to improve diet quality (Top End: 56%, Gulf Savanna: 61%), followed by hay production (56%, 32%) and improved pasture systems (67%, 19%) (DEEDI 2010). Most Top Enders (80%) and 29% of Katherine pastoralists planned to increase their use of exotic pasture species between 2011 and 2014 (DEEDI 2010). Pasture species recommended for irrigated forage production include the low impact species Rhodes Grass (*Chloris gayanus*), Forage Sorghum (*Sorghum* spp. hybrids) and Lablab (*Lablab purpureus*), but also include some invasive species, such as Buffel Grass (Cockfield and Botterill 2006).

[60] www.abc.net.au/am/content/2007/s2144436.htm

[61] www.environment.gov.au/biodiversity/invasive/weeds/weeds/lists/wons.html

4.2.2.4 FIRE

FIGURE 50: LOW INTENSITY FIRE IMPLEMENTED BY A SPOT IGNITION TECHNIQUE

Fire is a crucial factor influencing the condition of Northern Gulf ecosystems. Most ecosystems in the region benefit from some fire in the landscape, whether they be eucalypt woodlands with fire-promoted plant regeneration, or fire-sensitive *Acacia* thickets that benefit from low intensity protection burns in adjacent ecosystems.

Summer wet seasons can produce abundant grass in the eucalypt woodlands and grasslands, with these grasses drying off (curing) during the subsequent dry season. The consistency of this cycle leads to frequent and extensive fires across Northern Australia (Gill et al. 1996). Grasses rapidly regenerate following fire, re-establishing fuel loads and creating the potential for fire intervals as low as one or two years in high rainfall tussock grass areas on Cape York Peninsula and around five years in semiarid spinifex areas (Felderhof et al. 2006; Gill et al. 2000).

A high proportion of native plants of the eucalypt woodlands and grasslands across Northern Australia survive fire by re-sprouting, providing some stability in species composition (Cowley et al 2014; Russell-Smith et al 2012; Williams et al 2003). This vegetative regrowth stems from buds located on the branches, trunks, roots or base of a plant. Given adequate soil moisture, regrowth can be rapid due to reserves stored in the stem and roots of plants.

The seed germination of many eucalypt woodland plants is triggered by fire as a result of several distinct cues. The heat of a fire can promote germination by breaking physical restraints in the seed coat of some plants, such as legumes (Clarke et al. 2000). Seed dormancy can also be broken chemically as a result of a fire, from smoke, charcoal and increased nitrates in the soil (Williams et al. 2014). The short-term release from competition provided by the removal of the grass biomass after fire may also enhance seed germination. The fodder quality of perennial grasses typically increases after fire, with the removal of old rank growth and regrowth of nutritious “green pick”.

Fire is also essential for the management of native fauna and their habitats, where the production of a fine scale patchwork of burnt areas can be used to maintain a continuous supply of grasses and herb seeds throughout the year, which is important for many granivorous birds, such as finches (Williams 2009b). In contrast, extensive areas that are completely burnt-out will have reduced food and shelter over large areas, increasing competition between animals and threats from predators.

Unmanaged wildfires in north Queensland can be more severe and extensive than planned burns (Williams et al. 2015). The way fires are ignited can have considerable impact on fire intensity, with spot ignitions less severe than fires ignited from a continuous fire line (Williams et al 2015). Recent declines in small native mammals (< 2 kg) in the Northern Territory has been linked to extensive and less patchy fires (Lawes et al. 2015).

There is evidence that the use of fire for pasture management has been decreasing in frequency across Northern Australia, increasing the risk of pasture reduction through either extensive wildfires or woody thickening from the absence of burning (Crowley et al. 2013b). In the late dry season of 2012, wildfires burned out over 5.5 million ha over 49 large grazing properties across the Northern Gulf (NGRMG 2013). These fires began as isolated wildfires in the north west of the Gulf plains, and were exacerbated by a large, dry storm front which crossed the region in October 2012, creating an outbreak of fresh fires. The fires started by these dry storms were followed by very hot, dry and windy conditions over November and December which rapidly extended the fire fronts and burnt out extensive areas.

Several factors influence the variation in fire regime across the region, especially variation in rainfall and grass biomass. The plains to the north and south of the lower Mitchell River have received the most frequent fires over recent years (Figure 51), which may be due to the high biomass of grasses. While the issue of woody thickening is loosely related the areas of least fire frequency (pale green - yellow and white in Figure 51). However, the relative pattern of fire frequency by itself is not a good refection of the appropriateness of fire programs in an area because different landscapes and vegetation benefit from different fire regimes. Also, the season of fire has significant effects the vegetation responses. Figure 52 shows that the 2014 fires across the region were dominated by late dry season fires, several of which appear to have been large and intense.

In a recent review of fire regimes across the region, Gobius et al. (2014) found that several areas had been receiving fire regimes that are broadly reflective of expert opinion for their local ecosystems. These include the Atherton, Gilbert Plateau, Herberton- Wairuna and Claraville plains. Areas where fire regimes do not reflect recommended fire frequencies include Georgetown to Croydon, Kidston, Karumba plains and Woondoola Plains and Mitchell Gilbert fans. Note that some of these areas (e.g. Georgetown to Croydon and Karumba plains) have received fire frequencies that are considered too irregular, while the lower Mitchell - Gilbert River fans have received more frequent fires than considered preferable in recent years (Figure 51). Therefore refinement in fire programs will require an increase in the frequency of fire in some areas (mostly in the south of the region) and a reduction in fire frequency in some northern sections of the region.

Land managers across the region are clearly interested in increasing their understanding of the use of fire for managing preferred pasture species, controlling weeds, containing wildfires and reducing woody thickening (Alvarez-Romero 2013; Crowley et al. 2013b). In areas where there is good pasture (eg. Bluegrass country at the base of the Gulf), there is some evidence to suggest that fire exclusion, high grazing pressures and weed invasion are causing lower levels of biodiversity (CRC 2014).

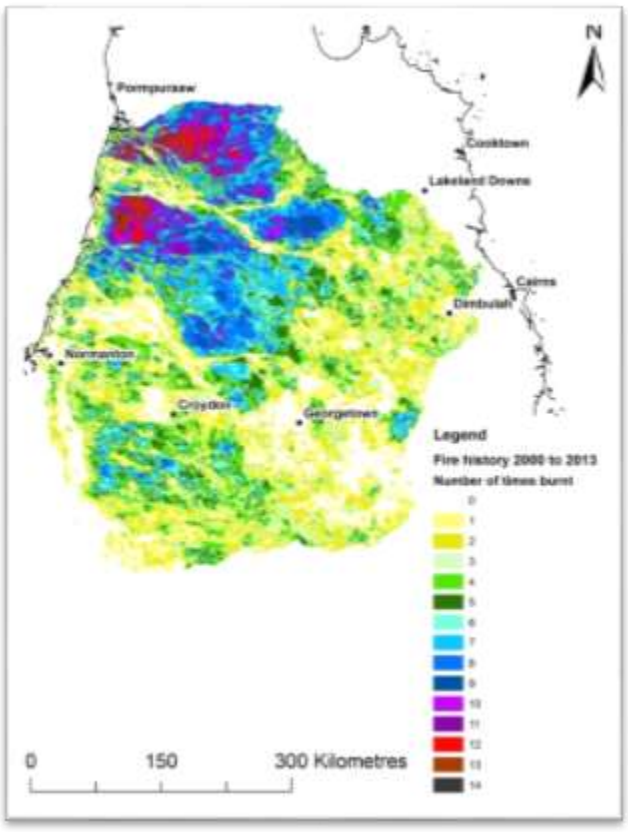


FIGURE 51: THE NUMBER OF FIRES RECORDED OVER A 14 YEAR PERIOD BETWEEN 2000 AND 2013 ACROSS THE NORTHERN GULF. FIRE DATA FROM NAFI.

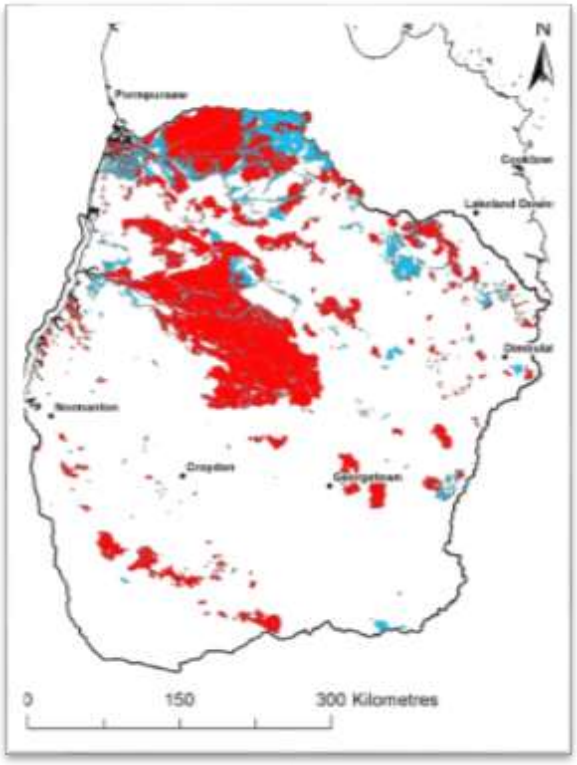


FIGURE 52: THE SEASON OF FIRES IN 2014, SEPARATED INTO WET SEASON TO EARLY DRY SEASON (BLUE SHADING; JANUARY TO JULY) AND LATE DRY SEASON (RED SHADING; AUGUST TO DECEMBER). FIRE DATA FROM NAFI.

Fires produce substantial emissions of greenhouse gases such as carbon dioxide, carbon monoxide, methane and various oxides of nitrogen. Fires in Australian savannas contribute to approximately 3% of the national greenhouse gas emissions, however on a regional NRM perspective the Northern Gulf region would contribute minimally to these emissions as prescribed burning is not used extensively across the region. The emission of greenhouse gases varies with fire regimes, with late dry season fires resulting in relatively high greenhouse gas emissions (Williams 2007).

The large fluxes of carbon through tropical savannas have led to research into the active management of fire in tropical savannas, with work focussed on the use of early dry season burning and reducing fire frequency to explore the lowering of greenhouse gas emissions and improvements in carbon sequestration (Richards et al 2011). Reducing fire frequency has proven to be an effective method in increasing savanna woody biomass and hence stored carbon (Russell-Smith et al. 2003; San Jose´ et al. 1998). Although woody thickening is considered to be a problem to graziers, through reduction in grazing land value and increases in the costs of mustering, the growth of woody vegetation could offer some carbon abatement opportunities in the Northern Gulf region.

Useful information can be found at <http://www.nprsr.qld.gov.au/managing/planned-burn-guidelines.html>.

Fire management

There is documented support for the use of fire to restore pasture by managing grazing pressure, restore the tree-grass balance, reduce the risk of wildfire and for the control of some woody weeds (ILC 2013). Fire is also used to remove rank grass and stimulate green pick. While this has merit for spreading grazing pressure, the nutritional benefits are questionable.

Outside the Northern Territory, fire use has declined over the last two decades (Table). In surveys undertaken before 2005, fire use was around 90-100% in all of the Monsoonal North except for north-west Queensland and the Queensland Mitchell Grass region. In subsequent surveys, fire use halved in north Queensland and declined to a trickle in the Kimberley. However, more recently, Savanna Burning projects for carbon abatement have reinstated fire use in the Kimberley.

TABLE 28. USE OF FIRE ON GRAZING LAND OF THE MONSOONAL NORTH

SOURCE: COMPILED BY CROWLEY ET AL. (2013)

N/R = NOT RECORDED

Year	Use fire	Wildfire prevention	Green pick/ Rank grass	Open up country	Pasture composition	Weed control	Pastoralists surveyed	Source
	(%)	(%)	(%)	(%)	(%)	(%)	(no.)	
North-west Queensland								
1996/7	59	50	66	78	19	N/R	54	CSIRO 2013
North Queensland								
1996/7	100	58	62	73	23	N/R	52	CSIRO 2013

Priority action summaries for critical fire management

The two most pressing areas relating to fire management are indicated in Figure 53. These two areas require help with coordinating the implementation of fires in particular districts. Actions to promote coordinated fire management involve education of the benefits of active fire management to relevant land managers. Working with the Rural Fire Brigade will be crucial to enable coordinated fire programs, including aerial ignition across adjacent properties.

