The effect of climate change on pastoralism in the Australian arid and semi-arid rangelands

Understanding the impacts and risk management strategies for rangeland pastoralists

A report for:

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Executive Summary

The arid and semi-arid rangelands of Australia is one of the world's most volatile climates. This report identifies the environmental and socio-political impacts of climate change on pastoral enterprises in the Australian rangelands and looks at ways to increase the resilience of these systems. Pastoralists are skilled in dealing with devastating droughts quenched by flooding waters and this skill will position them well for a future where droughts and flooding occur with increasing frequency. Climate modelling developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) has indicated a high likelihood that temperatures will increase, and duration in drought will also increase. Pastoralists need to recognise this risk and make plans to increase the resilience of their businesses.

The environmental effects of climate change are only one aspect of a multifaceted issue facing the red meat industry. The socio-political effects may have a greater impact in some areas then environmental changes. Policies focusing only on the efficiency of a system to produce a kilogram of protein would deprive society of a sustainable food source that works synergistically within its environment. Industry research into the greenhouse gas (GHG) emissions of extensive rangeland production systems needs to be undertaken. Increasing consumer understanding and promoting the positive impact livestock can have on ecosystems is vital to maintain social license.

This report highlights how producers in harsh climates across the world are working to ensure they have a system that works in harmony with their environment and capitalises on the benefits they bring to industry.

Case studies in this report demonstrate that agriculture and conservation can have a synergistic relationship ensuring both production and environmental goals are met. These producers have capitalised on the unique opportunities their environment presents by utilising climate adapted species, recognising the ecological importance of biodiversity and continual business innovation. As part of the research, the author observed how:

- A market was created for Bison in Northern Canada, an area with a very harsh climate;
- Grazing cattle amongst elephants on a nature reserve in Kenya allows greater economic stability through tourism and livestock; and

- Producing lamb under a predator friendly certification scheme in South Africa created a value-added product.

Recognition for the ecological services that Australian pastoralists provide needs to be advocated for at industry level. Ecosystem services and carbon farming present a unique opportunity as a relatively weather-independent income for landholders. Pastoralists that live and care for rangelands worldwide are poised to capitalise on the opportunities that arise from a more ecologically engaged society.

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Foreword

Growing up on the edge of the Simpson Desert in far northern South Australia I am used to the prospect of drought. We live in one of the driest places in Australia, renowned for its boom and bust cycles, homestead ruins and graves from pioneers that arrived in a good season and couldn't leave in a drought are scattered across our properties.

My family has been successfully farming here for over 50 years, but climate change poses a new threat to this way of life, not just because of the risk of this area getting even drier but also our social license to run cattle and sheep. Ruminant production systems are under increasing public pressure to be more sustainable and efficient with beef now being viewed by many as not part of a sustainable diet. I spent 12 months working as a veterinarian in London before moving back to the family station and I witnessed the huge surge in vegan restaurants and beef losing its 'cool' factor. I wanted to share a different story of beef production than the one shown through social media, depicting a system that looks solely at inputs versus outputs and data largely based on feedlots. I wanted to understand the role that ruminants play in climate change and how we can ensure that our production systems are decreasing their emissions.

I believe the attributes that make each production system unique are where the advantages are, and I wanted to explore this further. Due to a low population in the arid and semi-arid rangelands, there is little focussed research and with my Nuffield Scholarship I wanted to bring more focus to this area and highlight the importance of red meat and environmental services.

My study took me to producers in rugged lands in Canada, Kenya and South Africa to see how they cope with their climatic stressors. My husband joined me in Kenya, and we stayed at a cattle ranch that was also a conservation park with 71 lions among other wildlife roaming amongst the cattle that are herded each night. Staying in a bungalow we woke to the sounds of lions roaring and it was a beautiful reminder that ruminants are a unique food source that can flourish within a natural ecosystem.

Acknowledgments

Thank you to Nuffield Australia and Westpac Agribusiness for giving me this opportunity not only for the scholarship this year but to be part of such an inspiring group of people. I have created lifelong friends and mentors all over the world through this experience and that I will be forever grateful for.

