Extensive Tropical and Sub-Tropical Beef Cattle Operations

Production issues relating to historical land use, its effect on ongoing viability and related development opportunities

A report for

By Adam Coffey

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Executive Summary

The purpose of this report is to discuss production issues relating to historical land use and the development potential of extensive tropical and sub-tropical cattle producing regions and the businesses within them. The information in this report has been compiled from experience as a manager, and a family business owner in these areas, and is an attempt to pull together knowledge gained over this time, coupled with recent experience and travel as a Nuffield Scholar. In considering development of these predominately native environments, the industry needs to study production issues that have arisen from historical grazing use and how best to tackle these problems. Issues such as woody encroachment and thickening, perennial pasture dieback and the increasing populations of undesirable species within pasture systems need to be addressed. Many of these issues relate to grazing methods and their effect on soil moisture and nutrient infiltration, associated availability and plant uptake. Differing burning regimes of native grass and rangeland are also discussed in this context.

Development can be in many different forms as discussed in the body of this report such as implementing change management through gaining a better understanding of the biological processes of land systems, or conventional intervention using mechanical and chemical methods in addition to integrating high production pasture species, fencing, water development and utilising advancements in technology.

Recommendations and implications of this report include:

- considering intensification of operations by simply expanding in size;
- considering change management in relation to perceived issues;
- focusing on production outcomes;
- developing increased focus and awareness of extensive grazing soils and considering management practices that may affect soil health;
- fostering the need to enhance and build diversity within extensive grazing lands; and
- reviewing burning methods in tropical and sub-tropical regions and any associated environmental effect.

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Foreword

The topic of my Nuffield research study: Extensive Tropical and Sub Tropical Beef Cattle Enterprises; Investigating production issues relating to historical land use and its effect on ongoing viability, is the result of management experience of corporate owned cattle entities through to our family's entry into private enterprise, all within the Northern Australia beef cattle industry.

Over the last ten years I have been fascinated by trying to squeeze the most out of our land assets in a scenario where the high capital cost of entry into land ownership means that making any significant return on your investment can be a difficult task.

Originally from a southern farming environment, I have been drawn to Northern Australia by the sheer size of the numbers, both cattle and land area. Whilst believing that much of Southern Australian farming country is being well utilised, the North remains a land of opportunity but also with inherent risk and production difficulties that sometimes are not immediately apparent.

The beef market in Australia is currently enjoying record prices, which is fantastic to see and we need to make sure that we re-invest this current level of wealth back into our production systems to ensure the ongoing profitability of our industry.

As a first-generation entrant into agriculture it is vital 'get it right' in the initial years of our investment. We, like many others sometimes, struggle to make ends meet in a reasonably highly geared investment with traditionally low cash flow and often marginal returns. As a family, we recognise the need to try and leverage what we have in a way that ensures our ongoing viability and gives our investment the chance to grow. This all relates back to how we use our land and what we produce from it. In a way, we have learnt to look at what we are doing in a more holistic manner and are starting to see a much bigger picture than simple performance measurements such as calves branded or kilograms/hectare (ha) produced.

Having this frame of mind when I travelled meant I started to see some very common threads amongst extensive beef producers across the globe and, in particular, the problems they were dealing with in relation to the land they were farming. Some examples of this are perennial pasture dieback in the United States of America (USA), Brazil and here in Australia, or the advancement of Mesquite and Huisache in Southern Texas that is slowly but steadily encroaching on what have always been vast treeless prairies and hence, very sought after grazing land.

The aim of this report is to investigate and discuss extensive beef cattle production scenarios in several different countries. More specifically; how land may have changed in recent history and what we are doing to tackle problems arising from it. In the context of our

situation as first-generation farmers, I hope we can learn from these scenarios or at the very least, start to question more as to why these things are happening and continue on our path as successful beef producers.

Although my report does not contain absolute answers to the aforementioned issues, I am hoping to share what I have found from the view of a family cattle grazier and promote some of the problems faced by livestock graziers to the wider public. This will hopefully help to generate further discussion and debate on what I regard as substantial impediments to our goal of increasing world food production for our ever-growing population – in this case protein in the form of red meat.

Acknowledgments

I would like to acknowledge and commend Nuffield Australia for their support - what a vital organisation for all Australian agricultural industries.

I would also like to acknowledge the Northern Territory Government Department of Primary Industry and Resources for their foresight in providing support of my scholarship.

A huge thank you is extended to all of the people who hosted me on my travels throughout North and South America. The hospitality of farmers throughout the world has been humbling and I can only hope to return the favour one day.

Lastly, I would like to thank my wife Jacynta and our two boys Will and Sam for their support during what has been an incredible journey but also a big commitment for our family and our business.

Abbreviations

CP – Crude Protein

DM – Dry Matter

GRT – Giant Rats Tail grass

Ha/ha - hectare

NRCS – Natural Resources Conservation Service

NT – Northern Territory

QLD - Queensland

R&D – research and development

SE Asia – South East Asia

TST – tropical and subtropical

TX - Texas

USA – United States of America

USDA - United States Department of Agriculture

WA – Western Australia

Objectives

The objective of this report is to investigate current management practices in tropical and sub-tropical environments and their associated use for beef cattle production, specifically:

- Problems arising from historical management – how have traditional practices affected soils and vegetation in extensive rangeland environments?
- Barriers to increasing production in relation to the land asset and tackling these issues.
- Intensification of operations in extensive environments as opposed to increasing land area to provide economies of scale.

Chapter 1: Introduction

Tropical and sub-tropical grazing environments around the world have great potential for better land utilisation with more strategic management for the purpose of beef production. As land is not the limiting factor in any of these areas, increases in productivity can benefit from a multiplier effect as improved strategies can potentially be applied over large areas. Conversely, barriers to improving production in these extensive systems can have the opposite effect and result in a drastic reduction in a business's ability to return a profit from its land asset.

Like many global agricultural environments, extensive sub-tropical grazing environments have changed in recent times and the ongoing use of these areas has the potential to continue to change these land systems in positive and negative ways. It has been observed that historical grazing practices have affected general soil makeup and health, and many graziers are tackling issues such as woody encroachment, the spread of undesirable and less palatable forages, and issues such as pasture dieback.

The Northern Australian cattle industry utilises around 75% of total farming land in Australia, although only accounts for less than half of the national beef herd -2016 data estimated 26 million head (Meat and Livestock Australia, 2016). This trend is reflected worldwide where tropical and subtropical (TST) environments cover vast areas with a relatively low comparative return in regard to production.

Some of the issues associated with a lack of production efficiency in these areas include:

- High average annual precipitation often leading to leaching and soil infertility.
- Large capital requirement for average scale of operations.
- Harsh weather conditions - often long dry seasons and hot, humid growing seasons.
- Often high level of pest and disease pressure.
- Greater numbers of predatory animals.
- Generally, more unpalatable, brittle nature of tropical forages compared to more temperate grasses.
- Distance to market and cost of shipping and transport for inputs.
- Political instability.
- Sparsely populated.
- Lack of infrastructure and government investment in more remote areas.
- Lack of research and development (R&D) investment and application.