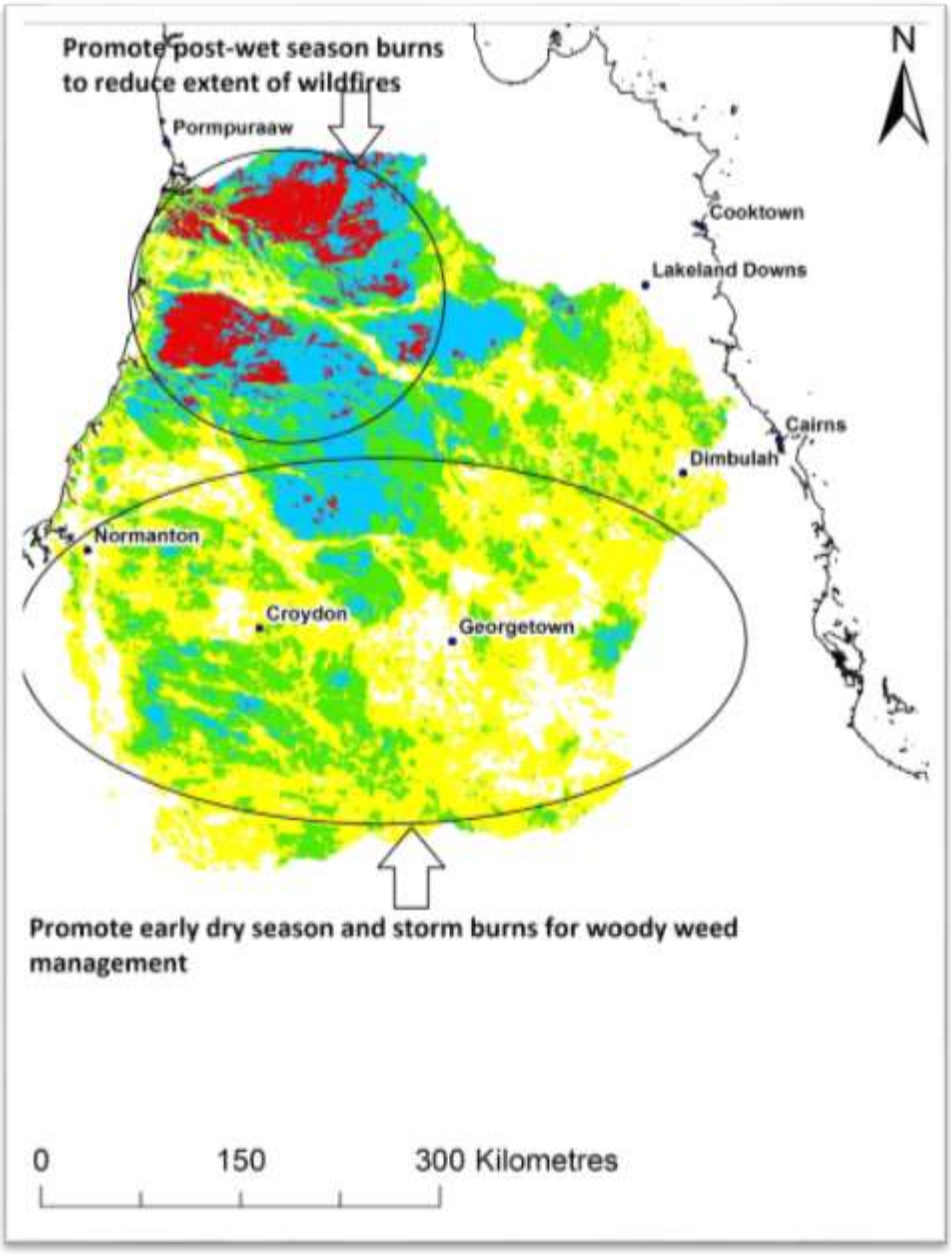


FIGURE 53: THE TWO KEY AREAS WITHIN THE REGION THAT WILL BENEFIT FROM ASSISTANCE TO COORDINATE APPROPRIATE FIRE MANAGEMENT FOR IMPROVED LAND MANAGEMENT OUTCOMES.

4.2.2.5 CLIMATE CHANGE

Climate change is likely to have some minor impacts on the flora in the Grazing lands. Problems such as woodland thickening may increase through elevated CO^2 levels and wildfires (Bond et al. 2000; Eamus et al. 2007). A change in composition of flora communities may be caused by change in rainfall and longer dry seasons, as some species may be less resilient to drought periods (Fensham et al. 2007b; Fensham et al. 2009). Drought will also place greater pressure on pasture species (Crowley et al. 2015), particularly if grazing pressure is not managed in response to drought conditions. Pasture receives the most benefit from a spread of rainfall across a season and high rainfall events may promote erosion over soil moisture retention, opening up bare areas for a change from perennial to annual pasture species (Bray et al. 2014). Exposed bare ground may also provide the opportunity for weed establishment once rain returns (Hilbert et al. 2014). Some flora species may respond to increased warming of temperature by flowering early, other less resilient species may decline in distribution with some possible local extinctions (Hughes 2003). Best practice grazing management may help build the resilience of flora communities to the impacts of climate change through reducing the impacts of grazing on sensitive flora species.

3.0 FAUNA

3.1 Assets

The current Wildnet data has identified a rich and diverse array of vertebrate fauna inhabiting the Northern Gulf region. This includes 99 native mammal, 163 reptile, 56 amphibian and 446 bird species. Of these a total of 84 native mammal, 149 reptile, 33 amphibian and 377 bird species are found predominantly in the grazing lands (Table 29).

TABLE 29: THE NUMBER OF SPECIES AND THEIR CONSERVATION STATUS (STATE AND FEDERAL LEGISLATION) IN THE GRAZING LANDS IN THE NORTHERN GULF REGION

Order	Total	Nature Conservation Act listing		
		Near threatened	**Vulnerable**	**Endangered**
Mammals	84	2	3	3
Reptiles	149	4	3	0
Amphibians	33	1	0	1
Birds	377	3	10	5

Northern Gulf Grazing lands provide significant habitat for a number of species listed as threatened under the Australian Government legislation (E***nvironment Protection and Biodiversity Conservation Act 1999*** [the EPBC Act]). These include: the golden-shouldered parrot (*Psephotus chrysopterygius*); gouldian finch (*Erythrura gouldiae*); star finch (eastern subspecies) (*Neochmia ruficauda ruficauda*); red goshawk (*Erythrotriorchis radiatus*); northern quoll (*Dasyurus hallucatus*); and the yakka skink (*Egernia rugosa*). Suitable habitat for the water mouse (*Xeromys myoides*) also occurs in this region (DEWHA 2009), however there have been no sightings to date.

The Northern Gulf Grazing lands are also home to a wide range of invertebrate species. Two main faunal groups, ants and termites, are abundant and diverse. A number of unique and endemic invertebrate species are found within cave systems throughout the region, many of which are undescribed (Clarke 2010). Studies have shown ant communities to be sensitive to disturbance and are widely used as bioindicators in land monitoring and assessment programs (Andersen et al. 2004a).

4.3.1.1 PROTECTED ESTATE

National Parks and other protected areas

There are currently 25 protected areas within the Northern Gulf region, 12 of these are located in the Grazing lands. These are predominantly made up of National Parks and Resource Reserves. The largest protected area is Staaten River National Park, which is approximately 4,700 km^2. Staaten River National Park holds one of the two remaining populations of the golden-shouldered parrot, the other is found in Cape York (QPWS 2013).

Eight wetlands are listed in the Directory of Important Wetlands as having national significance (Australia 2001). These are Dorunda Lakes, Macaroni Swamp, Mitchell River Fan Aggregation, Smithburne-Gilbert Fan Aggregation, Southeast Karumba Plain Aggregation, Southern Gulf Aggregation, Undara Lava Tubes and Spring Tower Complex. These wetlands provide significant wintering, feeding and breeding grounds for migratory birds, as well as being important sites for aquatic vertebrate species (fish, crocodiles, marine and fresh water turtles). Undara Lava Tubes and Spring Tower Complex have important cave complexes that provide roosting habitat for a range of microbat species.

4.3.1.2 FAUNA SURVEYS

Northern Gulf remains one of the least studied management areas for biodiversity in Australia. There are few publications in the scientific literature specific to the region, and numerous unpublished reports. Systematic terrestrial vertebrate fauna surveys have been conducted on only 33 properties across the Northern Gulf region, and only eight properties have had these surveys repeated. Figure 54 shows the properties that have been surveyed across the Northern Gulf region. Additional university studies (mostly species specific) have occurred based on information reported from landholders, however were unable to access these, and many appear to only occur as grey literature. Single species studies can be used to determine species responses to their environment and in some cases can be used to direct management activities; this can be particularly useful for threatened species and/or species that are determined to be indicators of good habitat health.

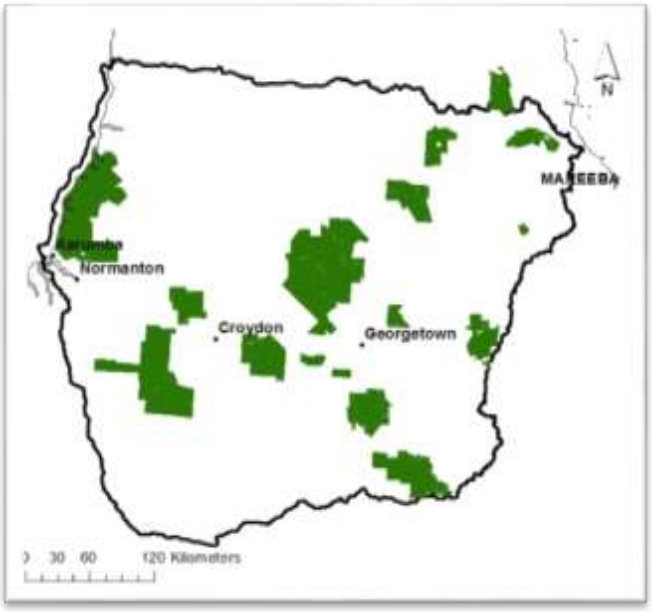


FIGURE 54: PROPERTIES THAT HAVE BEEN SURVEYED IN THE NORTHERN GULF GRAZING LANDS.

Long-term monitoring of biodiversity across Australia is important in providing insights into ecology, natural resource management, biodiversity conservation and environmental change (Lindenmayer et al 2012). Few studies of fauna have occurred In the Northern Gulf region (Burnett 2001; Preece and Preece 2012; Preece and Franklin 2013; Preece 2009, 2010, 2011, 2012; Sanders 2011; Vanderduys and Kutt 2011; Vanderduys et al 2012), and there is uncertainty about the health of native species, given the absence of repeated systematic sampling. Determining management objectives aimed at maintaining biodiversity in the Northern Gulf region is difficult as there is a paucity of information about the distribution, abundance, ecological pattern, trend and condition of terrestrial biodiversity. Systematic long-term biodiversity studies may provide information on the resilience of fauna to climate change and identify relationships between threats such as changing fire regime, increasing abundance of pest animal species, grazing pressure and disease. Long term study sites should be prioritised based on areas expected

BLACKBRAES NATIONAL PARK (VANDERDUYS ET AL. 2012)

Blackbraes National Park is located in the Einasleigh Uplands bioregion and is the highest altitude tropical savanna in Australia, extending from approximately 800 m to 1,047 m above sea level. A survey conducted by Vanderduys et al (2012) identified Blackbraes National Park as an important refuge in northern Queensland for a number of terrestrial vertebrate species. Nine species, including two mammals and seven reptiles, were recorded at the limits of their range, or in seemingly disjunct populations, examples include the chestnut dunnart *Sminthopsis archeri* and wood gecko *Diphdactylus vittatus* which were both found in areas quite far from their known range. The mammal and reptile fauna were found to be particularly diverse and abundant in comparison to other areas of tropical savanna in the Northern Gulf region. Arboreal species such as the greater glider (*Petauroides volans*) and common brushtail possum (*Trichosurus vulpecula*) have been recorded at high abundance during surveys in the National Park (Winter 2010). Ground-dwelling mammals were also high in abundance and richness, when compared to other areas in the Northern Gulf Region. Mammal captures included species that are in the weight range that are showing serious declines across the northern Australian savannas such as the common planigale *Planigale maculata* and eastern chestnut mouse *Pseudomys graciticaudatus*.

to have high level threats, ecosystems where threatened or endangered flora and fauna communities exist and/or house highly endemic species. Areas within Northern Gulf that are the most data poor should be prioritised for future rapid fauna surveys to collect an inventory of species that are present.

4.3.2 Threats to Fauna

The most widespread processes causing threats to fauna biodiversity in Northern Gulf region are the impacts from extensive land use, changed fire regimes and pest animal species, possibly coupled with disease. Modern fire regimes, particularly frequent and extensive late dry season fires, and overgrazing by livestock, have been implicated as the major contributing factors in the recent observed decline of many Northern Australian small mammal and granivorous bird species (Burbidge and McKenzie 1989; Franklin et al 2005; Legge et al 2011; Russell-Smith et al 2001; Woinarski et al 2007; Yates et al 2008). Threatened bird species such as the gouldian finch and golden-shouldered parrot that have significant range throughout Northern Gulf Grazing lands have declined presumably as a result of changed fire regimes and overgrazing (O'Malley 2006; Russell-Smith et al. 2001), recognising however, that the most recent survey of golden-shouldered parrots detected no decline over 7 years (Preece et al. 2009). These land management changes impact on these species by removing food resources during a critical time of the year and reduce the amount of cover, exposing the birds to predation (Kutt and Woinarski 2007; O'Malley 2006; Russell-Smith et al 2001).