To the many people that opened their doors and schedules for me, it is very much appreciated. A big thank you to Justin Du Toit from South Africa, Tara and Bryn Llewelyn from Kenya, and Christoph and Erica Weder from Canada for not only allowing us to stay but also organising so many other amazing visits with people I would never have been able to find.

Thank you to my fellow 2019 scholars that joined me on my Global Focus Program, the lively conversation after each meeting was always thought-provoking and has helped to shape my view of global agriculture.

To my amazing husband, thank you for all your support and kindness. I left for six weeks only five days after our wedding and you didn't mind that our honeymoon was spent looking at cattle and measuring plant biodiversity.

Finally, thank you to my parents for looking after everything so perfectly at home especially during a tough drought.

Abbreviations

BOM:	Bureau of Meteorology
CH4:	Methane
CO2:	Carbon dioxide
CAP:	Common Agricultural Policy
CSA:	Community supported agriculture
CSIRO:	Commonwealth Scientific and Industrial Research Organisation
ETS:	Emissions Trading Scheme
EU:	European Union
FAO:	Food and Agriculture Organisation
GHG:	Greenhouse gas
GWP:	Global warming potential
IPCC:	International Panel on Climate Change
N2O:	Nitrous oxide
PES:	Payments for Ecosystem Services
RCP:	Representative Concentration Pathways

Objectives

Scholarship objectives were to:

- Understand the role of livestock in climate change.
- Understand the future impacts of climate change on the arid and semi-arid rangelands.
- Research how other producers have decreased climate risk on marginal lands.
- Identify opportunities from climate change for the arid and semi-arid regions.

Introduction

The semi- arid and arid rangelands cover 75% of Australia and sheep and cattle pastoral enterprises are the primary use across the rangelands (Fargher, Howard, Burnside, & Andrew, 2003). This report identifies the environmental and socio-political impacts of climate change on the rangelands and looks at ways to ensure the ongoing profitability of pastoral enterprises. Global greenhouse gas (GHG) emissions are continuing to rise and have already caused a global warming of 1.0°C and on the current trajectory will reach 1.5°C by 2030 (IPCC, 2014). With this comes an increased frequency of drought and further increases in temperatures. Mid latitude areas such as the Australian rangelands may see temperature increases of 3°C (IPCC, 2014). Whilst environmental conditions are getting more adverse, protein demand is growing. In addition, the global population is set to reach 9.5 billion by 2050 and will see protein demand double (Wik, Pingali, & Brocai, 2008).

The environmental effects of climate change are only one aspect of a multifaceted issue facing the red meat industry in Australia. The socio-economic effects may have a greater impact in some areas then the environmental changes. Early publications stated that the livestock industry contributed 18% of global GHG emissions, more then all transport emissions (Steinfeld, Gerber, Wassenaar, Castel, & De Haan, 2006), however, this amount was later rebuked and acknowledged to be inaccurate by the Food and Agriculture Organisation (FAO) and found to be much lower with a direct emissions accounting for around 3% of global emissions (Pitesky, Stackhouse, & Mitloehner, 2009). The negative impacts on the image of red meat has already occurred and threatens the social license of the industry.

Agriculture can also be part of the solution to mitigating climate change and carbon farming presents a new market opportunity for primary producers (Macintosh & Waugh, 2012). The report demonstrates that primary producers across the world are working to decrease their vulnerability to climate extremes and ensure they have a secure market for their product. The ability of Australian pastoralists to recognise and respond to climate and societal changes will be paramount in ensuring the sustainability of pastoral enterprises.

Chapter 1: What is Climate Change?

Earth's climate has changed dramatically over the millennia moving from the ice age in the glacial periods to a warmer, tropical environment in the interglacial periods. Changes in temperature are quantified by looking at ice cores that trap atmospheric GHG particles at different times over the last 800,000 years. Since the year 1750 GHG concentrations have been increasing at a rapid rate due to land use changes and burning of fossil fuels (IPCC, 2014). Rising of the three predominant GHG's- carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) are responsible for 80% of the heating in the Earth's atmosphere. The current concentrations of these gases are higher than they have been in the last 800,000 years (IPCC, 2014). There are natural carbon sinks, which is how the Earth regulates its levels normally, as depicted in Figure 1, the ocean, soil and trees are natural carbon sinks that take CO2 out of the atmosphere. The current rate at which GHG are being released into the atmosphere is greater than the sequestration ability of the natural cycle.