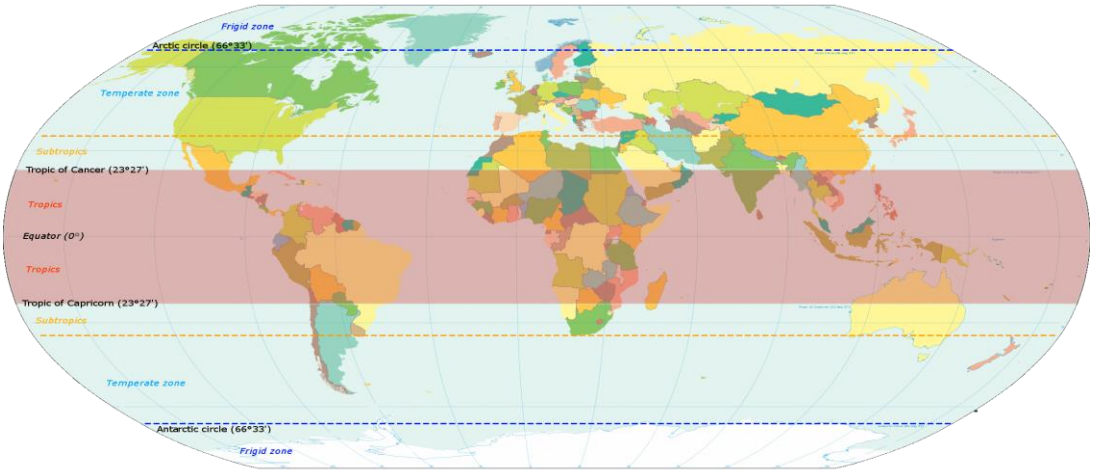

Figure 1: Tropical and Subtropical regions of the world

SOURCE: https://en.wikipedia.org

Many TST areas (as shown in Figure 1 above, Tropical and Subtropical regions of the world) have been used to breed and fatten ruminant animals for almost 200 years. Prior to human intervention much of this area was periodically grazed heavily by herding animals. Since then grazing has predominantly been very traditional, with set stocking undertaken in many native pasture environments. Today, many of these grasslands have been developed for more intensive farming purposes – however vast areas still remain more or less in their native state with little to no development. Large parts of TST regions also consist of native forest, savannah and rainforest, of which some have been cleared and developed for improved pastures and cropping land.

In the context of this report the focus is humid sub-tropical climates, which are typified by warm, wet summers and fairly mild dry winters with little or no frost. Soils range from highly weathered Oxisols to less weathered Alfisols and consist of many different types, from sandy red loams to heavy cracking clays.

Chapter 2: Extensive Cattle Grazing Systems

Snapshot of Northern Australia - 2017

The vast majority of Northern Australia consists of pastoral leases which are traditionally native grazing environments that have been slowly transitioning from 'harvesting' type operations with one annual muster to wean progeny, to more intensive levels of animal husbandry including multiple cattle handling events annually, controlled mating and in some instances more intensive rotational grazing. Many northern grazing businesses have traditionally relied on economy of scale to remain viable, battling factors such as harsh climate, infertility in their cattle herds (in relation to their suitability for the environment), operational logistics (scale), distance (and associated costs) of inputs and outputs and reliance on predominantly one market (live export to SE Asia).

Much of inland Queensland (QLD), Northern Territory (NT) and Western Australia (WA) consist of open native grassland of seasonal quality. Development, from a pasture improvement perspective, is somewhat limited in these areas due to the semi-arid nature of the climate, and is also of questionable benefit given the high nutritive value of existing native forage. There have been some large infrastructure projects in some of these areas, such as on Beetaloo Station North of Elliot, NT. The Beetaloo project has consisted of a large investment into water and fencing infrastructure on over one million hectares of native grassland in order to intensively graze (using rotational grazing principles) and provide long periods of rest; the aim is to vastly improve carrying capacity of these traditionally set stocked areas.

It will take some time to appreciate the true results of the Beetaloo project. However, there is no doubt that it is an ambitious attempt to address the generally poorer economic and environmental performance of traditional Northern beef cattle businesses. Some would argue investment of this size is both unachievable for most in terms of capital outlay and that the results are questionable. Others believe this type of development is the most efficient way to utilise native grasslands and that the benefits, in terms of return on investment and sustaining and improving land condition are obvious.