4.3.2.1 Grazing impacts on fauna communities

Management of extensive land uses such as grazing can affect many aspects of biodiversity condition and trend. Some of the key threats posed by cattle grazing enterprises include:

- Increasing spread of introduced pasture and weed species on native vegetation and vertebrate fauna;
- Changing fire regimes in response to increasing land use intensification and changes in ground cover and woody vegetation structure due to climate change and grazing patterns;
- Increasing grazing pressure through:

Have critical weight range mammals declined across the Northern Gulf region?

Since European settlement, Australia has experienced an alarming decline in native mammalian fauna. Between 1850 and 1960, 22 mammals have become extinct and a further 10 now persist only on islands (Burbidge et al 2008; McKenzie et al 2007). Most mammalian extinctions and population declines since European settlement have occurred in the arid, semi-arid and temperate regions of Australia (Fisher et al 2013; Woinarski 2014). Recent evidence has emerged of regional extinctions and reduced distributions (some down to as little as 10% of their former range) of small-medium sized mammals (≤ 5 kilograms) across parts of tropical northern Australia (Fitzsimons et al 2010; Woinarski 2010; Woinarski et al 2011). This trend appears to follow patterns of decline in other areas of Australia where the more specialised species such as bandicoots, possums, quolls and larger rodents appear to be extinction-prone whereas the smaller, more generalist species (i.e. favoured by disturbance) appear to increase in numbers (Woinarski et al. 2007a).

The decline of small-medium sized mammals in Northern Australia has largely been documented in the Northern Territory, where systematic repeated sampling has occurred over more than 20 years. In the Northern Gulf region, however, it is impossible to determine if small-medium sized mammals have declined as there are no long-term historical data. That stated, the available recent mammal data from systematic fauna surveys does indicate that the small-medium sized mammals may be in trouble in our region. The survey data collected from 2004 to 2013, do not show any mammals of this size on 63% of sites surveyed across the Northern Gulf Region between 2004 and 2014, suggesting either very low abundance or complete absence. On those sites that mammals were found, there appears to be a relationship between land use and altitude, with small-medium sized mammals occurring more often on conservation lands at higher altitudes. This highlights that these areas are likely to be important refugia for this mammalian size class in our region.

- increasing stocking rates, driven by cost-price pressures and therefore property intensification and impacts on maintaining ground cover; and
- increasing number of water points and impacts on the species reliant on these otherwise remote and ungrazed areas as habitat refuges (NGRMG 2008).

Introduced herbivores can affect native terrestrial vertebrates in a number of ways. Grazing may directly reduce food resources for herbivorous and granivorous animals through changes to flora composition and availability (Legge et al. 2011; Sharp et al. 2003). Trampling causes soil compaction which affects the habitat quality for ground-dwelling and fossorial animals (Legge et al 2011). Cattle grazing can also facilitate or suppress recruitment of woody vegetation (Archer 1995; Burrows et al 2002; Harrington 1991; Scanlan et al 1996; Van Auken 2000) and therefore, indirectly influence species reliant on that vegetation. The reduction in ground cover caused by grazing can also increase the risk of predation to some species (Fleischner 1994; Legge et al. 2011). Grazing can reduce the overall productivity of the landscape by altering soils and affecting soil and ecosystem processes (Lunt et al. 2007). The effect of grazing by livestock is exacerbated close to artificial watering points and along riparian areas (Lunt et al 2007) where fauna are likely to seek refuge throughout drought periods.

In Northern Australia it is difficult to determine the impacts of grazing on fauna as most of the landscape has been grazed for a long period. Studies that have sampled grazed and previously grazed (destocked) land have shown recovery or higher abundance of mammals (Kutt and Gordon 2012; Kutt and Woinarski 2007; Legge et al 2011; Read and Cunningham 2010), reptiles (Kutt and Gordon 2012; Kutt and Woinarski 2007) and birds (Kutt and Gordon 2012; Kutt and Woinarski 2007) in destocked habitats. One study, however, found that after 5 years of destocking, mammals still remained at low abundance (Kutt et al. 2012a). Other species prefer disturbance caused by cattle grazing (Read et al. 2010; Woinarski et al. 2002), thus suitable stocking rates, and destocking of some grazed areas, can provide habitat that is suitable for a range of species. Rocky habitats are naturally protected from grazing impacts due to their inaccessibility and may provide refuge for many fauna species impacted by cattle grazing (Fisher et al. 2004).

The number of cattle that can be sustained without irreversible damage to soil and vegetation resources is strongly controlled by climate, particularly rainfall and its seasonal distribution (McKeon et al. 2009). Increased temperatures and longer dry seasons as a result of climate change are likely to cause a decrease in forage production. It is predicted that the livestock carrying capacity of the land is likely to decrease in Northern Australian rangelands (McKeon et al. 2009) due to the reduction in forage production. Fauna communities may be increasingly impacted by grazing if livestock carrying capacities are not adaptively managed in response to climate change predictions. Land managers should maintain lower stocking rates or manage herd numbers in response to drought or above-average conditions to protect natural resources and maintain biodiversity values. Adapting land management practices now is important in maintaining sustainable use of grazing lands, as past emissions of greenhouse gases have already committed Australia to further warming and these emissions are continuing to increase (Cobon et al. 2009).

4.3.2.2 Fire

Some fauna are vulnerable to extensive and frequent fires (Andersen et al 2012; Legge et al 2008; O'Malley 2006; Russell-Smith et al 2001; Valentine et al 2012), especially species that utilise food and dens that are destroyed or reduced by fire, or have small home ranges (Yates et al. 2008). Fires are less frequent across the Northern Gulf Region than in other areas of Northern Australia as a result of more intensive grazing and graziers' reluctance to burn pasture grasses needed for fodder. Large-scale high intensity wildfires late in the dry season are more likely to occur in unburnt habitat as fuel loads are greater in these environments. Intense wildfires, at times reaching the crowns of trees, have devastated large areas of the Northern Gulf region, causing losses to stock and wildlife (NGRMG 2013). The wildfires in the Etheridge Shire between September and December 2012 burnt across 5 million hectares and wildlife were observed dying even after fires due to illness and starvation. Fires such as these are likely to kill fauna directly or increase the risk of predation due to loss of vegetative cover. These fires also reduce resources available to some fauna species as they cause widespread reduction in seeds and grasses, mortality of small trees and shrubs, and reduce flowering and fruiting of savanna trees, particularly in the season following the fire (Liedloff et al. 2001; Russell-Smith et al. 2001). The direct loss of one or more important food resources over a large area may cause some populations to crash.

High intensity wild fires are predicted to occur more frequently in the Northern Gulf Grazing lands as a result of climate change. The recommended fire regime for conserving biodiversity and preventing high intensity wildfires include a mosaic of small fire patches across the landscape, preferably conducted in the early dry season (Dyer et al. 2001). Fire regimes that maintain some long-unburnt areas are important for particular species such as the common brushtail possum (*Trichosurus vulpecula*) (Woinarski et al. 2007a). Low intensity mosaic fire regimes aim to prevent the build-up of high fuel loads that may contribute to intense wildfires later in the dry season. Habitat variety created by patch burning can be used to promote biodiversity by increasing the diversity of habitat types or post-fire successional stages in the landscape (Fisher et al. 2004; Russell-Smith et al. 2001). Traditional fire management in the Northern Gulf region, such as burning regular, small fires, lit throughout the year, may be used to increase the diversity of flora and fauna. Studies have found that this regime has been successful in maintaining a high representation of fire sensitive vegetation types, high diversity of vertebrate fauna (including rare and range-restricted species), and maintaining relatively low numbers of exotic plant species (Yibarbuk et al. 2001). Further, low intensity mosaic fire regimes also provide unburnt refuge areas which increases survival rate of fauna during the fire.

Increased wildfires will negatively impact many fauna species. The most important effects of fire on fauna are indirect, through changes in habitat, resource availability and predation risk, rather than direct mortality (Andersen et al. 2012). Some bird species, such as small frugivores and granivores, will be impacted long-term by severe fires removing fruit and seed resources (Valentine et al. 2012; Yates et al. 2008). Bird species that will be most affected are those with small home ranges or are highly mobile and move between seasonal resources (Valentine et al. 2012; Yates et al. 2008). The endangered Gouldian finch is a highly mobile species that relies on seasonal seed resources (O'Malley 2006) and more frequent fires, particularly large fires early in the wet season are likely to impact heavily on this species by reducing seed availability (Woinarski et al. 2005). Rodents and marsupials with small home ranges are particularly vulnerable to large fires as they lack the ability to disperse large distances and critical resources such as ground cover, leaf litter and hollow logs are often destroyed. Medium sized mammals such as the black-footed tree rat, northern brown bandicoot and common brushtail possum are more frequently found in unburnt habitat, and more frequent fires may result in these species declining in many areas of the region. Low intensity, early season, fine-scale burning across the landscape and strategic burning of firebreaks that are used to protect areas from being long unburnt can be used to reduce the chance of high intensity wildfires (Yates et al. 2008) and therefore reduces a fires impacts on fauna communities.

AGILE WALLABIES IN CROYDON

A survey of the Agile wallaby population in Croydon was undertaken in 2013 by Boar Busters. The survey found that between two to three thousand wallabies were found within 5 km^2 of the Croydon township. The wallabies have presumably moved into the town area due to the drought conditions and the more abundant food and water resources around the town.

The wallabies are causing damage to the local areas through erosion in public access areas and along riparian areas. The wallabies also pose a public health risk through road strike incidents, feces and ticks. It is recommended that the agile wallaby population in the Croydon township be culled using field shooting.

4.3.2.3 Pest animals

Pest animals pose a significant threat to ecosystems across the Northern Gulf Grazing lands. Pest species may prey upon and compete with native fauna; degrade habitat by assisting in the spread of invasive weed species; cause erosion through trampling, be hosts and vectors of diseases and pathogens, and compete with production animals through the grazing of native pastures.

The pest species which pose the most serious threats to biodiversity in the region are the feral pig (*Sus scrofa*) and the feral cat (*Felis catus*) (Centre 2007a, 2007b), IACRC 2007a, 2007b). Both species are listed by the Queensland government as 'abundant and widespread' throughout the Northern Gulf region (IACRC 2007a, 2007b). The impacts of feral pigs and cats on biodiversity values have been listed as key threatening processes under the Australian Government's *Environment Protection and Biodiversity Conservation Act 1999*. The cane toad (*Rhinella marina*), wild horse (*Equus caballus*) and the European rabbit (***Oryctolagus cuniculus)*** also occur throughout the region. Overabundance of some native species such as the agile wallaby (*Macropus agilis*), may cause degradation along riparian areas and around some townships, causing financial losses to cattle industries (A Taylor 2014, pers. comm., 15 June; (Brown 2014; Smith 2013).

Feral pigs

Feral pigs cause economic losses to production systems through direct losses to agricultural production, the continued cost of pig control and indirect losses from missed opportunity to create profits from alternative investments (McGaw et al. 1998). The species can cause degradation of native pasture and can facilitate the spread and establishment of weeds and woody vegetation (Bradshaw et al. 2007; Hone 1980). Feral pig damage is exacerbated along drainage lines, riparian areas and wetlands as the species congregate and feed in these areas (Hone 1988, 1995; Mitchell 1993). Digging behaviours in soft soils reduces regeneration of plants and causes degradation of soil biology, which may cause drastic changes to the composition of native vegetation communities (McGaw et al. 1998).

Feral pigs also cause environmental damage through degradation of habitat and competition with native fauna for food resources. The species are omnivorous with a diet including: tubers, native seeds and fruits, earthworms, amphipods, beetles, frogs, lizards and the eggs of crocodiles and turtles (Consulting 2006; McIlroy 1990; Mitchell 1993; Pullar 1950; Roberts et al 1996; Tisdell 1984, KSE 2006). They also prey on small nesting birds, eggs and some aquatic species, and have been implicated in the decline of the snake-necked turtle (Tisdell 1982). A survey of aquatic fauna in Karumba found very low abundances of fresh water turtles which was partially attributed to feral pigs predating turtle eggs and disturbing nesting sites (Hogan et al. 2011). Feral pigs also have the potential to be vectors of zoonotic diseases such as Japanese encephalitis which was found in Torres Strait pig populations in 2004 (Department of Health and Ageing, 2004, In Bradshaw et al 2007) and Cryptosporidium and *Echinococcus granulosus* (Jenkins 2006).