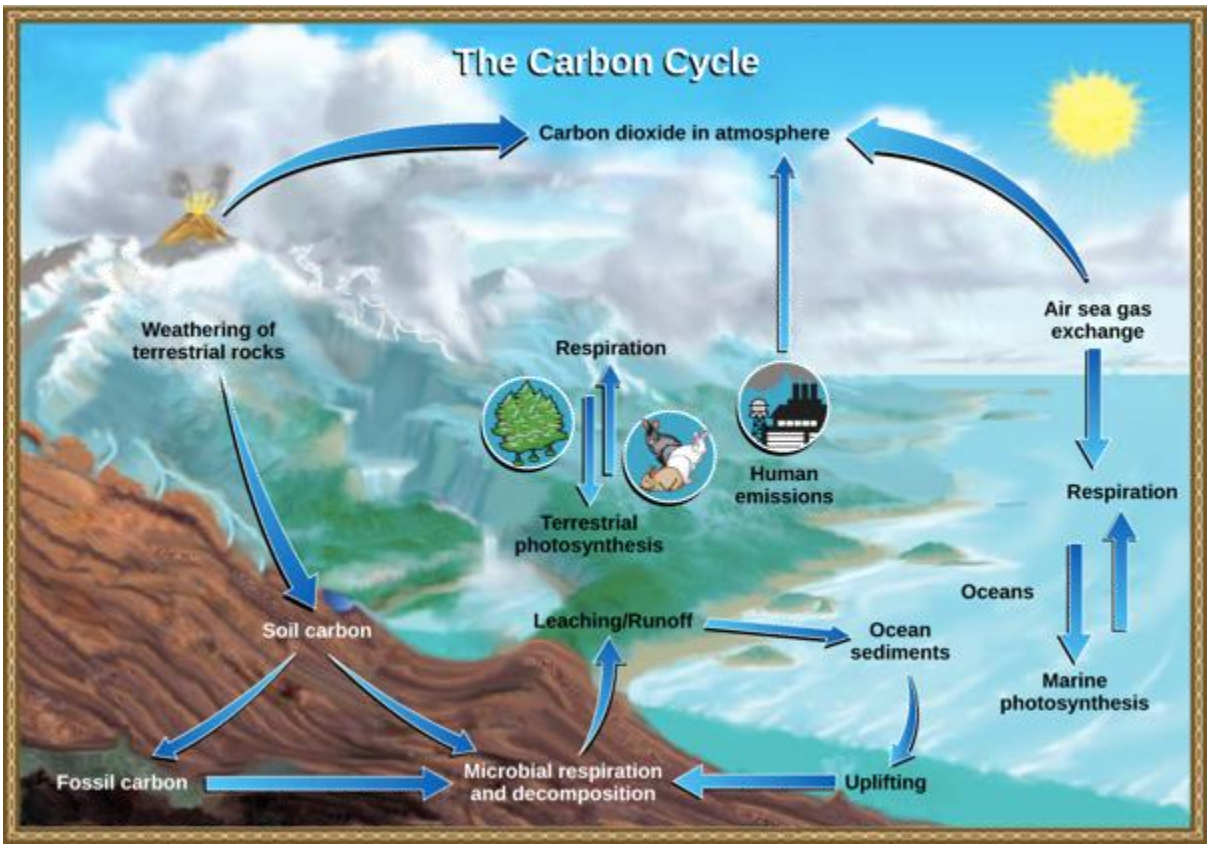

Figure 1 The Carbon cycle, taken from https://openstax.org/books/concepts-biology/pages/20-2-biogeochemical-cycles

Historically, dramatic changes in the Earth's climate occurred over 1000's of years but anthropogenic climate change is warming dramatically within ten year periods (Hansen & Sato, 2012).