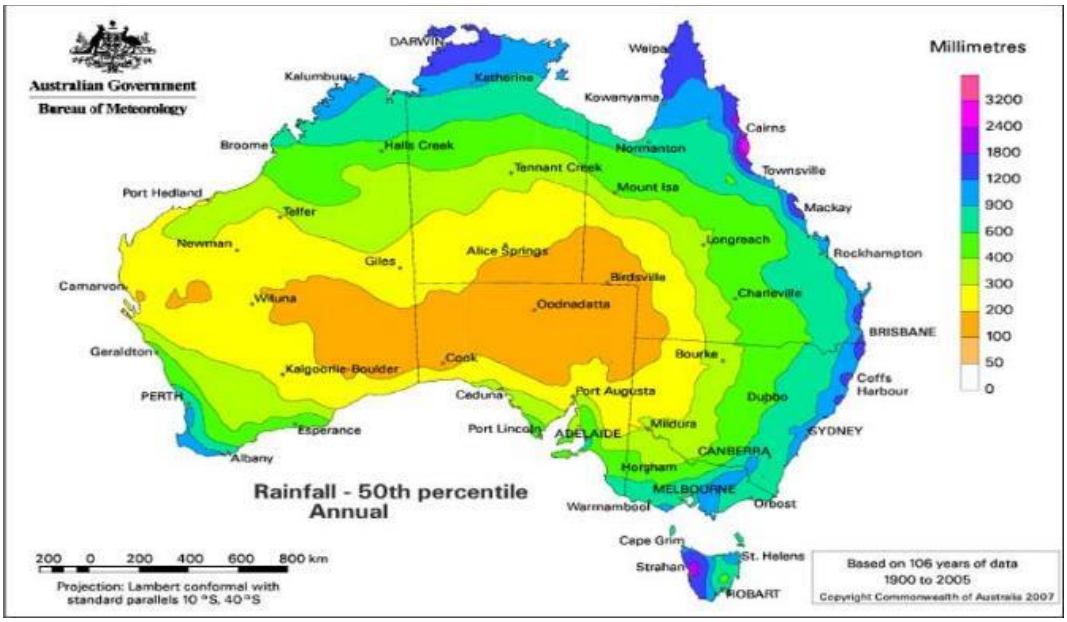

Figure 2: Rainfall - 50th percentile Annual

Source: www.bom.gov.au

Currently in Australia there is a lot of emphasis being placed on "Developing the North" across all associated industries. Land tenure has been one issue that has been debated, with some feeling that the existing structure of 99-year pastoral leases has hampered further private investment and development. Diversification permits have recently been legislated in the NT, allowing pastoral leaseholders to apply for 30-year permits to diversify their grazing activities into areas such as cropping, forestry, aquaculture, tourism et cetera. Uptake of diversification permits has been slow to-date. This may be a result of some particularly tough economic years for the cattle industry in the NT and Northern WA, and also the fact many pastoral businesses will look to intensify their grazing operations before diversifying into other income streams, thus not requiring diversification permit approval. The vast majority of Northern NT and WA are still in their native state outside the cropping and horticultural areas of Kununurra, Katherine and Darwin. Development has enabled a massive potential increase in productivity in these areas of higher rainfall. In the 700mm+ zones of the north, the predominantly savannah type of vegetation is fairly marginal in its native form for cattle production with its sandy loam, leaching soils and generally brittle grass base. Improved pastures for hay production and grazing have been proven on a comparatively small scale and have the potential to be implemented over large areas with minimal relative environmental downside given the sheer scale of the country suitable for such development.

Woody Encroachment and Thickening on Extensive Grazing Lands

Woody encroachment is a term used to describe a change in the physiognomy of vegetation – in this case, areas of open grassland that have been (in recorded human history) mostly devoid of any woody vegetation. These areas mostly consist of native perennial grasses and herbages, and have proven very valuable for producing ruminant animals. Another form of

woody encroachment is thickening where savannah type vegetation such as that found in many parts of Northern Australia has been observed to be increasing and out-competing native grasses, resulting in a decrease in grass production and a devaluation of the land in its associated use for cattle production.

Woody encroachment and thickening has been observed in many areas of the world, including parts of Australia, Africa and America for well over 50 years and yet the underlying causes are still subject to debate. Most relevant studies agree that the tree/grass relationship is affected and altered by differing levels of moisture and nutrients at any one time (Patrick Graz, 2008).

In QLD, above ground biomass has increased by 1200kg/ha/year over a 20-year observation period in QLD from 1993-2012. This is despite ongoing land development and observed 'panic clearing' in anticipation of the state's new Vegetation Management Act in 1999 (Burrows, 2015).

Southern Texas, USA has very similar country in agronomic terms to much of Western QLD and NT downs land types. These are mainly heavy dark clay based soils and have traditionally been open grasslands. Ranchers in Texas are faced with a very costly battle in which they are trying to control the spread and thickening of woody plants. In this case, Honey mesquite (Prosopis Glandulosa), Velvet mesquite (Prosopis velutina) and Huisache (Vachellia farnesiana) are the main problem species. In the United States, Prosopis species has become the dominant woody plant on 38 million hectares (ha) of semiarid grasslands (United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) plants database).

According to the Arizona-Sonora Desert Museum website (2017), *"Because dense mesquite outcompetes grass for water and light and because mesquite groves don't support fire, this conversion is permanent (on a human time scale) without physical intervention"*

Figure 3: Mechanical clearing of Mesquite, Victoria TX. Source: A. Coffey 2017

Stephen Deiss (2017) of the USDA-NRCS explained that once woody canopy density of 15% or above is reached, brush control becomes very difficult in these areas and a rapid decline in grass and forb growth is the result. Once canopy density reaches 30% an equal impact of a 30% loss of grass is observed. Above 450 plants per acre is regarded as a dense woody canopy, which significantly impacts available feed. This level of encroachment also has a negative effect on native flora and fauna due to a reduction in grassland ecosystems supporting species such as deer, quail and turkey, also important economic contributors in these areas due to their managed hunting (Deiss, USDA-NRCS 2017).

Below, in Figure 4, is some economic analysis of a three-year aerial spraying program undertaken near Victoria, Texas (TX). As can be seen there has been a significant reduction in canopy cover and increase in available feed in a more or less break-even scenario. Once the aerial spraying program has been completed additional and ongoing control can be achieved through spot spraying and prescribed burns.

	Chemical treatment ($/ac)	Canopy reduction (% cover)	Additional Fodder production (kg/dm/ac)	Additional AUM's/acre	AUM Value ($)	Economic benefit ($/ac)	GM/ac ($)	Break Even ($/ac)
Year 1	22	30	680	1.7	12	20.4	-1.6	-1.6
Year 2	17.5	40	567	1.4	12	16.8	-0.7	-2.3
Year 3	17.5	50	794	1.9	12	22.8	5.3	3

*Assumptions

1 AUM (Animal Unit Month) = 400kg dry matter (DM)

Grazing breeder has 25% utilisation of available feed

Figure 4: Economic analysis of brush control. Source: Coastal Prairies GLC Victoria, TX

There has been an important realisation by many in the coastal prairies region of southern Texas with regard to combatting woody encroachment; that is to focus on the production benefits associated with control methods, rather than the problem plant itself. Chip Merrill (Coastal Prairies GLC, [2016]) in relation to achieving ranch objectives explained "*as land managers, if we focus on dealing with problems we will continue dealing with problems. If we focus on our desired objectives and visualize what it takes to achieve that objective, then we can get it done".*

This approach is consistent with a change toward a somewhat more holistic approach now taken by many beef cattle producers around the world. These producers are recognising that grass production is not necessarily inhibited by moderate infestations of woody plants and that the desire for uniform, tidy paddocks is causing over-investment in control methods that may not ultimately improve a business's bottom line. There is a capital consideration here in terms of a negative impact on land value due to woody infestation, however if it can be proven over time that some level of canopy cover and more diversity in paddock species does not negatively impact production then potential impacts on land values may be negated.

Refocusing on production gains as a result of conventional control methods, in addition to a more holistic approach seems to be providing the best outcomes for producers in areas affected by woody thickening and encroachment on grazing lands.

Figure 5: Successful aerial chemical control of Mesquite and Huisache, Victoria TX. Source: Coastal Prairies GLC 2016

Mesquite is also an invasive species in parts of Northern Australia, as are other woody species such as such as Gidgee (Acacia cambagei), Prickly Acacia (Vachellia nilotica), and Parkinsonia, (Parkinsonia aculeate). Some species of woody plants seen as a threat to

livestock producers, such as Gidgee, are in fact native plants to Australia and thus have levels of protection from clearing. Under changes to state vegetation management laws in recent times the level of protection has increased significantly for many of these types of vegetation and has sparked heated debate about what is regarded as remnant, regrowth or encroaching vegetation.

Figures 6 and 7 (below) illustrate Gidgee encroachment over a period of 60 years on a property in the Longreach district, Western QLD. As can be seen, there has been significant spread and thickening of woody vegetation over that period. As with Mesquite, Gidgee displays a strong allelopathic effect, so inhibits growth under and around its canopy. Little to no pasture or herbage will grow in this environment, meaning associated land is rendered unproductive, which also has a detrimental effect on capital value. Much of this type of encroachment is now classed as remnant vegetation under the state Vegetation Management Act set in place in 1999. As there seems to be no set definition of what constitutes “remnant vegetation” this can be a considerable frustration for livestock graziers in these areas. From an environmental standpoint, many graziers would also argue that due to its growth- inhibiting traits, a monoculture of Gidgee has little real benefit in terms of supporting native flora and fauna.