Pig control options include ground and aerial bait dispersal, trapping, fencing, ground hunting, fertility control and aerial culls by shooting from helicopters (Hone 2012; Mitchell 2011). In regions as remote and vast as the Northern Gulf, aerial culls are often considered to be the most viable option, but they are expensive. Feral pig control needs to be regularly repeated to maintain the reduction in pig numbers. Poisoning is 'the most appropriate technique for large scale feral pig population control' because it is economic, efficient and is accessible (Mitchell 2011). Poison baiting can affect non-target species such as goannas and birds of prey, but with careful selection and management of the baits and poisons used, non-target impacts can be reduced considerably (Mitchell 2011). A feral pig program must consider a range of management options, as pigs can become wary of baits, can become trap-shy, and wary of shooters. The critical points of feral pig control are to achieve at least 70% reduction in populations for at least several years in a row, within a catchment where ingress of replacement pigs in minimal. Therefore coordinated efforts between properties and across regions are essential to success. Monitoring of pigs by aerial and ground counts is necessary to ensure that populations are reduced, so that the efforts are not wasted. It is often best to undertake control when pigs are concentrated rather than dispersed, such as during the late dry season. Targeted baiting programs to reduce pigs at critical times (such as leading up to the turtle nesting season or during the dry season where wetlands may be more vulnerable to damage) can be highly effective in reducing pig damage. This improves success rates and reduces effort, thereby reducing costs (Hone 2012; Mitchell 2011). A side effect of feral pig control may be that predators which relied substantially on pigs for the diet, such as dingoes, may switch to other prey, such as cattle, kangaroos and wallabies and smaller mammals. Monitoring of populations of these larger predators should be included in the feral pig monitoring program.

Gilbert River pig control program (NGRMG 2014)

In October 2013 a feral pig control program was established along a 170km section of the Gilbert River. During the initial control operations in October 2013, 3410 pigs were culled using aerial shooting. Follow up aerial culls performed in October and November 2014 shot a total of 3010 pigs. This project encompassed a group of smaller properties plus one large holding added during the program. The numbers of feral pigs shot during 2013 and 2014 were relatively comparable and indicate that the feral pig population had recovered in numbers between the 2013 and 2014 culls. Aerial shooting is considered effective in reducing feral pig numbers, however this method is not cost effective long-term as populations recover quickly.

Feral cats

Feral cats prey on native birds, frogs, reptiles and small mammals. The success of the feral cat can be largely attributed to the lack of native meso-predators and the efficacy of the species' hunting behaviour (Kutt 2012). The group of species most impacted by feral cat predation throughout Northern Australia are critical weight-range mammals (35g to 5.5kg) with gut content analysis indicating that cats in northern Queensland have a strong dietary preference for small mammals (Dickman 1996; Kutt 2012). In particular, four of the five species of native mammal considered to be declining in Northern Australia (the northern quoll, ***Dasyurus hallucatus***; northern brown bandicoot, *Isoodon macrourus*; common brushtail possum, *Trichosurus vulpecula* and pale field-rat, *Rattus tunneyi*) are found in the Northern Gulf region and of these, most overlap the medium to high selectivity size for the feral cat diet recorded in North Queensland (Kutt 2012). Cats can also act as hosts and vectors of a number of wildlife diseases, notably toxoplasmosis.

Control options for feral cats include fencing (the only feasible option for complete removal from protected areas), shooting, poisoning using lethal baits and trapping (Department of Agriculture 2013a)DAFF 2013). Currently there are no viable options for controlling feral cats over large areas. Baits specifically developed to target cats (Eradicat® and Curiosity®) have shown to be effective; however these may also poison non-target species (Hetherington et al. 2007; Johnston et al. 2011). More research is required to further develop these baits for safe application across Australia.

Feral cat diet - a study in Charters Towers area (Kutt 2012)

A total of 169 cat stomachs were examined, containing 974 items, representing 106 unique prey types. The prey items consisted of invertebrates (10 genera/families), amphibians (9 species), reptiles (43 species), birds (21 species) and mammals (23 species). Of the 974 prey items identified, 8% were invertebrates, 9% amphibians, 41% reptiles, 20% birds and 22% mammals. This study demonstrates that feral cats consume a large amount of prey per cat (approximately 200 g per cat, per night) and that mammals are the dominant prey item by mass in the 100-3,500 g range (other prey species have few species within this size class), although reptiles and birds within 10g-100g weight range are a major component of the diet. The size and amount of native fauna in the cat diets of this study are of particular concern for Northern Australia and suggest that predation by introduced carnivores such as feral cats is possibly a significant cause of mammal extinctions in the small size range.

Evidence of causal linkages between feral cats and small mammal decline (Dickman 1996)

The range of species consumed by feral cats varies depending on the environment and prey availability. Birds and reptiles are the predominant prey item consumed on islands in arid areas respectively. Across the dry tropical savannas, mammals below 200g in weight have been found to be a preferred prey item. The predation of small mammals has implicated cats as one of the factors causing the decline of small to medium sized mammals across Northern Australia. Historical records show that all mammal species that disappeared from the Australian mainland by the 1850s weighed 200g or less, this timing is consistent with the introduction of the cat. The loss of these animals pre-dates the introduction of the rabbit and fox, as well as broad-scale changes to the landscape. Habitats of many now-extinct species were open plains, grasslands and woodlands, which provided limited shelter from visually hunting predators. Several of these species would have had behaviours which made them conspicuous to cats, including hopping, ground foraging and nesting.

Cane toads

The Cane toad is a serious threat to biodiversity as it poisons, preys upon and competes with native species. Although the cane toad has not caused the extinction of any native Australian fauna (Bradshaw et al. 2007), evidence shows that they have caused major declines and local extinctions of some goanna species (Taylor et al. 2005). Evidence also suggests that a wide range of species are impacted by cane toads including mammals (dingo, *Canis lupus dingo*; northern quoll, *Dasyurus hallucatus*), birds (kookaburra, *Dacelo* spp.; little and black bitterns, *Ixobrychus minutus*, *I. flavicollis*), reptiles (red-bellied black snake, *Pseudechis porphyriacus;* mulga snake, *Pseudechis australis;* green tree snake, *Dendrelaphis punctulata;* dragons and goannas) and frogs. There are, however, very few studies that present any data on population consequences of mortality from poisoning (Taylor and Edwards 2005). Control options for cane toads include exclusion fencing, live trapping and direct killing through bounty hunting (Taylor and Edwards 2005). Currently there appears to be no financially viable option for controlling cane toads over large areas.

Dingoes and feral dogs

Dingoes and feral dogs may impact on native fauna through predation and by competition with native predators. Although dingoes in some areas have shown a preference for mammals in their diets (Dickman 1996), their impacts on mammal communities are considered to be less than feral cats (Bradshaw et al. 2007). There is evidence of a high degree of hybridization of native dingoes and feral dogs in some areas (Crowther et al. 2014). Dingoes and hybrid animals are considered to have some beneficial impacts on native wildlife, by restricting populations of feral cats and foxes (Dickman 1996) however, the story is not clear and is subject of considerable debate recently (eg. (Allen et al 2014; Letnic et al 2012; Ritchie 2011). The risk of predation of livestock has resulted in wide scale control of feral dogs using toxic baits and shooting by property managers. The reduction in feral dog numbers is considered to be one of the key reasons why cat populations have become widespread and subsequently caused a loss of small native fauna (Brook et al. 2011; Fitzsimons et al. 2010).

Studies across Australia show that while feral dogs do predate livestock, the majority of losses occur to sheep enterprises. Cattle grazing properties appear less affected; however, dingoes and feral dogs may prey upon young cattle. Although feral dogs are widely persecuted by property managers, the species may benefit some landowners. The majority of dingoes' diets are medium to large macropod species, which may have positive implications for production animal systems by reducing competition between macropods and cattle. In some areas in the Northern Gulf region agile wallabies (*Macropus agilis*) have reached high numbers, which may have been caused by the suppression of dingoes through control programs (Brook and Kutt 2011). Further, feral dogs also predate pigs, hares and rabbits which may also benefit grazing productivity (Ritchie 2011; Brook and Kutt 2011). Subsequently there may be significant scope to use dingo populations to provide cost effective benefits to both productivity and biodiversity, while managing the predatory

SPECIES ADAPTATIONS TO CANE TOADS (O'DONNELL ET AL 2010; TAYLOR AND EDWARDS 2005; WOINARSKI ET

All stages of the cane toad's life cycle (eggs, tadpoles, toadlets and adult toads) are poisonous. If ingested, the poison can cause rapid heartbeat, excessive salivation, convulsions and paralysis and, in severe cases, death. Some species such as the keelback (*Tropidonophis mairii)* appear to have a high level of resistance to cane toad poison (Phillips et al. 2003), other species avoid ingestion of poisonous parts (e.g. ravens and crows (*Corvus spp.*) (Covacevich et al. 1975) or reject eggs or tadpoles if they are caught (e.g. barramundi (*Lates calcarifer*) (Crossland 1997). Although the cane toad has been implicated in the decline and change in distribution of the northern quoll, studies have now found the species coexisting with cane toads across Queensland (Woinarski et al 2008). It is not known if the quolls persistence is due to some quolls having developed avoidance behaviours.

Researchers from the University of Sydney have successfully trained northern quolls to avoid eating cane toads by feeding the animals a dead toad containing a nausea-inducing chemical (thiabendazole) (O'Donnell et al 2010). Results from this study show that toad-smart quolls were less likely to attack toads, and females were less likely to attack than were males. These results show that conditioned taste aversion is possible in this species and may have assisted the northern quoll to persist in the presence of cane toads (O'Donnell et al 2010).

impacts of dogs on young livestock._Control options for feral dogs include shooting, trapping or poisoning using lethal baits.

Managing feral species

Population control is often used to reduce the environmental damage caused by feral animals as eradication is not considered to be a viable option for most feral species in Australia. Controlling populations through culling is generally not a long-term solution, as populations recover quickly, particularly for species with high fecundity. Other methods such as exclusion fencing or targeted control programs with direct management objectives may be more effective in protecting highly vulnerable environmental assets or rare or threatened fauna communities.

POISONING FOR FERAL DOGS, PIGS OR FERAL CATS REQUIRES A PERMIT

If using fresh meat baits containing 1080 an APVMA Permit (PER14015 effective until 30 June 2016) is required. 1080 baits can only be obtained from authorised persons from local government or Biosecurity Queensland (you can obtain the details of authorised persons from your local council).

WILD DOG SCATS (BROOK AND KUTT 2011)

A total of 178 dingo scats were collected between 1994 and 2000. The samples comprised 185 prey items, and represented 21 discrete prey types. Native mammals were recorded in the majority of scats (69.7%), mostly being medium macropods (predominantly the agile wallaby) and large macropods (predominantly the eastern grey kangaroo). Cattle were recorded as prey in the Einasleigh Uplands, but was only about 10% of their diet overall.

4.3.2.4 CLIMATE CHANGE AND IMPROVING THE RESILIENCE OF SPECIES

Research indicates that only 30 years of warmer temperatures at the end of the twentieth century have affected the phenology of organisms, the range and distribution of species, and the composition and dynamics of communities (Walther et al. 2002) Unfortunately, the rate of environmental change associated with climate change is predicted to be faster than any change in the past, therefore many species are unlikely to adapt (Hughes 2003). The fauna most vulnerable to the impacts from climate change are those species with long generation times, low mobility or have small and isolated populations (Hughes 2003). Further, fauna that are dependent on waterholes for maintenance of populations may be threatened by higher evaporation and changes in flow regime (Cobon et al. 2009). Increased drought may result in changes in vegetation composition in grassland and savanna communities with more adapted species (including pest species such as cane toads) being more resilient to the changes than less adapted species (Rios-López 2008).

Although specific actions can be undertaken to reduce the impacts of climate change, such as facilitated migration of species, reducing existing threats is often considered to be more valuable for maintaining biodiversity. Many activities to mitigate existing threats to fauna can be used to not only preserve biodiversity values but also will assist fauna in adapting to climate change. Areas that are a high priority for management include high value areas, housing threatened or highly endemic animal or plant communities or habitat connected to or within potential refuge areas. A biodiversity planning assessment (The Biodiversity Assessment and Mapping Methodology [BAMM]) has been prepared for the Einasleigh Uplands and the Gulf Plains bioregions.The BAMM is an assessment of biodiversity values at the landscape scale and is a tool that can be used for prioritising areas for current management. This tool can be useful for identifying areas most important for endangered, vulnerable or rare (EVR) taxa, potential high value refuge areas or areas considered significant for biodiversity at the state, regional or local scales. Unfortunately the paucity of fauna data records for the Northern Gulf region reduces the accuracy of this data and this should be considered when determining areas for management. Figure 55 below shows an example of some of the BAAM outputs for the Einasleigh Uplands for the following biodiversity values:

a) Wildlife refugia – e.g. Islands, mount springs, caves, wetlands, gorges, mountain ranges and topographic isolates, ecological refuges, refuges from exotic animals and refuges from clearing;
b) Areas with very high species richness;
c) Areas with very high species endemism.