The rangelands have always been subject to extremes of hot weather and volatile rainfall (Figure 2) ("Bureau of Meterology: rainfall variability", 2019). Mid-latitude regions are expected to see the greatest temperature increases and changes to rainfall patterns are poorly understood (IPCC, 2014). The pastoral enterprises are relatively well-adapted to the current climate but as climate changes impacts increase in severity and duration the point at which agriculture will no longer be sustainable in this area is unknown (Marshall & Smajgl, 2013). Mitigation of GHG emissions is required to slow down the warming and that is where pastoralists and policy makers alike must understand the role of ruminants in climate change.

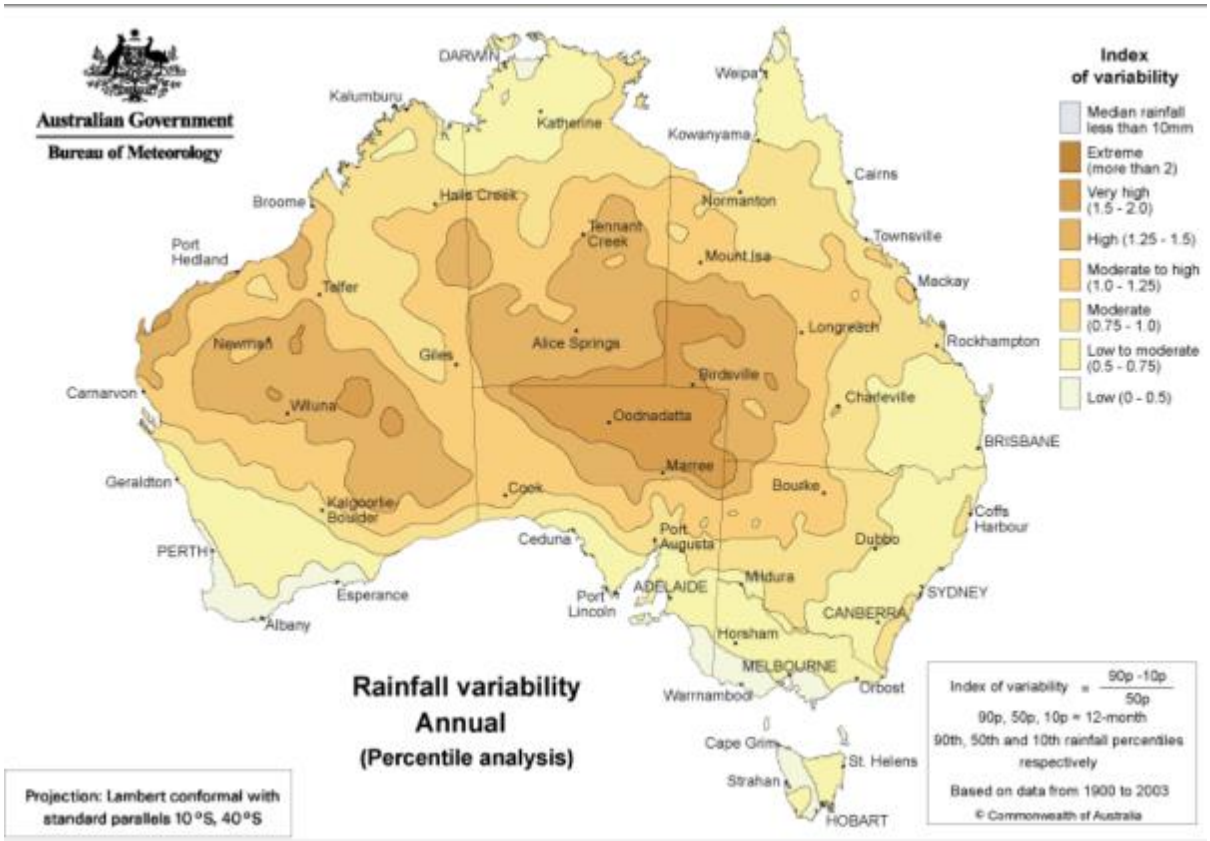

Figure 2: Rainfall variability in the arid zone
http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall-variability/index.jsp

1.1. The role of ruminants in climate change

Understanding livestock productions role in emissions and sequestration is important to ensure policies and commercial production systems can have a positive impact. Ruminant production's contribution to global warming occurs through two main pathways:

- Land use change, such as forest clearing to increase grazing area, which takes away the ability of trees to sequester CO2; and
- Ruminant's production of methane.