If the issue of woody encroachment in Western QLD is compared to Mesquite thickening and encroachment in Texas there are many similarities. In many cases the continued encroachment of woody species can be put down to overgrazing of palatable grass and legume species, resulting in reduced plant competition and therefore a reduction in the amount of organic matter returned the soil, inhibiting the natural soil/water/nutrient cycle. This reduction in ground level dry matter may also reduce the intensity of periodic fires, which have historically played a role in controlling woody plants. This suggests a necessary review of grazing management on an individual basis so overgrazing of more palatable species does not facilitate encroachment.

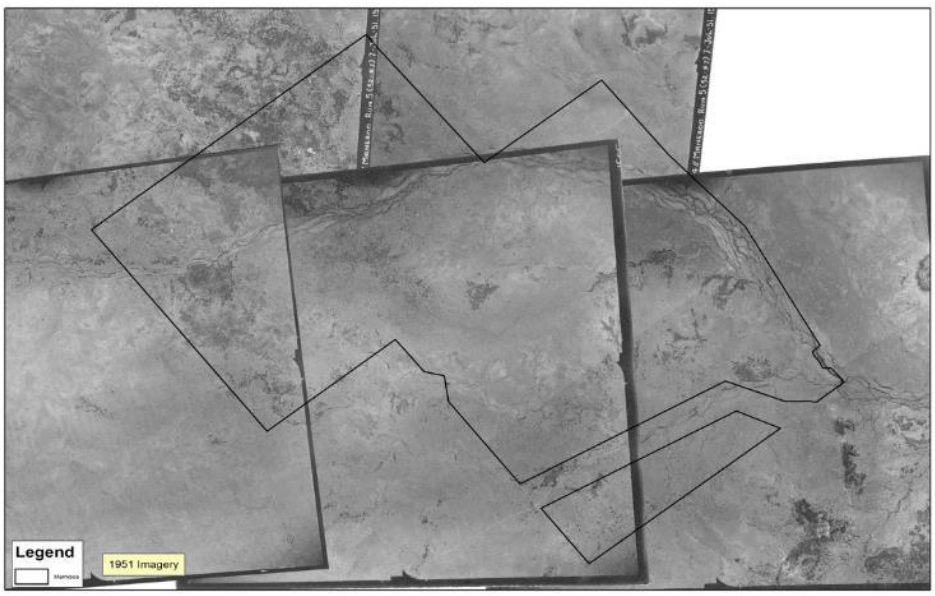

Figure 6: Longreach aerial image, 1951

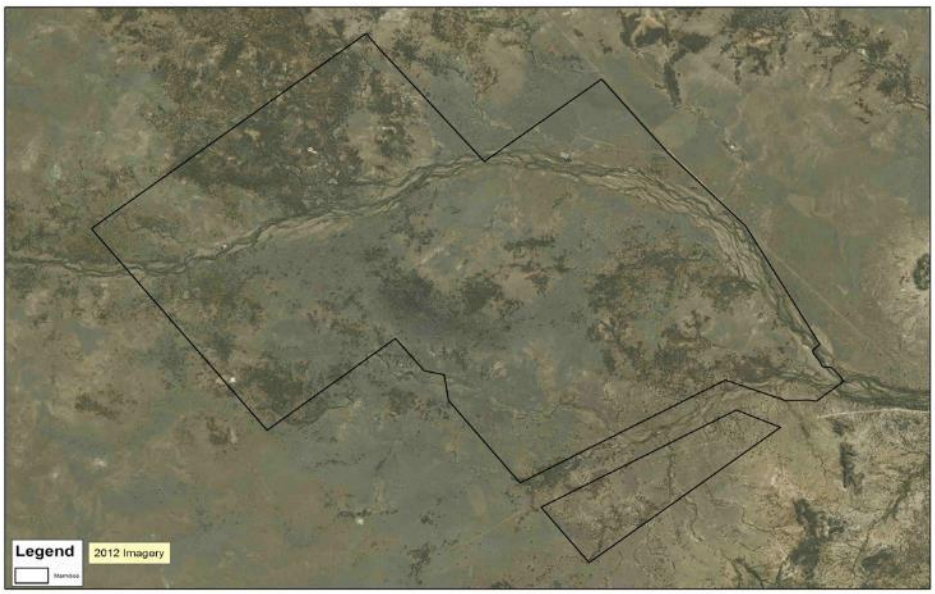

Figure 7: Longreach aerial image 2012

Moisture Availability and Utilisation

One theory about the relationship between woody plants and grass relates to the uptake of moisture and nutrients from differing soil depths, and the associated timing of these events throughout the season. Research has shown that perennial grasses have a high transpiration rate and have the ability to withdraw and utilise moisture beyond the 'wilting point' of woody plants (Frost, 1986). In healthy perennial grassland, much of the moisture can be kept and utilised in the top few inches of the soil, thus limiting availability for woody plants.

Soil water infiltration versus runoff is also a key factor in determining the health and viability of any herbaceous system. A healthy grass sward will slow water runoff with the result of much greater infiltration into the soil profile. This is a key component of minimum and no till cropping systems that aim to maintain ground cover as a way of maximising moisture yields from rainfall events. Many farmers operating broad-acre cropping operations in Texas and Oklahoma are now introducing multi-species (sometimes ten or more) pasture cover crops and livestock back into their cropping rotations as they recognise the need to maintain cover and keep a living root in the ground for as long as possible through the production season. Organic matter from cover cropping programs also encourage the infiltration and retention of water within the soil profile and help to increase microbial activity and carbon levels in the soil.

If these methods are related back to a native grazing environment there is a need to stop and in some cases reverse woody encroachment for both environmental and production gains. The exact cause(s) of woody encroachment may still be up for debate however increasing monocultures, whether a result of human intervention or not, do not seem to generate positive outcomes for native flora and fauna and the detrimental impacts to farming productivity and land values is obvious.

Grazing

As already mentioned, migrating animals have historically grazed many TST grasslands. Prior to European settlement, certainly in Australia, the main limiting factor for wild herbivores was not forage but water. Water availability determined how long a herd of animals would graze a particular area before moving on. In the event of a lower than average rainfall season, grass availability would not be as high and concurrently neither would runoff water. In turn, animals would generally have to move on earlier than normal given their water supply would not hold up, thus helping protect what available feed there was from over grazing.

Since European settlement people have developed fencing and artificial water infrastructure with the aim of breeding and fattening domesticated animals. As in any economically driven scenario the aim has been to operate viable businesses based on ruminant animal production, perhaps in many cases to the detriment of many native grasslands on which these businesses rely.