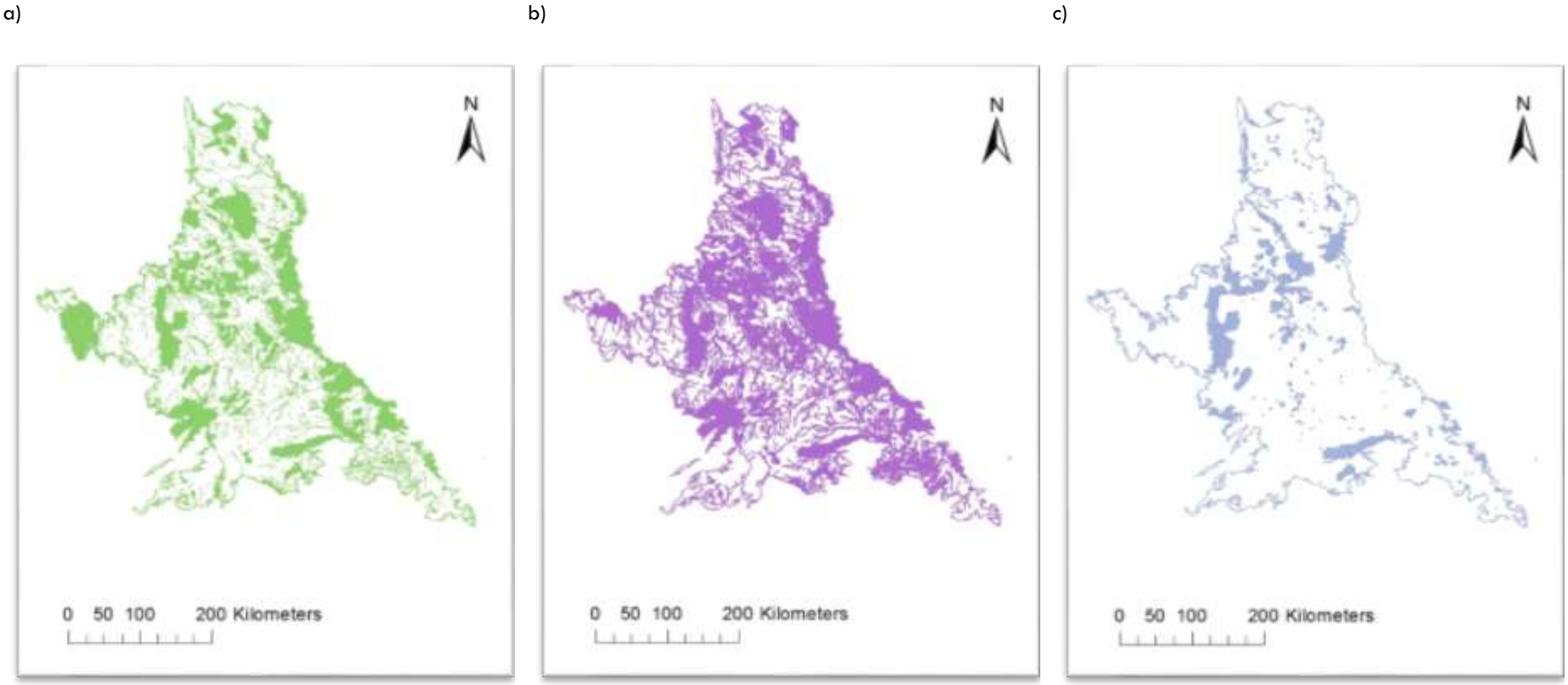


FIGURE 55: THE EINASLEIGH UPLANDS BIODIVERSITY ASSESSMENT AND MAPPING METHODOLOGY OUTPUTS FOR A) WILDLIFE REFUGIA, B) HIGH SPECIES RICHNESS & C) HIGH SPECIES ENDEMISM

Systematic collection of biodiversity data can be used to improve the accuracy of planning assessments such as the BAMM. Areas that should be targeted for surveys include threatened regional ecosystems, habitat for Endangered, Vulnerable or Rare (EVR) taxa, areas that have huge gaps in data records such as the north-west or south-west Gulf country or broad vegetation groups that have a lack of data. Although collecting additional fauna data is useful for determining the distribution of species to help inform where to implement management programs for particular species or ecological communities, without the understanding of how these species or communities respond to threats, effective management is not possible. Therefore, it is important that research is undertaken to improve the understanding how species respond to threats and what actions are most effective at mitigating threats to species.

APPENDIX 1: AUSTRALIAN NATIONAL AND STATE/TERRITORY-LEVEL CONSERVATION PRIORITISATION SYSTEMS

Commitment: ACAP, Agreement on the Conservation of Albatrosses and Petrels; Bonn Convention, Convention on the Conservation of Migratory Species of Wild Animals; CAMBA, China-Australia Migratory Bird Agreement; CBD 1992, Convention on Biological Diversity 1992; CLMA 1984, Conservation and Land Management Act 1984; CPALSMPA, Cobourg Peninsula Aboriginal Land, Sanctuary and Marine Park Act (NT); **EPA 1994**, **Environmental Protection Act 1994** (Qld); EPBC 1999, Environment Protection and Biodiversity Conservation Act 1999(Cwlth); JAMBA, Japan-Australia Migratory Bird Agreement; NCA 1992, Nature Conservation Act 1992 (Qld); NNPA, Nitmiluk (Katherine Gorge) National Park Act (NT); PA, Planning Act (NT); PWCA, Parks and Wildlife Commission Act (NT); Ramsar, Ramsar Convention on Wetlands; ROKAMBA, Republic of Korea-Australia Migratory Bird Agreement; TPWCA, Territory Parks and Wildlife Conservation Act (NT) VMA 1999, Vegetation Management Act 1999 (Qld); WCA 1959, Wildlife Conservation Act 1950 (WA); WHC 1972, World Heritage Convention 1972; WRA 2005, Wild Rivers Act 2005 (Qld)

Name	Assets	Metrics	Commitment	Source
		National		
National Reserve System	Terrestrial and marine ecosystems	Comprehensiveness, Adequacy, Representativeness	EPBC 1999, CBD 1992	www.environment.gov.au/land/nrs National Reserve System Task Group 2009, Stokes et al 2006
Threatened species list	Plants and animals	Population size and decline, distribution, probability of extinction	EPBC 1999, CBD 1992	www.environment.gov.au/biodiversity/threatened/species
Threatened ecological communities	Ecosystems	Extent & rate of decline, threatened species habitat value, condition, probability of extinction	EPBC 1999, CBD 1992	www.environment.gov.au/biodiversity/threatened/communities
Migratory species	Migratory reptiles, birds, mammal & sharks	Movement across international boundaries	EPBC 1999, ACAP, Bonn Convention, JAMBA, CAMBA, ROKAMBA	www.environment.gov.au/biodiversity/migratory-species

Name	Assets	Metrics	Commitment	Source
World Heritage List	International heritage	10 IUCN natural and cultural criteria	EPBC 1999, WHC 1972	www.environment.gov.au/heritage/about/world-heritage
Commonwealth Heritage List	Natural and cultural heritage values of Commonwealth-owned places	Nationally significant natural or cultural values	EPBC 1999	www.environment.gov.au/topics/heritage/heritage-places/commonwealth-heritage-list
National Heritage List	Natural and cultural heritage	Nationally significant natural or cultural values	EPBC 1999	www.environment.gov.au/cgi-bin/ahdb/search.pl?mode=search_form;list_code=RNE

Name	Assets	Metrics	Commitment	Source
		National		
National Estate List	Natural and cultural heritage	State/territory level or locally significant natural or cultural values	Repealed	www.environment.gov.au/cgi-bin/ahdb/search.pl?mode=search_form;list_code=RNE
Ramsar wetlands	Wetlands	Representativeness, rarity or uniqueness, biological diversity	EPBC 1999, Ramsar	www.environment.gov.au/water/wetlands/ramsar
Nationally Important Wetlands	Wetlands	Representativeness, ecological function, critical habitat, threatened species, cultural significance	None	www.environment.gov.au/topics/water/water-our-environment/wetlands/australian-wetlands-database/directory-important Environment Australia (2001), DoW WA, et al. (2014)
National Biodiversity Hotspots	Plant and animal species	Integrity, biological diversity, endemic species	None	www.environment.gov.au/biodiversity/conservation/hotspots/national-biodiversity-hotspots
High Conservation Value Aquatic Ecosystems	Wetlands	Diversity, distinctiveness, vital habitat, Evolutionary history, naturalness, representativeness	None	Sinclair Knight Merz (2007) (James Cook University and CSIRO 2013) Kennard (2010) (CSIRO 2013)
Water Quality Hotspots (formerly Coastal Hotspots)	Coastal and marine environments	Conservation values threatened by water quality decline resulting from population pressure and poor land management	None	www.environment.gov.au/water/quality/improvement/hotspots
Wild Rivers	Rivers and floodplains	Alteration to flow regime	None	Stein et al. (2001) (Petheram et al 2013)
Important Bird Areas	Bird habitat	Diversity and abundance, rarity, threatened species, management potential	None	Dutson et al. (2009) (Ash, A.J. 2014)

Name	Assets	Metrics	Commitment	Source
		Western Australia		
Terrestrial Protected Areas	Terrestrial ecosystems	Comprehensiveness, Adequacy, Representativeness	CLMA 1984	http://www.dpaw.wa.gov.au/
Marine Protected Areas	Marine ecosystems	Comprehensiveness, Adequacy, Representativeness	CLMA 1984	www.dpaw.wa.gov.au/management/marine/marine-parks-and-reserves
Threatened species list	Plant and animal species	Population size, distribution, rate of decline, probability of survival	WCA 1950	www.dpaw.wa.gov.au/plants-and-animals/threatened-species-and-communities
Threatened ecological communities	Vegetation communities	Extent, individual occurrences, modification, decline, rehabilitation potential	None	www.dpaw.wa.gov.au/plants-and-animals/threatened-species-and-communities
Priority areas for conservation of Western Australian coastal fishes	Coastal fish	Species richness, endemism, biogeographic zoning,	None	Fox *et al.* (2005) (Head, L. 1999)
		Northern Territory		
Protected Area Estate	Ecosystems	Comprehensiveness, Adequacy, Representativeness	TPWCA CPALSMPA NNPA PWCA	TPWCA, CPALSMPA, NNPA, PWCA
Threatened species list	Plant and animal species	Population size, distribution, rate of decline, probability of survival	TPWCA	www.lrm.nt.gov.au/plants-and-animals/threatened-species/specieslist
Sites of Conservation Significance	Biodiversity values		None	www.lrm.nt.gov.au/plants-and-animals/conservation-for-land-managers/sites-of-conservation-significance
Eco-Link	Broadscale biodiversity values	Connectivity	None	Heckbert, S., et al. (2009), Griffiths et al (2007)

Name	Assets	Metrics	Commitment	Source
		Northern Territory		
Sensitive vegetation communities	Vegetation communities	Communities sensitive to clearance (mangroves, monsoon rainforest, riparian vegetation, sandsheet and vegetation containing large trees with hollows suitable for fauna	PA	www.lrm.nt.gov.au/land-clearing/clearing-guidelines,-fact-sheets-and-reports
		Queensland		
State Reserve System	Protected Area estate	Comprehensiveness, Adequacy, Representativeness		
Threatened species list	Plant and animal species	Population size, distribution, rate of decline, probability of survival	NCA 1992	www.ehp.qld.gov.au/wildlife/threatened-species/index.html
Regional ecosystem biodiversity status and vegetation management class	Vegetation communities	Extent of regional ecosystem relative to pre-clearing extent	VMA 1999	www.qld.gov.au/environment/plants-animals/plants/ecosystems/biodiversity-status/
Critical habitat	Habitat essential for a viable population of protected wildlife or community of native wildlife	Not in use (none declared)	NCA 1992	EHP (2014) Heckbert, S., et al. (2012)
Back on Track species prioritisation framework	Plant and animal species	Probability of extinction, consequences of extinction, potential for recovery	Policy	Marsh *et al.* (2007) Cowley, R.A., et al. (2014)

Name	Assets	Metrics	Commitment	Source
		Queensland		
Biodiversity Assessment and Mapping Methodology (BAAM)	Ecosystems and species habitat	Critical habitat, threatened species, regional ecosystem biodiversity status, important wetlands, extent, representativeness, condition, biological diversity, context and connectivity	None	EHP (2014) Crowley et al 2009
AquaBAAM	Aquatic ecosystems and species habitat	Critical habitat, threatened species, regional ecosystem biodiversity status, important wetlands, extent, representativeness, condition, biological diversity, context and connectivity	None	Clayton *et al.* (2006) Crowley, G.M. and S.T. Garnett (1998)
Great Barrier Reef (GBR) protection measures	GBR water quality	Catchments and industries contributing to GBR pollution	**EPA 1994**	www.qld.gov.au/environment/agriculture/sustainable-farming/reef/
Wild Rivers	Rivers, floodplains and artesian basin	Lack of modification	**WRA 2005 (Repealed)**	Ginnivan 2012 Crowley, G.M. and S.T. Garnett (2000), Dale 2014 Bortolussi, G., et al. (1999)