Worldwide, cattle numbers have been relatively stable at around one billion since 2012 but they did decrease from 2015 to 2018 and are now back at previous levels (Shahbandeh, 2019). However, atmospheric CH4 levels have tripled since 1750, remained stable between 2000 to 2007, but since 2007 have been rising and the cause is unknown (Kirschke et al., 2013). The scientific community has not been able to come to a consensus on the cause of this rise and although there are different isotypes of CH4 it cannot identify the source or country because of how quickly the gases can travel in the atmosphere. Since the cause of the rise in methane is not known the method of reducing methane falls on all the known pathways, such as decreasing ruminant numbers as recommended by the international panel on climate change (IPCC).

Methane (CH4) has a far higher global warming potential (GWP) then CO2 but CH4 has a half-life of 100 years in comparison to NO2 and CO2 which are 1,000 years (Cain et al., 2019).

When measuring emissions in the current system, values are taken back to CO2 equivalents and this loses accuracy for short lived pollutants like CH4. As part of this research, the author visited the Oxford Martin School in the United Kingdom where researchers have developed a more accurate measurement of the GWP of CH4 (Cain et al., 2019; Lynch, Cain, Pierrehumbert, & Allen, 2020). This measurement accounts for the decreasing heating forces of the CH4 as it is broken down in the atmosphere over a period of 120 years. This highlights the contrast to CO2, which has an additive effect as shown in Figure 3. If CH4 emissions are at a constant rate, there is no increase in warming because they are breaking down at the same rate they are being released. CO2 emissions will have an increasing warming effect

because they do not leave the atmosphere quick enough. Figure 3 illustrates these effects under rising, constant and falling emission scenarios with the warming effect depicted below.

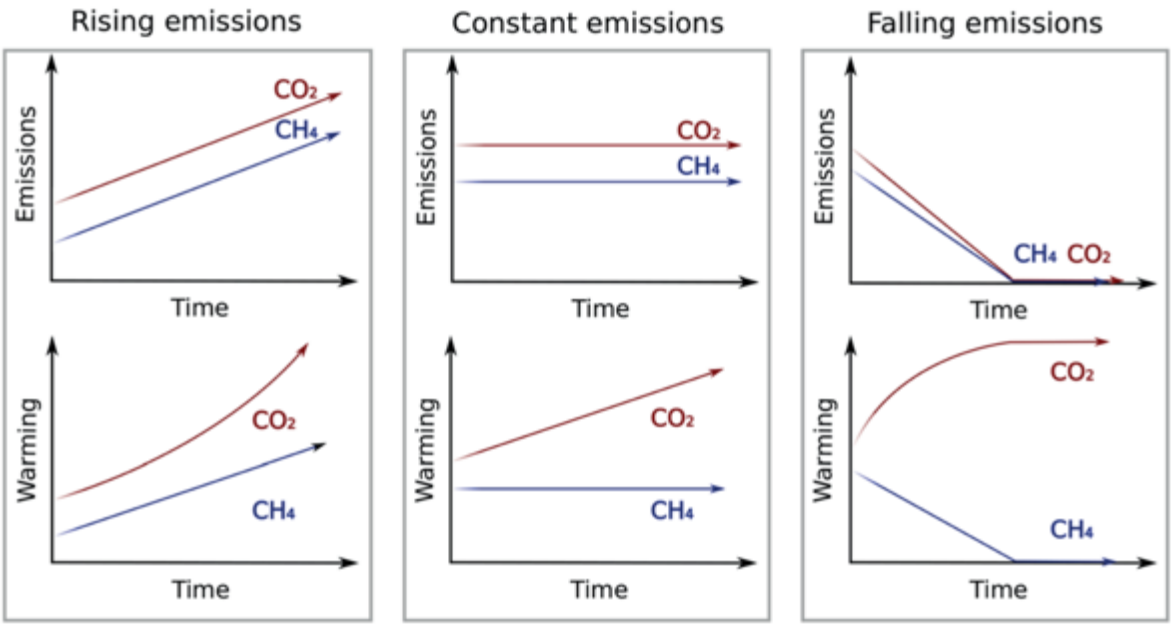

Figure 3: Rising, constant and falling emission scenarios Cain et al., 2019

Different livestock production systems produce differing amounts and ratios of GHGs, for example manure management and energy required in intensive livestock production produces more NO2 and CO2 but less CH4 (Bentley, Hegarty, & Alford, 2008).