Figure 8: Cattle grazing once open grassland, Victoria TX. Source: A. Coffey 2017

Some beef cattle producers have recognised a need to re-incorporate into extensive grazing businesses many of the fundamental practises applied to herding animals before domestication. The basic functions of intensity and timing of grazing, rest periods and nutrient (manure) replacement are key in any successful grazing operation. Evidence suggests the lack of application of these early grazing principles are also contributing to woody thickening through a lack of grass competition, in particular native perennials, upon which the current TST grazing systems are based. Under persistently heavy grazing conditions, more desirable perennial plants are eaten to the point of unviability and are often replaced with less desirable annual grasses over time. Annual grasses are usually of lower palatability, are often invasive by nature, producing more seed with a longer life and require less water than perennial grasses. Root structures are generally shallower meaning

less nutrient transfer back into the soil and potentially leaving more moisture and nutrients lower in the soil profile for woody plants. Research has proven that perennial grass that is grazed short will also stunt root growth which has many flow-on effects such as a reduction in organic matter and carbon, moisture utilisation, and microbial activity promoting beneficial soil organisms. Bare soil is usually another consequence of overgrazing, increasing water runoff and limiting infiltration whilst encouraging competing plants to succeed including non-herbaceous woody seedlings.

One study conducted in the northern prairies of Texas USA compared set stocking and rotational grazing management techniques and their associated effects on vegetation, soil biota and chemical, physical and hydrological properties. It concluded, amongst other outcomes, that multi-paddock (rotational) grazing with appropriate plant rest regimes (40-80 days) had high seral (perennial) grass species, less bare ground and lower penetration resistance. Although water infiltration did not differ between the groups, sediment loss (erosion) was higher in set stocked, heavily grazed paddocks whilst rotational grazing resulted in higher organic matter, cation exchange, fungal/bacterial ratio and associated water holding capacity, nutrient availability and retention (Teague et al, 2011).

Fire

Fire has long been an integral part of TST grassland systems. Natural fires have occurred throughout history and in more recent times have been used by humans for purposes such as hunting, grass and woody vegetation control and regeneration, land development and hazard reduction.

In Northern Australia, there are essentially two types of fires, cooler early dry season burns and hotter late dry season fires. This is reflected worldwide in sub-tropical regions. In the context of grazing, early dry season burns are used to reduce dry, senesced grass and promote fresh green growth on residual moisture from the previous growing season.

Studies suggest that frequent early dry season burning can have a negative effect on perennial grass survival, as energy reserves within the plant normally used to initiate growth at the start of the next growing season can be exhausted prematurely (Cuomo, Anderson and Young, 1998).

Early dry season burning can also produce bare ground with similar results to overgrazing, as mentioned above. In the instance of traditional set stocking, as is still the norm in Northern Australia, burnt areas can be preferentially grazed for years to come, again resulting in overgrazing and ultimately the removal of desirable perennial grasses from the system. Flowering of most woody plants in Northern Australia occurs in the dry season, and seed set from these plants may increase given the favourable competition factors created by early dry season burning.

Late dry season burning is often lit naturally by early lightning storms, or undertaken in a bid to control woody vegetation. At this time woody plants retain a level of moisture, as opposed to dry grass, and therefore have much greater thermal conductivity — meaning hotter temperatures in woody material, increasing mortality (Frost and Robertson, 1987). Woody plants also tend to utilise existing energy reserves to shoot new growth at this time in anticipation of the coming growing season, again leaving them more susceptible to fire (Frost et al, 1987). Late dry season fires have always been regarded as a good tool for eliminating woody seedlings however there is no research to suggest that seed survival is affected adversely by fire. In fact some mature Eucalypt and Acacia species of Northern Australia respond to hot fire by seeding in large numbers.

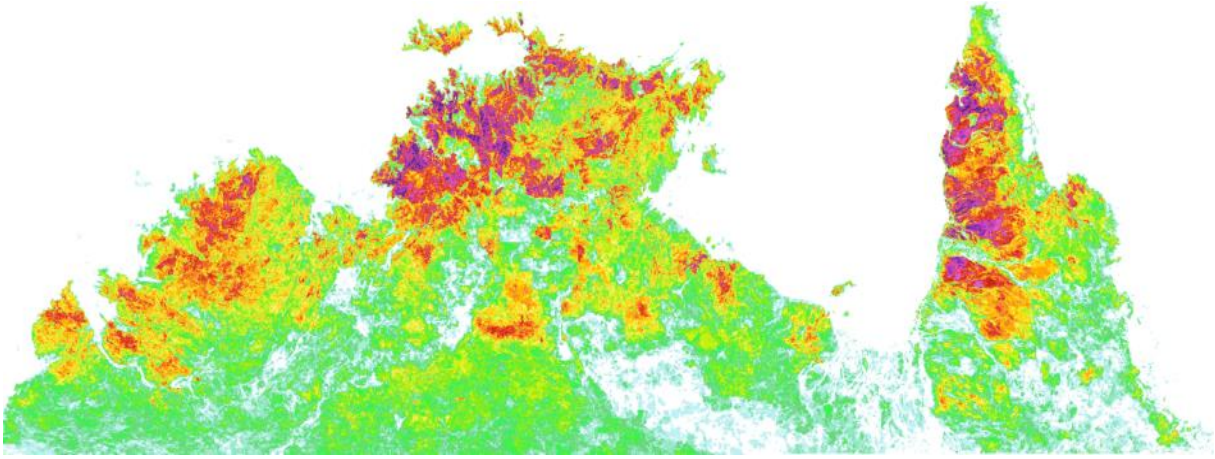

Figure 9: Years burnt 2000-2016

Source: firenorth.org.au

Figure 9 displays the frequency of burning over a period of 16 years in Northern Australia obtained using satellite monitoring. The orange and red zones show areas that have been burnt a minimum of ten years over the period, through to the purple areas that have been burnt annually. Much of the more frequent burning is a result of government fire hazard reduction through early dry season burns. The environmental effect of repetitive annual burning needs to be further examined in relation to known effects on soil health and the resulting tree/grass balance.

Figure 10: Trialling burning regimes on Mesquite, Victoria TX. Source: A. Coffey 2017

Whilst the best timing of fire to achieve certain objectives throughout the season seems to still be open for debate, more is being understood about the effect of different burning regimes, particularly regarding their frequency. In contrast to the heavy, high clay content soils of traditionally open grasslands, savannahs are predominantly light, sandy soils with comparatively little in the way of nutrient and moisture holding capabilities. Soil has a low thermal conductivity with the top two centimetres of soil rarely exceeding 35ºC during a normal savannah fire, with the exception underneath dense material such as burning logs. Therefore, temperatures do not climb high enough to cause any direct changes (Frost et al, 1986). However, soil bulk density can be affected drastically by frequent (annual) burning due to removal of the herbaceous layer, associated plant matter, mineralisation and reduced beneficial microbial activity. According to research (Frost et al, 1986), African savannah fires consume around 70-90% of the herbaceous layer (groundcover). Frequent burning can also affect moisture infiltration and the soil's ability to hold moisture. Burning creates bare soil, increasing evaporation, surface crusting, runoff and risk of erosion. With a lack of structure, soil particles can become detached during rainfall events, repelling water even on sandy soils (Frost et al). Burning can affect soil biota, with a reduction in seed carrying ants and beneficial insects recorded in annually burnt trial lots, reducing organic matter returned to the soil (Cardoso et al, 2008).