APPENDIX 2: HIGHEST PRIORITY WEEDS ON THE GRAZING LANDS AND THEIR PREDICTED RESPONSE TO CLIMATE CHANGE PREDICTIONS

Weed Name	Biology	Where found	Effect on Biodiversity	Effects on production grazing	Changes due to climate change
Asbestos Grass *Cenchrus basedowii (Formerly Pennisetum basedowii)*	Asbestos Grass is a usually annual grass of the open clay soils and floodplains of northern Australia (Alsemgeest et al. 2004). In recent decades Asbestos Grass has increased in both incidence and distribution. In some areas it has replaced Mitchell and bluegrasses thus leading to significantly reduced pasture condition, and subsequently a drop in carrying capacity. It is chiefly unpalatable, especially when seeding (Earl 2014). Heavy stands often collapse covering the soil surface and preventing germination of other species (Hall 1982). Asbestos Grass has the ability to respond to rainfall more quickly than other native perennial grasses and is more likely to grow in areas that have been inundated or in heavily grazed areas where there are fewer perennials (Fensham et al. 2000). In badly affected areas Asbestos Grass is the only visible species and drastically reduces stocking rates for that country. It is a possibility that Asbestos Grass will spread throughout the region if Biosecurity procedures are not adhered to.	Herbarium has records from scattered occurrences throughout the NG area. Heavy infestation in the inundated areas of floodplains south of Normanton and eastwards. Grows mostly on cracking clay and alluvial soils and is mostly found in bluegrass/brownTop/Mitchell grass country and some flood plains (Alsemgeest et al. 2004).	Replaces native grasses in inundated and heavily grazed areas (Alsemgeest et al. 2003). Collapsed dead grass covers other grasses preventing germination.	Asbestos grass is considered unpalatable and livestock do not graze the grass at all once it has gone to seed. The plant is usually avoided even when young, however in some cases stock have been observed to graze new growth under certain situations and to continue grazing it until it seeds (Alsemgeest et al. 2003, 2004). No nutritional analysis has been done on asbestos grass.	***-Increased incidence of destructive wild fires*** Asbestos Grass response to fire is unknown in a grazing situation ***-Increased intensity of high rainfall events (flood and cyclones)*** Asbestos Grass prefers inundated country. More inundation, more Asbestos Grass invading pastures ***-Increased storm surge and rising sea levels*** No foreseeable affect. ***-Longer dry seasons and increased incidence of drought*** Asbestos Grass will recover quicker than native grasses after drought. Where it is dominant, asbestos grass may create a matted ground cover and discourage desirable species from germinating ***-Continued warming of temperature, including more hot days*** The effect of temperature on the spread of Asbestos Grass is unknown
Bellyache bush *Jatropha gossypiifolia*	Bellyache bush is a squat, thick-stemmed shrub 2.5–4 m tall developing from a short, single-stemmed plant with three or four young leaves sprouting from the top. Young leaves are deeply divided into three rounded lobes, and are purple coloured and sticky (Bebawi et al. 2007). The whole plant is sappy and the plant leaves and seeds are poisonous. Seeds are scattered by explosive force up to 10m from the parent plant, but the main movement of seed is by water during flood time where the seeds are deposited on the floodplain to grow new infestations. Bellyache Bush forms a thicket where the roots and canopy excludes all other plants (Bebawi *et al.* 2007).	Bellyache Bush is in the bed of the Walsh and Palmer Rivers and the seeds move downstream with every flood event (Bebawi et al. 2002b). Bellyache Bush has the potential to occupy the whole of the riparian zone and extended floodplain of the Mitchell River if not controlled (Vogler et al. 2005).	Bellyache Bush is a transformer species forming thickets excluding understory species.	Excludes grass and prevents grazing of normal abundant grasses	-***Increased incidence of destructive wild fires*** Bellyache Bush will not burn but is killed by fire, but its thicket growing nature excludes other burnable material from the stand so fire is less effective in pure stands (Bebawi et al. 2002a). Fire removes competition from the seedbed. -***Increased intensity of high rainfall events (flood and cyclones)*** Increased flooding will carry more seeds further and deposit them further out on the floodplain. ***-Increased storm surge and rising sea levels*** Potentially more coastal flooding that spreads more seeds from and to inundated areas

					-Longer dry seasons and increased incidence of drought Being a xeric species, Bellyache Bush can withstand longer and more severe drought. ***-Continued warming of temperature, including more hot days*** The effect of temperature on the growth and spread of Bellyache Bush is unknown
Gamba Grass *Andropogon gayanus*	Gamba grass is a perennial grass from Africa, growing up to 4 m tall with tussocks up to 70 cm in diameter (Bowden 1964). The leaves are 30–60 cm long and up to 3 cm wide, with a distinctive white midrib and covered with soft hairs. Stems are robust and covered in soft hairs. The root system spreads up to 1 m from the tussock, close to the soil surface.	Gamba grass is widespread throughout the tip of Cape York and along transport corridors south of Mareeba (Rossiter et al. 2003). Isolated occurrences exist where landowners have introduced it to their properties.	Gamba Grass produces high biomass for fuel, and more intense fires can kill and replace native vegetation (Setterfield et al. 2010). Gamba Grass is currently only present in the region in isolated areas but has the potential to spread to the whole area. Gamba Grass is mainly spread along roadways and deliberate introduction for cattle fodder.	Gamba grass is prized for cattle fodder (Zemmelink et al. 1972) and is distributed and introduced for this purpose.	***-Increased incidence of destructive wild fires*** Gamba Grass in a fire increaser and more intense bushfires favour Gamba Grass over native species (Rossiter et al. 2003). ***-Increased intensity of high rainfall events (flood and cyclones)*** High rainfall favours C4 pathway plants, more robust growth and more water borne seed spread ***-Increased storm surge and rising sea levels*** Little or no impact on the growth and distribution of Gamba Grass ***-Longer dry seasons and increased incidence of drought*** Being a clumping grass it is able to withstand longer and more intense drought and has the ability to respond quicker than native species. ***-Continued warming of temperature, including more hot days*** C4 pathway plants respond favourably to higher and more sustained temperatures
Giants Rats Tail *Sporobolus pyramidalis* and *S. natalensis*	Weedy Sporobolus grasses are robust, tufted, perennial grasses growing up to 2 m tall (Jacobs 2007). They are difficult to distinguish from other pasture grasses before maturity. Seeds are mainly spread by animals, vehicles and water, the seeds remain viable for up to 10 years (Bray et al. 1998). Weedy Sporobolus grasses have low palatability when mature, are difficult to control, can quickly dominate a pasture, especially following overgrazing or soil disturbance (Vogler et al. 2006). It can affect cattle health and productivity. Rats Tail Grasses can become a serious fire hazard in spring months.	Rats Tail Grasses are spreading west from the coast along roadways and through cartage of fodder hay (Batianoff et al. 2002).	GRT can invade natural grassland reducing species diversity and promoting hotter fires.	Giant rat's tail grass and other weedy Sporobolus grasses are invasive grasses that can reduce pasture productivity, out-compete desirable pasture grasses and cause significant degradation of natural areas (Vogler et al. 2006).	***-Increased incidence of destructive wild fires*** GRT responds well after fire (Gaff et al. 1997) and out competes other native grasses ***-Increased intensity of high rainfall events (flood and cyclones)*** Seeds spread well in floodwaters and with increased movement of cattle and fodder ***-Increased storm surge and rising sea levels*** No perceivable affect ***-Longer dry seasons and increased incidence of drought*** Able to withstand drought and respond better to first rainfall than native grasses ***-Continued warming of temperature, including more hot days***

					No foreseeable effects
Grader Grass *Themeda quadrivalvis*	Themeda quadrivalvis, also known as Oatgrass, Habana Oats and kangaroo grass is similar to native kangaroo grass and native oatgrass. An annual grass, it grows up to 1-2.5m in height with jointed cane-like stems and long narrow leaf blades up to 60cm in length. It has bent, brown bristles along the flower spikes. Seed heads are reddish-brown, changing to a golden colour at maturity, 15-60cm long. Seeds last up to four years in the soil and germinate throughout the year when light and moisture is present (McIvor et al. 2000). Flowering occurs from six weeks after germination and when seeds are mature, the grass then dies. Seeds are spread by vehicles, machinery, and animals and on clothing. Also spread by soil movement along roadsides by graders and slashers.	It is found along roadsides and disturbed areas throughout coastal, sub-coastal and seasonally dry tropical regions of Queensland and Northern Territory (Keir et al. 2006).	Invades grassland and disturbed areas. Spread by cattle and machinery	No grazed by cattle. Invades pastures and is selected for by grazing of mixed pastures	***-Increased incidence of destructive wild fires*** Obligate seeder so germinates well after wildfire at right time of the year ***-Increased intensity of high rainfall events (flood and cyclones)*** In creased opportunity for seed spread and germination. ***-Increased storm surge and rising sea levels*** No perceived effect. ***-Longer dry seasons and increased incidence of drought*** May delay germination until more opportune time ***-Continued warming of temperature, including more hot days*** Increased germination depending on available moisture
Hymenachne *Hymenachne amplexicaulis*	An introduced perennial stoloniferous grass from South America. It can reach heights of 2.5 m and possesses glossy leaves and stems that run on wet ground or float on water (Bogdan 1977). Hymenachne spreads by sticky seeds on animals and water birds and by floodwaters. It is spreading down rivers flowing into the gulf. Although useful as ponded pasture, it soon became an unwanted pest in stream banks, wetlands and irrigation ditches (Kibbler et al. 1999). In some areas it has invaded low-lying sugarcane, fish habitats and natural wetlands with high conservation value. It increases flooding by chocking waterways, builds up and put extra pressure on bridges, weirs and other water infrastructure. It destroys aquatic wildlife habitat and excludes recreational activities in infested waterways (Houston et al. 2003).	Introduced in coastal and near coastal areas (Batianoff et al. 2002). Now spreading throughout the whole of the region down rivers and into wetlands by water birds (Wearne et al. 2010).	Out competes native water plants (Houston et al. 2003), chokes waterways and reduces in-stream habitats and reduces DO levels.	Very effective as a ponded pasture grass being the only green around in drought time (Wearne et al. 2010).	***-Increased incidence of destructive wild fires*** Hotter seasons may see fire extend into wetland habitat. ***-Increased intensity of high rainfall events (flood and cyclones)*** Increased flood events, cause seed spread and increase habitat for waders that spread seed. Huge increase in flood debris in infested rivers ***-Increased storm surge and rising sea levels*** Little to no effect foreseeable. ***-Longer dry seasons and increased incidence of drought*** Heavier reliance on Ponded pastures during dry times. Increased plantings and intentional spread of this grass to counter reduced grass away from wetlands ***-Continued warming of temperature, including more hot days*** Increased growth of Hymenachne. Increased water quality problems with increased water temperature in chocked streams and ponds.
Parthenium *Parthenium hysterophorus*	Parthenium weed is an annual herb with a deep taproot and an erect stem that becomes woody with age and may reach a height of 2m. It has creamy white flowers and pale green leaves, which are deeply lobed and covered with fine soft hairs (Pitt 1998).	Originally a weed of cultivation now spread to poor grazing country	Parthenium can invade brigalow, gidgee and softwood scrub soils (Milson 2000).	Parthenium weed colonizes weak pastures with sparse ground cover, bare areas along roadsides and heavily stocked areas	***-Increased incidence of destructive wild fires*** Generally not affected by fire but will colonize burnt areas. ***-Increased intensity of high rainfall events (flood and cyclones)***