The aim is to get to net zero emissions. This is much more achievable with CH4 because there is no additive effect, in contrast to CO2 that will need to be sequestered to ensure global warming stops at 1.5°C. Industry bodies representing the beef industry – and to a lesser extent the sheep industry – must ensure that policy makers and the consumer are aware of this.

Ruminants also play a significant role in the sequestration of carbon back into soils and plants through grazing. A study done on a degraded rangeland in South Africa found significantly higher soil carbon when livestock were grazed at high density and short duration (rotational grazing or holistic grazing) compared with the soils where livestock were excluded (Chaplot, Dlamini, & Chivenge, 2016). Using livestock grazing to increase carbon sequestration is a recognised method of carbon farming and is being demonstrated in many parts of the world (Soussana, Tallec, & Blanfort, 2010) (Teague et al., 2016).

The author visited Devenish, a farming and nutrition company which is also a pioneer in measuring this form of sequestration, running a suckler cow herd on 170 hectares in Douth, Ireland. Using Lidar satellite-based technology, they have determined the amount of carbon sequestered in their hedgerows and soil. Increasing herd efficiencies through genetics decreases CH4 emissions, using grazing methods that increase carbon sequestration into the soil and afforestation are all methods they have found that when used together produce a fundamental decrease in carbon footprint. Devenish are demonstrating that when taking a whole landscapes view of grazing ruminants many of the emissions can be offset.

An Australian study examined GHG emissions and sequestration of beef and sheep farms across Australia to create a carbon balance sheet. Doran-Browne, Wootton, Taylor, and Eckard (2018) found if a property had 20% tree cover, this was enough to offset all emissions. At the lower stocking rates (6DSE/ha) the properties were sequestering more GHG than they were producing. This study was undertaken in higher rainfall areas but can potentially be extrapolated to lower rainfall production systems in the rangelands that have significantly lower stocking rates (0.1DSE/ha) with lower growth rates of trees but over larger areas. Scientific research to confirm this is required by the industry, it presents an opportunity for rangelands pastoralists to decrease the impacts of GHG mitigation policies and recognise their role in sequestration.

1.2 Climate impacts on arid and semi-arid rangelands

Droughts are part of the production system for producers in the Australian rangelands but the prospect of droughts increasing in frequency and/or duration is a new threat. ‘Semi-arid’ is characterised as a rainfall of 250mm to 350mm and arid is defined as rainfall <250mm annually (Ehman, 2005). The IPCC has said with medium confidence that probability of droughts will increase and this is supported in a climate modelling tool developed by CSIRO ("CSIRO: Climate Change Predictions in Australia," 2019). Table 1 identifies the percentage chance that annual time in drought and mean surface temperature will change in the Australian arid and semi-arid rangelands in a medium emissions scenario (Representative Concentration Pathways (RCP) 4.5) or high emissions scenario ((RCP) 8.5) ("CSIRO: Climate Change Predictions in Australia," 2019). The representative concentration pathway (RCP) refers to different GHG emission scenarios, RCP 4.5 is a medium emission scenario and RCP

8.5 is high (Riahi et al., 2011; Thomson et al., 2011). Using RCP 4.5 20% of models predict an increase in temperatures of 1.5 to 3.0°C and >30% increase in time in drought by 2050 but under RCP 8.5 it was predicted by 41% (table 1). Pastoralists need to recognise the increased risk of drought and adopt sufficient risk management strategies to combat this impact in the future.