Undesirable Pasture Grass Species

Undesirable pasture species, or weeds as many people refer to them, are continuing to have a negative impact on the productivity and profitability of beef producers worldwide. There are two types of undesirable grass species:

- Invasive, unpalatable grasses that have been introduced and are foreign to the specific environment for example; Rats Tail (GRT) grasses (*Sporobolous*), Grader Grass (*Themeda Quadrivalvis*).
- Undesirable native grasses. This is specific to individual growing environments as a particular native species may be sought after in one region but regarded as less desirable in others due to factors such as low palatability, nutritive value et cetera, for example, Black Spear (*Heteropogon contortus*).

Determining which species will grow where obviously comes down to agronomic and climatic factors in a native sense. Proper grazing management taking into account stocking rate, rest periods, timing of graze are excellent tools to ensure that desired pasture species persist.

High Production C4 Grasses

In order to maximise production from extensive land assets there is a need to ensure the quickest weight gains possible in the most efficient manner. Intensification in the form of pasture improvement and/or feed supplementation is a very common theme throughout the developed farming world. Like any inventory-based business, the need for a high rate of turnover and turnoff (kg/unit, kg/ha et cetera) is a key performance indicator and will be measured in any progressive grazing business. North and South American graziers are, in general, prepared to spend money on extra inputs to increase performance, whether that is for pastures, feed or infrastructure, rather than rely on their existing capital base. This may be due to a few different factors:

- High capital cost of land means it is more viable to develop existing land than to purchase additional land;
- Inputs such as feed, fertiliser, fuel, and seed are comparatively cheaper than in Australia;
- Labour costs are lower. In Brazil, for instance, labour costs are around 1/3 the cost per labour unit compared to Australia;
- Often lower rates of farm business debt allowing extra cash to be used for developments rather than finance; and
- Higher levels of government subsidies and support via direct and non-direct avenues.

Figure 11: Nelore weaner heifers grazing Brachiaria Brizantha. Mato Grosso, Brazil. Source: A. Coffey 2017

In Brazil, the main form of production improvement comes from high vigour, hybridised pasture species, many of which have been developed by the national government agricultural R&D department, Embrapa (www.embrapa.br). Grazing and cropping land has been extensively developed from virgin forest and savannah country over the last 30-40 years. As there are now tight restrictions on clearing, land has become relatively expensive. Good grazing land in Mato Grosso can sell, comfortably, for $5,000-$6,000 AUD per hectare.

One operation near Cuiabá in Mato Grosso, Brazil has incorporated high dry matter producing Brachiaria hybrid grass species and a feedlot into their 700-ha bull beef producing operation (Figure 12). Through strategic use of their feedlot during the dry (winter) season they have tripled their cattle numbers from a conservative grazing operation to turn off approximately 3,500 head of slaughter (500kg+) bulls on an annual basis. The feedlot is utilised to grain finish cattle, however one of the most important aspects is the ability to return large volumes of feedlot manure to high performing hybrid pastures capable of producing 28T/DM/Ha/annum which are mob grazed and rested accordingly (DeVitto, Jan 2017). The owners have noted an exponential increase in their carrying capacity, which they attribute to increased levels of soil nutrients and moisture retention as a result of hybrid pastures, reincorporating feedlot manure and improved grazing management.

Figure 12: Brachiaria hybrid pasture, Cuiaba Brazil. Source: A. Coffey 2017

Figure 13 (below) compares three different native Australian grass species with three introduced species, all of which are, or have been, available in Australia. Gamba grass is now a declared weed in Northern parts of Australia due its aggressive nature when competing with existing grasses. Due to its ability to produce high levels of dry matter it also represents a significant fire risk. Brachiaria and Green Panic are fairly common grasses in Australia, particularly in coastal areas of QLD and Northern New South Wales with relatively high annual average rainfalls (1000mm+) and medium to fertile soils. Most Brachiaria in Australia is B. Decumbens, with different cultivars such as B. Brizantha, or the relatively new hybridised Mulato 2 (B. Brizantha x B. Decumbens x B. Ruziziensis) showing improved DM and crude protein (CP) traits. These high production tropical grasses are well adapted to high rainfall climates, however will tolerate much lower rainfall with an associated reduction in productivity. When factors such as CP, DM and digestibility are taken into account it is easy to see how introduced grasses will vastly outperform native Australian grasses, converting into significant improvements in live weight gain and animal performance.

Vigorous C4 grasses also have the ability to continue tillering and producing green leaf much longer in the non-growing season, providing higher protein levels than native grasses and extending the growing season to convert into higher annual animal weight gain. Once established, grasses such as Brachiaria are known to be a good increaser species. Brachiaria has been shown to out-compete less digestible native grasses such as Black Spear/Kangaroo and under good grazing management will perform similarly against invasive species such as GRT.

As per Figure 13, the average increase in potential dry matter production of improved species over native grasses is over four times. Even adjusted for a lower average rainfall and

growing season, production gains would be significant. CP is almost double that of the native grasses. Soil type suitability would be specific to individual areas, however all of the improved species below have been grown successfully across much of Northern Australia.

Common Name	Scientific Name	DM Production T/ha/yr	Crude Protein % (growing season)	Annual Rainfall mm	Soil Fertility Required
Native					
Black Spear	*Themeda quadrivalvis*	6	5 (4-6)	600-1000	Low
Kangaroo Grass	*Themeda triandra*	5	6 (2.8-12.4)	500-2000	Low
QLD Bluegrass	*Dicantheum ceriseum*	5	8 (6-10)	500-700	Med-High
Introduced					
Brachiaria Hybrid	*Brizantha x Ruziziensis*	28	14 (12-16)	1000-3500	Med-High
Gamba	*Andropogon gayanus*	25	10 (7-18)	400-3000	Low-Med
Green Panic, Guinea	*Panicum maximum*	25	15 (6-25)	800-3000	Med

Figure 13: Comparison of native and improved C4 species

Source: www.tropicalforages.com

Although there does not appear to be any data available regarding the percentage of native versus improved pastures in Northern Australia, there is no doubt substantial room in arable country for further development of existing pastures to greatly boost production within the Northern beef sector. Most high vigour C4 grasses will grow in the higher percentile rainfall areas of Northern Australia, the only real limiting factor would be relating to species such as Brachiaria, which require higher soil fertility. Although Gamba grass is a declared weed in the NT and QLD, its ability to spread outside of intended areas is questionable in all but the highest rainfall (1000mm+) areas where it already exists. Gamba grass was introduced widely in Northern Australia as a pasture species and still persists around Darwin and parts of Cape York, where it is regarded as excellent quality cattle feed due to its vigorous growth, good nutritive value and ability to perform in low fertility soils.