	As a pioneer species, it invades disturbed soil by seed, which normally germinates in spring and early summer. In ideal conditions, parthenium can grow and produce flowers at any time of the year. Parthenium weed may also cause health problems, as contact with the plant or the pollen can cause serious allergic reactions such as dermatitis and hay fever. Most common cause of spread of Parthenium is by contaminated grain or fodder, as well as contact with vehicles or animals. (Milson 2000).			around yards and watering points.	Increased spread of seed in floodwater and more suitable wet areas for growth. ***-Increased storm surge and rising sea levels*** No perceived effect ***-Longer dry seasons and increased incidence of drought*** May be change in growth cycle (earlier flowering and seeding) may interrupt or change cultural practices ***-Continued warming of temperature, including more hot days*** Increased temperature may have a negative effect on germination and growth.
Prickly Acacia *Acacia nilotica (Vachellia nilotica subspp. indica)*	Prickly acacia is a thorny shrub or small tree to 4–5 m high and up to 10 m. The young shrubs form dense thorny thickets, while mature trees are usually single stemmed, with spreading branches that have lost most of their thorns. It has a distinctive umbrella shape canopy and seed pods. Leaves are bipinnate with four to ten pairs of leaf branches and ten to twenty pairs of small, narrow, green leaves on each branch. Pairs of stout thorns, usually 1–5 cm long, grow at the base of the leaves. Golden-yellow, ball-shaped flowers, about 1 cm across, grow on stems from leaf joints with two to six flowers per group (Gracie 1992). Seed pods are 10–15 cm or longer, flat, with narrow constrictions between the seeds, grey when ripe. Prickly Acacia was introduced for fodder and shade but soon became a pest (Pedley 1987).	Major infestations to the south and west of our region (Mackey 1996).	Replaces grassland along watercourses. A transformer species	Introduced as a tree legume it does improve soil nitrogen, but shades out important grasses (Pedley 1987).	***-Increased incidence of destructive wild fires*** Being a legume, the seed bed has enhanced germination with fire. Generally excludes grasses so difficult to burn ***-Increased intensity of high rainfall events (flood and cyclones)*** Seeds will spread further with increased flooding events ***-Increased storm surge and rising sea levels*** No foreseeable effects ***-Longer dry seasons and increased incidence of drought*** With a hard seed it is able to withstand droughts better than many native species. ***-Continued warming of temperature, including more hot days*** Unknown effects on this species
Rubber Vine *Cryptostegia grandiflora*	Growth habit from a single stem to an untidy 1-2m high shrub to a vine 30m high in trees. Glossy dark-green leaves, 6-10cm long by 3-5cm wide in opposite pairs. Stems, leaves and unripe pods exude a white, milky sap when broken or cut. Flowers are large and showy with five white to light purple petals arranged in a funnel shape. Pods have a tuft of long, white silky hairs, are 10-12cm long by 3-4cm wide and contain up to 450 brown seeds that can easily be disperse on wind and water currents (Kleinschmidt et al. 1977).	A native to Madagascar and introduced as an ornamental, it can now be found throughout river systems of southern Cape York and the Gulf of Carpentaria, south along the coast to the Burnett River(McFayden et al. 1990).	Smothers riparian vegetation and forms dense thickets. Infestations expand outward from waterways, hillsides to smother most productive pastures (Batianoff et al. 1997). Decreases biodiversity and impedes stock and native animal movement.	Reduces grass growth in the regions most productive grazing areas	***-Increased incidence of destructive wild fires*** Rubber vine is controlled by appropriate fire so increased fire may have a controlling effect ***-Increased intensity of high rainfall events (flood and cyclones)*** Increased spread of seed by floodwaters. ***-Increased storm surge and rising sea levels*** No perceived effect ***-Longer dry seasons and increased incidence of drought*** May reduce growth and flowering. ***-Continued warming of temperature, including more hot days***

					May cause increased growth vigour.
Siam weed *Chromolaena odorata*	Siam Weed has been called the world's worst weed. (Holm et al. 1977) Siam Weed grows as a single stem, then scrambling clump, than a vine that uses trees for support. It can grow up to 5 m per year. Once at the top of the tree it spreads out to cover the canopy. Leaves are soft and have a "pitch fork" 3 veins pattern, slightly purple when young. Flowers are similar to Blue Top but many more on each flower head. A huge number of seeds are produced, and this is its main source of reproduction (Henderson 1989). Siam weed is not currently present in the catchment except for a small infestation found near Irvinebank but landowners are asked to be aware of this weed.	It is present in tropical coastal areas, Tully, Cairns, Mossman and now in the headwaters of the Mitchell River, Siam Weed is present in New Guinea, West Papua and Timor and Torres Strait Islands (Bingelli 1998), and with increasing domestic travel across the strait, there is a high risk of it entering Cape York from north (Henty et al. 1988).	Smothers trees and shrubs in riparian areas to the east. Slowly spreading west (Henderson 1989).	Reduces grass cover in the most fertile riparian areas	***-Increased incidence of destructive wild fires.*** Siam weed is burnt back by fire but re-sprouts quickly from a basil ball, giving it an advantage. Amazing growth rates results in this species out competing other species in the race for the canopy. ***-Increased intensity of high rainfall events (flood and cyclones)*** With windborne seeds, there is increased risk of cyclonic winds spreading seeds over large distances. Increased rain events would increase the risk of seed travelling down-stream into new country. ***-Increased storm surge and rising sea levels*** No foreseeable effects ***-Longer dry seasons and increased incidence of drought*** Siam weed dies back to the basil ball when heavily affected by drought, but can reshoot after rain and attain growth rates of up to 5 m per year, outcompeting most native and weeds species. ***-Continued warming of temperature, including more hot days*** If not coupled with water shortage, Siam Weed is able to use higher temperatures to achieve even higher growth rates, quicker flowering and seeding times making it more competitive.
Sicklepod, *Senna obtusifolia, Senna toro, Senna occidentalis*	Sicklepods are a vigorously growing, very competitive woody shrubs which grows 1.5–2.5 m tall and 1 m wide. Normally an annual, but plants which have been slashed or have survived chemical treatment often reshoot, flower and last for another year (Smith 2002). Leaves are divided into three opposite pairs about 4 cm long and 2 cm wide rounded at the end and wedge-shaped at the base.	These species can invade and completely dominate pastures and other disturbed areas such as roadsides, fence lines, creek banks and disturbed areas (Smith 2002). They have the potential to become major weeds of many crops within a matter of two or three growing seasons (Smith 2002; van	Mainly a weed of pasture. Is a transformer species that takes over pastures (Smith 2002). Does well on sandy river drifts and riparian open areas (Wheaton 1994). Currently working down rivers to the Gulf.	Sicklepods and sennas are unpalatable to domestic stock. However, cattle and horses will injest mature seed, which can pass through the animal and germinate in dung. This is the most common manner of seed spread from one property to another (Smith 2002).	***-Increased intensity of high rainfall events (flood and cyclones)*** Increased flooding will help to spread the persistent seed further ***-Increased storm surge and rising sea levels*** No foreseeable effect ***-Longer dry seasons and increased incidence of drought*** Sicklepods will germinate any time of year whenever conditions are favourable (Smith 2002; van Rangelrooy 1992). In less than ideal conditions the plant does not grow as tall but still flowers and seeds (Smith 2002). ***-Continued warming of temperature, including more hot days***

		Rangelrooy 1992).			Higher temperatures could mean increased germination of the soil seed bank
Water Hyacinth *Eichhornia crassipes*	Water hyacinth is a floating waterweed with a fibrous root system and dark green rounded leaves up to 5 cm in diameter. The leaf stalks are swollen into spongy, bulbous structures. Flowers are light purple with a darker blue/purple and yellow center. They are carried in dense spikes projecting above the plant (Smith 2002). Heavy infestations can affect water bodies in a number of ways: • Safety risk, children can become entangled in roots and stolons • Impedes passage of boats (Smith 2002) • Clogging of stock watering and irrigation • Damage to structures by the buildup of organic matter during floods (Flanagan 1998) • High rate of water loss through transpiration as against evaporation from the surface (Flanagan 1998; Smith 2002) • Degradation of water quality. • Loss of habitats (Smith 2002) • Recreation and aesthetics opportunity loss (Smith 2002)	Isolated occurrences in near town waterways and lagoons. It is only introduced by aquarium disposal and water vessel contamination. Seed is viable for up to 15 years (Smith 2002)	Completely covers water bodies limiting light, nutrients and oxygen. Reduces water levels in dams and waterholes by increased transpiration (Flanagan 1998; Smith 2002)	Readily eaten by cattle. But not readily accessible.	***-Increased incidence of destructive wild fires*** Of no consequence to aquatic vegetation; maybe increased nutrients in runoff entering waterways causing increased growth (Bayley et al. 1992) ***-Increased intensity of high rainfall events (flood and cyclones)*** New plants are rapidly produced from plant parts that break away and drift (Smith 2002). Increased debris burden on river and infrastructure, increase risk of damage ***-Increased storm surge and rising sea levels*** Some freshwater beachfront lagoons may become brackish and unable to sustain populations of freshwater weeds. ***-Longer dry seasons and increased incidence of drought*** Less water holes and more waterholes drying out should mean less waterweeds, but hyacinth regrows when the waterholes fill up again. ***-Continued warming of temperature, including more hot days*** Unknown what increased temperatures will do to growth rates but increased temperatures will increase the rate of deoxygenating of water trapped under the floating raft of Hyacinth.
Physic nut *Jatropha curcas*	A perennial shrub or small tree up to 6m high with alternate palmate-shaped leaves, 12.5-18cm long, originally from Central America and Mexico. Small flowers are yellow to green, with fruit an ellipsoid capsule 2.5-3cm long, 2-3cm diameter, initially yellow then turning black. Seeds are smooth, brown or black with fine yellow stripes, about 1.7cm long (Crothers 1994; Smith 2002). Occurs naturally in seasonally dry tropical savannas and thorn-forests. Can grow on harsh dry sites, is drought tolerant and can withstand light frost. It flowers throughout the year. Seeds are explosively released from the tree and are spread by water flow (Smith 2002). If not controlled this species will spread downstream throughout the whole of the Mitchell catchment.	Naturalised and weedy in QLD (Smith 2002). An infestation in Gibb Creek just downstream from Irvinebank in the Mitchell Catchment.	Invades riparian areas. A transformer species grows thickets and out competes other species (Crothers 1994; Smith 2002).	Invades the most productive areas of the landscape (Bingelli 1998; Smith 2002). Reported to be toxic to animals and humans (Smith 2002)	***-Increased incidence of destructive wild fires*** Affected by fire but not usually in a fire prone habitat or suppresses fuel growth in the infestation ***-Increased intensity of high rainfall events (flood and cyclones)*** Increased flooding brings increased spread of seed downstream (Bingelli 1998; Crothers 1994; Smith 2002). ***-Increased storm surge and rising sea levels*** No foreseeable effect ***-Longer dry seasons and increased incidence of drought*** Xeric nature of this species means it is able to withstand prolonged drought (Bingelli 1998). ***-Continued warming of temperature, including more hot days*** Unknown what effect higher temperatures will have on the growth and spread of Physic Nut

Breadfruit, *Gardenia vilhelmii* and Gutta percha *Excoecaria parvifolia*	Both native species that have "thickened" in response to grazing and fire. Can be controlled by appropriate fire if trees are under 2m. Other species involved in thickening are Wattles and Currant Bush (*Cariss ovate/ C. lanceolata)* and some Eucalypts (Lankester 2014).	More common on sandy country.	Not a problem in itself but the cause of thickening causes species and structural change in forests (Lankester 2014)	Thickening increases the shrubby understory reducing grass coverage.	***-Increased incidence of destructive wild fires*** As these species are part of the "thickening "process caused by wildfire, Increased wildfire will increase the populations of these species (Lankester 2014) ***-Increased intensity of high rainfall events (flood and cyclones)*** Riparian species such as these will have improved seed dispersal due to flooding ***-Increased storm surge and rising sea levels*** No foreseeable effect ***-Longer dry seasons and increased incidence of drought*** These native species may suffer in vigour during dry times but may respond with earlier and more prolific seeding and suckering. ***-Continued warming of temperature, including more hot days*** Unknown what effect this will have.
Buffel grass *Cenchrus ciliaris* and *Cenchrus pennisetiformis*	Buffel grass (*Cenchrus ciliaris*) is an introduced, perennial pasture grass that is found across much of the Australian continent, where it has been widely planted for livestock production and land rehabilitation (Smith 2002). It is well regarded as pasture because it grows rapidly under warm, moist conditions and persists under heavy grazing and drought (Cameron et al. 1982; Smith 2002). Buffel grass has spread well beyond planted areas and dominates the ground layer in many native plant communities. Buffel grass is just one of many perennial grasses invading Australia's native vegetation, particularly grassy plant communities, rangelands and coastal areas (Smith 2002).	Introduced to grow in cleared brigalow country now invades sandy and black soils throughout Australia (Smith 2002). Grasses introduced as pastures, such as gamba grass (*Andropogon gayanus*), mission grass (*Pennisetum polystachion*) and Birdwood grass (*Cenchrus setiger*) are a particular threat to tropical savannas in northern Australia.	It reduces native plant diversity and can affect vegetation structure by changing fire regimes (Smith 2002). In arid Australia, Buffel grass invades some of the wetter, more fertile parts of the landscape, important for the survival of native plant and animal populations in this highly variable climate. Buffel grass has been identified as a major threat to biodiversity in regional natural resource management strategies across Australia (SA Arid Lands, Rangelands (WA), Fitzroy (Queensland) and the Northern Territory).	A major grazing improvement to cleared and sandy country increasing stocking rates (Smith 2002)	***-Increased incidence of destructive wild fires*** Dry Buffel grass foliage burns readily and can carry extensive and intense fires. It recovers its biomass very rapidly when moisture is sufficient and can burn when partly green. Therefore it can carry fire at much shorter intervals than native understory. More frequent hot fires alter native plant community structure because established trees and shrubs can be killed and young ones destroyed before they have produced seed (Smith 2002). ***-Increased intensity of high rainfall events (flood and cyclones)*** Seeds are best adapted to spreading short to medium distances by wind, however Buffel Grass has spread extensively during infrequent episodes when summer rainfall was well above average for several years. It is reasonable to expect that this will continue with predictions ***-Increased storm surge and rising sea levels*** No foreseeable effect ***-Longer dry seasons and increased incidence of drought*** Buffel Grass has swollen stems that can store energy over unfavorable times. It is then quick to recover (Holm et al. 1977). Predicted climate changes will avour this species