		Annual Mean Surface Temperature (C)			
		Slightly Warmer < 0.50	Warmer 0.50 to 1.50	Hotter 1.50 to 3.00	Much Hotter > 3.00
Annual Time In Drought (%)	Large Increase > 30.00		+ 3 of 30 (10%)	+ 6 of 30 (20%)	
	Small Increase 10.00 to 30.00		+ 2 of 30 (7%)	+ 6 of 30 (20%)	
	Little Change -10.00 to 10.00		+ 4 of 30 (13%)	+ 5 of 30 (17%)	
	Small Decrease -30.00 to -10.00		+ 1 of 30 (3%)	+ 1 of 30 (3%)	
	Large Decrease < -30.00		+ 1 of 30 (3%)	+ 1 of 30 (3%)	

		Annual Mean Surface Temperature (C)			
		Slightly Warmer < 0.50	Warmer 0.50 to 1.50	Hotter 1.50 to 3.00	Much Hotter > 3.00
Annual Time In Drought (%)	Large Increase > 30.00			+ 13 of 32 (41%)	
	Small Increase 10.00 to 30.00			+ 6 of 32 (19%)	
	Little Change -10.00 to 10.00			+ 3 of 32 (9%)	
	Small Decrease -30.00 to -10.00		+ 1 of 32 (3%)	+ 6 of 32 (19%)	
	Large Decrease < -30.00		+ 2 of 32 (6%)	+ 1 of 32 (3%)	

Table 1 Annual time in drought and mean surface temperature increases by 2070 a) RCP 4.5 and b) RCP 8.5

1.2.1 Impacts on vegetation

Natural variability will likely determine rainfall in the short term to 2030, however changes in mean temperature and GHG in the atmosphere can have other effects on plant composition and growth rates. The author spent a month visiting the Karoo, in South Africa, an arid rangeland stretching across the Eastern Cape, Western Cape and Northern Cape provinces. The Karoo is similar to the Australian rangelands because of its low rainfall (190mm), high temperatures and shrubland vegetation (Wiegand, Milton, & Wissel, 1995), making it a valuable information source to extrapolate to the Australian rangelands. The Karoo is already

experiencing changes in vegetation composition believed to be a result of climate change (Rutherford, Powrie, & Schulze, 1999). At an agricultural research station near Middleburg in the Karoo they are looking at how their native shrubs and grasses grow in response to temperatures 1°C higher by putting enclosures around them that act like small greenhouses. Changes in plant growth were compared to the control shrubs and grasses that had no coverings (Figure 4). Edwardes (2018) didn't find changes in the growth rates. This was attributed to the low rainfall during the trial but they did find the soil moisture was significantly lower in the enclosures. Increased evapotranspiration of moisture out of the soil will have a significant effect on pasture production in the rangelands across the world. Increased soil evapotranspiration during all seasons is projected for the arid rangelands (Bastin, 2014). Pastoralists will need to manage stocking rates accordingly as a significant rainfall events that historically produced six-month pasture supply may be less frequent under climate change.

Figure 4 Native shrub in an enclosure to simulate higher mean temperatures in the Karoo, South Africa (Source: Author)

Some decreases in pasture production from decreased soil moisture will be offset by the higher atmospheric levels of CO_2. High CO_2 concentrations improve a plants ability to retain water and increase its growth rates (Morgan, Derner, Milchunas, & Pendall, 2008). C4 plants that are better adapted to high temperatures will spread to the southern areas of the rangelands in Australia but they have a lower nutritive value then the C3 pastures (Bastin, 2014). Pastoralists will need to assess the species when determining pasture utilisation rates and the use of nutritional supplements may increase in necessity.

This highlights that changes in CO2 atmospheric concentrations must be studied, not just to investigate their warming potential but also the effect on plant productivity and sequestration potential. The Eddy Covariant Flux tower (Figure 5) can calculate the carbon sequestration and release in a landscape over around 1/4 hectare in size, over this larger scale it demonstrates how land condition effects the CO2 cycle. Mchunu and Chaplot (2012) have found that the degraded areas of the rangeland release more carbon than the areas with more ground cover of grasses and shrubs. This finding is very important for adaptative responses, mitigation options and should be recognised as a key determinant of sustainable land management.