Figure 14: Inspecting pasture trial plots at research facility, Ona Florida University Institute of Food and Agricultural Sciences. Source: A. Coffey 2017

Perennial Pasture Dieback

Monocultures have become a huge part of pasture production systems globally. Once a particular grass species is proven to perform within a certain agronomic and climatic area it is inevitable it will be sown and produced on a large scale for ruminant production. Examples of this are *Brachiaria* (mostly *Brizantha)* in mid to high rainfall regions of Brazil, Bermuda grass (*Cynodon dactylon*) in Florida and Buffel grass (*Cenchrus ciliaris*) in central western areas of QLD and the NT. Symptoms of dieback have been reported in all of the above species over the last 30 years with incidences on the rise recently. To-date, the causes of spontaneous pasture dieback seem to be unknown however reports of anywhere from 5% to 100% of paddocks in central QLD have been affected. Some properties have reported losses of two thirds of their pasture at any one time. Once the affected pasture dies it is usually colonised by broadleaf pioneer type plants.

Fungal diseases have been reported in many paddocks affected. However, to-date there has not been a direct correlation found between fungus and pasture dieback. Sandrine Makiela (Central Queensland University, 2008) concluded in her thesis; "*It is likely that Buffel grass dieback is caused by a disease complex, with potential pathogens including soil-borne fungi and/or viruses*".

Regardless of the cause of perennial pasture dieback, it is clear producers are left open to the risk of particular diseases affecting certain species or cultivars if they are relying on a pasture monoculture for production. Even with the addition of legumes, as is common amongst improved and native pastures, relying on one or even two species of grass presents a risk. If perennial dieback is caused by a fungal outbreak or disease or pathogen, being soil borne, it may also simply be a function of a soils finite ability to support ongoing growth without adequate inputs. This may go beyond conventional thinking around macro and microelements, and there is a requirement for further research into biological and ecological factors in scenarios of pasture dieback. This is a logical conclusion given that the cause of dieback has not yet been ascertained despite considerable research on the issue.

Figure 15: Brachiaria dieback, Brazil

Source: www.embrapa.br

Building Better Biodiversity into Extensive Grazing Systems

On the back of a recent and fairly sustained upturn in Australia's cattle market there will no doubt be renewed spending on capital development on-farm and also investment into the production systems supporting these businesses. When investigating issues that are not fully understood, such as woody encroachment and pasture dieback, perhaps there is an element of nature's way of trying to restore some balance to what, in many cases, are either artificially created monocultures, or native environments that have been mined of their nutrients with insufficient or the wrong inputs returned for too many consecutive years.

Extensive grazing lands, in their natural state, contain great diversity of flora and fauna, which need to be replicated better in our production systems. At the very least, producers need to use practices that support current levels of biodiversity, or even better, increase them. Some operators in more intensive industries, such as the broad-acre cropping sector, have recognised this and implemented strategies such as the re-introduction of livestock into their systems to utilise cover crops. In a bid to imitate nature some cover crop seed mixes contain more than twenty different species. The cover crops themselves are providing plant diversity, which in turn supports a whole host of beneficial insects. These natural predators are then reducing and even eliminating the need for many conventional pest control processes, saving time and money. Re-introducing livestock provides paddocks with nutrient return to increase soil health and adds another enterprise to a farm's portfolio, boosting income, cash flow and spreading risk. Boosting on-farm biodiversity should be seen

as a profitable exercise, and there are many producers across various commodities who would attest to that.

Many beef producers are implementing technology to help improve their grazing management and combat rising labour and input costs such as remote monitoring, unmanned aerial vehicles and increased adoption of semi-permanent fencing systems. Innovations such as a pneumatic gate release mechanism as per Figure 16 in Hungerford, TX allows mobs to be moved, in this instance, up to eight times a day. Timers were set in the morning and spring gates released automatically to let the mob into a new cell without any additional labour input. This sort of grazing system is obviously vastly different from most extensive beef operations, however producers need to be aware of new technology and management techniques currently being utilised in intensive operations, as a natural progression will be for these to roll out into extensively managed environments in years to come.

Figure 16: Pneumatic timed gate release mechanism, Hungerford TX. Source A. Coffey 2017

Some strategies to increase biodiversity in extensive grazing businesses are:

- Assessing current grazing practices and how they may or may not be impacting paddock plant diversity. Traditional set stocking can promote overgrazing and repetitive selection of more palatable, desirable grasses leading to their extinction within a grazing system.

- The introduction of varying plants and grasses through re-seeding. These may or may not be native to a particular area. An example of this may be to introduce high production C4 grasses supported by nitrogen fixing legumes with the aim of building soil organic matter and boosting soil health.
- Examine current chemical application program (if any) and evaluate any potential negative effects on biodiversity. Consider timing of application of drenches, herbicides, insecticides and fungicides, and alternative products available.
- Mechanical and/or chemical intervention to address issues such as woody plant establishment, erosion and bare soil; for example, ripping clay pans and creating diversion banks in gully erosion.

Conclusion

On an international scale, there is, generally speaking, a more intensive nature of farming as a whole compared to Australia. As land is not commonly (in a global context) a limiting factor for agriculture in Australia, operations tend to be spread over a larger area and in most situations are instead, limited by economic constraints. More land does not necessarily mean more productivity and in many cases, particularly in northern beef production, it hampers improvements in production efficiencies.

Agricultural commodity prices in Australia have historically fluctuated, greatly at times, and agricultural industries have not benefited from government support in terms of subsidies, insurance and other financial incentives to the extent that has been seen on an international scale. The northern beef sector is no different in this regard and perhaps this is the main factor in shaping many extensive beef businesses to be more likely to operate under low-cost structures than high input/high output. The other main factor here is the relative availability of additional land to grow a business, as opposed to intensifying the existing capital base.

Bearing this in mind, extensive beef producers need to weigh up whether to focus on relatively smaller areas and intensify their inputs and hopefully production and profitability, or continue to operate lower-cost structures over larger areas. Perhaps many of the issues discussed in this report can be attributed to the general 'harvesting' nature of extensive beef cattle operations and their corresponding lack of a physical or financial ability to invest in inputs ensuring maintenance and growth of fertility and diversity in the system.

Intensification and development of extensive beef operations comes in many forms. On one hand, it could consist of sowing improved pastures, investing in additional fencing, water, irrigation infrastructure and new technology and tools. On the other hand, it may mean addressing environmental constraints such as woody encroachment and thickening, perennial pasture dieback and thinking about methods to increase plant biodiversity, change grazing management and alter or experiment with different burning regimes. As in any extensive operation the multiplier effect of operating on a large scale can mean management and practice changes can have a huge effect on viability in a relatively short period of time. Conversely; issues such as encroachment, dieback and the increase in undesirable plant species can manifest over a long period, during which time land holders can view the changes as having always been present or too large an issue to tackle, ultimately running the risk of rendering their businesses unprofitable.