					-Continued warming of temperature, including more hot days Unknown what effect this will have on the growth and distribution of Buffel Grass
Calotrope *Calotropis procera*	Calotrope is a spreading shrub to 4 m high with a milky sap (Smith 2002). Stems are smooth and pale greyish green. Mature stems have a characteristic beige corrugated bark, cork-like in appearance and texture. The grey-green leaves are opposite, sessile 10–20 cm long and 4–10 cm wide, with a short pointed tip and a heart-shaped base. The five-petalled waxy flowers grow in groups in the forks of the uppermost leaves, and are white with purple tips inside and have a central purplish crown. The large green fruit are similar in shape to a mango but hollow. When ripe, the fruit bursts and releases numerous seeds that have tufts of long, silky hairs at one end. These can be carried long distances by the wind (Smith 2002). Calotrope may sucker rapidly from the base of plants and from seedlings unless there is vigorous competition (Smith 2002).	Calotrope is a weed of roadsides and watercourses and commonly invades old cultivated land and heavily grazed areas where there is little competition from grass (Batianoff et al. 1997; Smith 2002).	Will invade native grasslands if overgrazed (Crothers et al. 1993; Smith 2002)	Will invade native pastures if overgrazed	***-Increased incidence of destructive wild fires*** Calotrope is resistant to fire and will recover from underground suckers if burnt (Crothers et al. 1993). ***-Increased intensity of high rainfall events (flood and cyclones)*** Increase in the potential spread of seeds ***-Increased storm surge and rising sea levels*** No foreseeable effect ***-Longer dry seasons and increased incidence of drought*** Large spongy roots enable Calotrope to resprout effectively after drought ***-Continued warming of temperature, including more hot days*** No foreseeable effect
Chinee apple *Ziziphus mauritiana*	Chinee apple is a large shrub or small spreading tree to 8 m. Densely branched, from ground level in some cases, chinee apple grows as open forests or form thorny thickets along waterways. Branches are zig-zag in shape and have a leaf and a thorn at each angle. Leaves are rounded, glossy green on top and almost white underneath, and grow on alternate sides of the branches (Smith 2002). The edible fruits are similar in size and structure to a cherry, but pale yellow or orange when ripe. Chinee Apple suckers extensively when above ground parts are damaged.	Mainly run down pastures where scant grass cover allows germination of the seed (Batianoff et al. 1997; Smith 2002)	Mature trees produce large quantities of fruit that are readily eaten by stock, feral pigs, wallabies and birds, which assists the spread of the seed (Smith 2002).	Dense infestations of chinee apple create impenetrable thickets that restrict stock management and reduce pasture production (Smith 2002).	***-Increased incidence of destructive wild fires*** Chinee Apple is susceptible to fire but suckers extensively to re-colonize burnt areas (Smith 2002) ***-Increased intensity of high rainfall events (flood and cyclones)*** Increased flooding will increase seed spread in floodwaters ***-Increased storm surge and rising sea levels*** No anticipated effects ***-Longer dry seasons and increased incidence of drought*** Chinee apple drops leaves in response to drought but will re shoot extensively once rains have fallen ***-Continued warming of temperature, including more hot days*** No foreseeable effect
Lantana *Lantana spp.*	Lantana is a heavily branched slightly prickly shrub that can grow in compact clumps, dense thickets or as a climbing vine. Leaves are opposite, about 6 cm long and are covered in fine hairs (Smith 2002). They are bright green above, paler beneath and have round-toothed edges, and produce a distinctive odour when crushed. Flowers vary from pale cream to yellow, white, pink, orange and red in clustered compact heads about 2.5 cm in diameter and appear throughout most of the year (Smith 2002).	Lantana is endemic on the eastern and wetter areas of the Bioregion and will be travelling west with normal dispersal methods (Smith 2002)	Lantana is mainly spread by fruit-eating birds and mammals (Smith 2002). It forms dense thickets that smother and kill native vegetation and are impenetrable to animals, people and	Invades and reduces pasture areas. Toxic to cattle if eaten by those (Smith 2002)	***-Increased incidence of destructive wild fires*** Can create hotter fires that kill native vegetation but fire is an effective control if right conditions (Swarbrick 1986) ***-Increased intensity of high rainfall events (flood and cyclones)*** Possibly increase in seed dispersal by floodwater ***-Increased storm surge and rising sea levels*** No foreseeable effects ***-Longer dry seasons and increased incidence of drought***

	Lantana produces round, berry-like fruit that turn from glossy green to purplish-black when ripe (Smith 2002). .		vehicles (Parsons 1992; Smith 2002). More than 1400 native species are negatively affected by lantana invasion, including many endangered and threatened species. As lantana is a woody shrub that has thin, combustible canes, its presence can create hotter bushfires (Swarbrick 1986).		Lantana reduces leaf cover to survive drought, so may out last other species. ***-Continued warming of temperature, including more hot days*** May limit it's spread westwards
Mesquite *Prosopis glandulosa, P. Pallida* and *P. vellutina*	Mesquite is a multi-stemmed shrub with branches drooping to the ground, around 3–5 m high, or as a single-stemmed tree with a spreading canopy growing to 15 m. Older bark is rough and grey or brown. Small branches are zigzag shape have smooth bark, dark red or green in colour. Leaves are bipinnate, 1–4 pairs of leaf branches (pinnae), each having 6–18 pairs of individual leaflets (Smith 2002). Leaflets are dark green, oval-shaped to long and narrow. Paired horns usually occur just above each leaf axil. Small greenish-cream 'lamb's tail' shaped flowers grow near the ends of branches in wattle-like spikes, 5–12 cm long. Seedpods are 10–20 cm long, straight to slightly curved, smooth, containing between 5–20 hard seeds Seed spread is by overland flow and in faeces of stock (Smith 2001).	Mesquite is widespread in the southern and western end of the catchment and is spreading north and east (Smith 2002).	Invades native pastures and open areas (Wheaton 1994).	Invades pastures and spreads rapidly in cattle faeces (Smith 2001, 2002)	***-Increased incidence of destructive wild fires*** Mesquite is killed by fire but it is rare that there is any fuel in the vicinity to carry fire. ***-Increased intensity of high rainfall events (flood and cyclones)*** Will increase the spread of seeds in floodwater (Smith 2002) ***-Increased storm surge and rising sea levels*** No foreseeable effects ***-Longer dry seasons and increased incidence of drought*** Possibly less growing time, smaller trees and more flowering and seeding. ***-Continued warming of temperature, including more hot days*** May increase growing time (No citation found)
Parkinsonia *Parkinsonia aculeata*	Parkinsonia is a small tree to 6 m high, with zigzag branches armed with sharp spines (Smith 2002). Its leaves are, flattened with small, oblong leaflets along each edge. Flowers are yellow, fragrant, five petalled, seeds are oval and hard, about 15 mm long, and borne in pencil-like pods 5–10 cm long, constricted between the seeds (Smith 2002). Parkinsonia is fast growing and may flower in early summer Pods, float on water and hence are readily dispersed by floodwaters (Department of Employment 2011).	Widespread throughout the region (DEEDI 2011)	Invades native grasslands (Smith 2002)	Invades pastures and spreads rapidly in cattle faeces (DEEDI 2011)	***-Increased incidence of destructive wild fires*** Parkinsonia will be affected by fire if there is enough fuel. Fire reduces standing seed bank. Fire promotes dieback in surviving population. Adult plants not particularly susceptible to fire (Navie et al. 2011). ***-Increased intensity of high rainfall events (flood and cyclones)*** Increased distribution of seeds down creeks and rivers (Smith 2002, DEEDI 2011) ***-Increased storm surge and rising sea levels*** No foreseeable effect ***-Longer dry seasons and increased incidence of drought*** May become more prevalent in eastern areas as they become drier (Navie & Adkins 2011) **Continued warming of temperature, including more hot days**

					-May be increased growth and enhanced germination due to hot weather.
Salvinia *Salvinia molesta*	Salvinia is a free-floating aquatic fern, with small, spongy, green leaves positioned in pairs along a common stem (Smith 2002). The surface of each leaf is covered with long, stiff, water-repellent hairs. When the plant matures, the leaves become thick and fold at the mid-rib. The young leaves of Salvinia are oval, about 12 mm wide, and lie flat on the water surface, often resembling duckweed. It does not produce flowers—reproducing only vegetatively. Salvinia prefers warmer temperatures and is frost sensitive. Under optimal growth conditions salvinia can double in volume every two to three days. Salvinia reproduces from fragments that can form large thick mats, which can completely cover water storages (Management 2003).	There are small infestations around the towns of Mt Isa and Cloncurry, presumably from local aquariums. These must be contained before they spread into connected waterways.	Completely covers waterways reducing biodiversity by shading, reducing DO and using nutrients (Piertarse et al. 1990).	Cattle eat Salvinia. Major infestations will clog pumps and increase pressure on in stream infrastructure during flood time (Smith 2002, CRC 2003)	***-Increased incidence of destructive wild fires*** As an aquatic weed fires have no effect on the population. Maybe increased nutrients due to runoff from burnt land (Bayley et al. 1992). ***-Increased intensity of high rainfall events (flood and cyclones)*** Increased flooding will help to distribute salvinia further (Piertarse et al. 1990). ***-Increased storm surge and rising sea levels*** No foreseeable effect ***-Longer dry seasons and increased incidence of drought*** As waterholes dry up the waterweeds will die out. As Salvinia does not set seed a complete and thorough drying out of the area will prevent it from re-growing. ***-Continued warming of temperature, including more hot days*** As Salvinia is frost sensitive, overall warming will reduce the number of cool days therefore the number of days that Salvinia grows at an optimal rate (CRC 2003).
Small Devil's Claw *Martynia annua*	Bushy annual herb to 2 m high. Leaves kidney-shaped to circular, mostly 6–15 cm wide, both surfaces equally hairy, margins with shallow lobes (Smith 2002); leaf stalk 9–14 cm long (Hyland et al. 2010). Pod green and fleshy at first, drying to a black woody capsule. Seeds brown to black, 2 to each pod. Leaves and stems covered with sticky glandular hairs; leaves pumpkin-like; flowers tubular, 4–6 cm long, predominantly white to pink with 5 spreading lobes at the apex, each lobe with a prominent purple spot, throat with red and yellow spots, fertile stamens 2; pod to 4 cm long and to 1.5 cm wide, with recurved claws about 1 cm long (Smith 2002). Spread by seeds that remain in the pod and are transported when the hooked fruits catch on passing objects (DEEDI 2011).	Currently scattered throughout Cape York and throughout NT to the west of this region (Hyland 2010)	Invades disturbed ground and run down pastures. (Department of Employment 2011; Smith 2002)	Invades disturbed ground and run down pastures	***-Increased incidence of destructive wild fires*** Not usually affected by fire. Seed pods are fire resistant but not fire proof (Thompson 2014). May cause some reduction in population ***-Increased intensity of high rainfall events (flood and cyclones)*** Could increase seed dispersal ***-Increased storm surge and rising sea levels*** No foreseeable effect ***-Longer dry seasons and increased incidence of drought*** May cause shorter growing time but seeds will still persist (DEEDI 2011) ***-Continued warming of temperature, including more hot days*** May have increased growth. May cause a population drift eastward from NT No source found.

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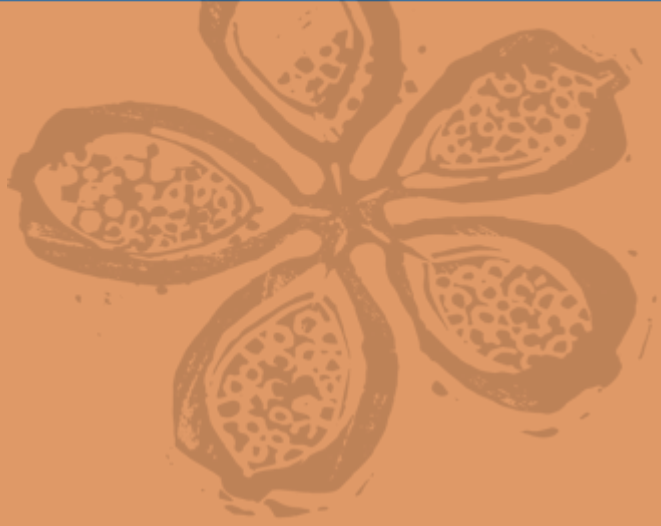

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