It can be concluded that a combination of conventional and biological tools and methods currently available will continue to be developed and used by progressive beef cattle producers. This blend of new technology and ideas, being incorporated with a better understanding of the environment we operate in, and hopefully a more reflective attitude to

our historical influence on the land should lead to a more profitable and sustainable beef industry in years to come.

Fast-forward 50-100 years and ever-present factors such as population growth (demand for food, and urban sprawl) and resource depletion will play a huge role in global agriculture, and Australia is no different.

When Australian agriculture is viewed in a global setting, there is potential for a distinct competitive advantage as a country to capitalise on its existing assets. In many more intensively farmed areas there is an interesting shift, perhaps not away from conventional farming altogether but a shift towards re-incorporating biological and ecological practices into existing technologies. There is general recognition that whilst there has been a reliance on significant advances in technology in relation to mechanical and chemical intervention in recent decades, the effectiveness of some of these tools is now starting to fade and producers need to think about alternatives to continue to improve farming efficiencies. Livestock and cropping producers who are starting to experiment more and trying to understand better the biological and ecological attributes of their land assets are realising that there is a great deal that is not yet understood.

Cattle producers in extensive environments are responsible for large tracts of land in Australia and across the world, and therefore will be held accountable for how they choose to continue to increase the productivity of their assets in the most sustainable manner possible. More importantly for these producers is to continually recognise the need to better understand the natural resource their business is based upon and strive to find ways to innovate in order to continue as profitable, healthy businesses well into the future.

Recommendations

- Consider intensification of grazing operations over expansion. Undertake financial analysis of different scenarios in relation to pasture improvement, fence and water infrastructure to boost production and build pasture rest into grazing systems.

- Consider change management in relation to current grazing practices in conjunction with mechanical and/or chemical intervention. Focus on increases in grass production rather than decreasing woody/weed burden. Historical grazing practices have contributed to woody encroachment, thickening and increase in undesirable plants.

- Develop an increased focus and awareness of extensive grazing soils in relation to nutrient levels, organic matter, carbon levels and moisture holding capabilities. Consider management practices that may harm or have the scope to improve soil health.

- Support and build increased levels of biodiversity in extensive grazing systems. Whilst monocultures are often perceived to be desirable from a production and practicality standpoint they are proving to be unsustainable, have a negative effect on biodiversity and are susceptible to issues such as dieback.

- Continued research into the cause and effect of perennial pasture dieback, with conventional and biological treatments needs to be further investigated.

- Review timing and frequency of burning regimes in relation to desired outcomes. More research needs to be undertaken to determine the effect of regular out of season burning over large parts of Northern Australia and what influence this may be having on soil health, biodiversity and tree/grass balance. The environmental effect of repetitive annual burning needs to be further examined in relation to known effects on soil health and the resulting tree/grass balance.

References

Author unknown, unpublished. *Mesquite Tree*. https://www.desertusa.com
New Brush Control Philosophy. Coastal Prairies GLC Victoria, Texas 2017. Unpublished paper.

Burrows, B. (Dec 2015) *Vegetation Management in Queensland - Some essential facts for politicians, rural industry and all Queenslanders,* www.beefcentral.com.au

Cardoso, W. Medina-Vega, J. A. Malhi, Y, S. Adu-Bredu, K.D. Ametsitsi, G. Djagbletey, F.V. Langevelde, E. Veenendaal, I. Oliveras. (2016), *Winners and losers: tropical forest tree seedling survival across a West African forest–savanna transition*
https://www.ncbi.nlm.nih.gov

Cuomo, G. J. Anderson B. and Young L. J. (Jan 1998) *Harvest frequency and burning effects on vigour of native grasses* Journal of Range Management 51

DeVitto, G. (January 2017) personal communication. Ox Pecuaria, Rondonopolis, Mato Grosso, Brazil.

Deiss, S. (February 2017) personal communication. Rangeland Management Specialist USDA-NRCS

Frost, P.G.H, Robertson, F. (1987) *The ecological effects of fire in savannahs*
www.researchgate.net

Galli, P.J. (January 2017) personal communication. Cuiaba, Mato Grosso, Brazil.

Graz, F. P. (2008), Science and Engineering. *The woody weed encroachment puzzle: gathering pieces,* University of Ballarat VIC 3353, Aus.

Haile, N. February 2017) personal communication. Wichita Falls, Texas, USA.

Locke, J. (February 2017) personal communication. Hungerford, Texas, USA.

Mayo, D., June 2012 *UF/IFAS Extension Surveying Bermuda and Bahia Pasture Decline*
http://walton.ifas.ufl.edu

Makiela, S. (2008) *Studies on dieback of buffel grass (Cenchrus ciliaris) in central Queensland*

Meat & Livestock Australia “Fast Facts 2016”
https://www.mla.com.au/globalassets/mla-corporate/prices--markets/documents/trends--analysis/fast-facts--maps/mla_beef-fast-facts-2016.pdf

Rangeland years burnt 00-16 North Australian Fire Information website
www.firenorth.org.au

Teague W.R. Dowhower S.L. Baker S.A. Haile N. DeLaune P.B. Conover D.M. (May 2011) *Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological properties in tall grass prairie*

USDA NRCS Plants Database. https://plants.usda.gov/java/

Plain English Compendium Summary

Project Title:	Extensive Tropical and Sub-Tropical Beef Cattle Operations
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Objectives	• Examine problems arising from historical management – how have traditional practices affected soils & vegetation in extensive rangeland environments? • Research barriers to increasing production in relation to the land asset and tackling these issues. • Investigate intensification of operations in extensive environments as opposed to increasing land area to provide economies of scale.
Background	Tropical and sub-tropical grazing environments (used for beef production) around the world have great potential for better land utilisation with more strategic management. The purpose of this scholarship has been to investigate options to increase production, which has included gaining an understanding of the impact historical grazing has had. This report researches and compares these issues on an international scale and evaluates different change management and control techniques used in different locations that share common climatic and agronomic attributes.
Research	Extensive Tropical and Sub-Tropical beef cattle operations. Research was conducted in Brazil, Uruguay, North America and Australia using a combination of interviews, farm visits, conferences and personal study.
Outcomes	In addressing issues affecting the viability of extensive beef production globally, several recommendations are made: • Investigate intensification of existing capital assets over expansion • Change management approach to focus on economic benefit of varying woody plant treatment regimes, pasture dieback and undesirable plant populations. • Investigate management and inputs in order to better promote soil health and biodiversity in native pasture environments.
Implications	Highlighting the need for extensive beef cattle producers to investigate intensification options to boost productivity and profitability within their businesses whilst tackling problems arising from traditional grazing practices such as woody thickening/encroachment, invasive undesirable plants, poor soil health and a lack of biodiversity.