Figure 5 EDDY Covariant FLUX tower in the Karoo, South Africa (Source: Author)

Soil carbon is low in arid and semi-arid regions compared to higher rainfall areas but even small increases in soil carbon levels increase the ability of the soil to hold moisture when it does rain (Waters, Melville, Orgill, & Alemseged, 2015). Within climate change, precipitation events that do occur will be more likely to be heavy and irregular so techniques to reduce the associated soil erosion and capture more water in the system will be imperative. Pastoralists must ensure that their rangelands have good soil cover of perennial plants that will increase soil carbon levels and increase the resilience of the rangelands to the climate shocks. This will require stocking rates that respond quickly to land condition and may have to be more conservative then they have been historically.

Chapter 2: Socio-Political Risks of Climate Change on Pastoralism

Climate change effects are not limited to impacts on the environment. Climate change is forcing consumers to recognise the impacts of their choices and understand their purchasing power. Consumers are putting strong pressure for action to mitigate emissions from all industries. Agriculture is under scrutiny globally for its role in GHG emissions and its social license is under question. The red meat industry must continue to acknowledge their role in climate change and demonstrate how it is working to improve. This chapter looks at consumer perceptions of red meat production, threats to market, policy decisions and how that can impact the Australian pastoralist.

2.1 Consumer perceptions of the role of ruminants

Red meat has always been part of the human diet and until recently this consumption pattern has never been threatened. The term *flexitarian* was first documented in 2003. It is predominantly vegetarian but an occasional meal with meat. Over the last few years, it has gained traction as the 'environmentally friendly diet', termed because of its low red meat content. It was supported by the EAT-Lancet Commission on Food, Planet and Health in 2019, creating the now infamous Eat- Lancet Diet (Willett et al., 2019). The rationale of the EAT-Lancet diet and policy brief is that introducing policies to decrease meat consumption gets three benefits from one policy; less GHG emissions, decrease obesity and decrease undernutrition (Willett et al., 2019). Professor Frank Mitloehner from UC Davis addressed the authors of the EAT-Lancet diet about how it would decrease climate change risk and the response he received is written below.

> *"Finally, the meat consumption limits proposed by the Commission were not set due to environmental considerations but were solely in light of health recommendations. The dietary guidelines only refer to healthy eating. Thus, is not the diet to reduce climate change."*

This response by Fabrice DeClerck, science director of the EAT-Lancet Commission, was retrieved from https://ghgguru.faculty.ucdavis.edu/2019/02/19/eat-lancet-report-is-an-epic-fail-and-commission-knows-it/

The author attended the FAO conference at the United Nations in Rome in 2019 and witnessed the plethora of policy briefs still supporting that the EAT-Lancet diet would decrease emissions. “If every American partook in ‘Meatless Monday’ it would reduce the carbon footprint by 0.6% in contrast to changing to energy efficient light bulbs it would reduce by 1.2%” (Personal Communication with Prof. Mitloehner, March 2019) (Figure 6). This report is not recommending that livestock production does not play a role in emissions, however policies should be directed at the areas that will have the greatest benefit for climate health. Decreasing fossil fuel reliance is the real answer to decreasing emissions but decarbonising the economy requires fundamental change. The livestock industry needs to ensure it can demonstrate that it is both mitigating emissions and sequestering carbon to maintain its market access and avoid detrimental policy decisions.

Figure 6 The author meeting with Dr Frank Mitloehner in Iowa with 2019 scholars. L-R: Thomas Green, Anthony Close, Prof. Frank Mitloehner, Ellen Litchfield, Christina Kelman

Consumers are losing trust in livestock production and this growing mistrust is fuelling their desire for a product that they believe is sustainable. There has been an increase in consumption of plant products and the growth of the organic beef sector as an example (Gregory, 2000; Zagata & Lostak, 2012). Whilst meat consumption has grown by 58% from

1998 to 2018, the industry should not rely on this continual growth as social license is key to sustainability (Whitnall & Pitts, 2019). In the United States, people identifying as vegans increased from 1% to 6% from 2014 to 2017, a 600% increase in three years. This shows livestock producers should not take their market for granted. Interestingly, a Meat and Livestock Australia (MLA) study into why consumers are eating less red meat found cost and health the main barrier to buying rather than environmental concerns. However, MLA has still stated that the red meat industry in Australia will be carbon neutral by 2030 (Mayberry, Bartlett, Moss, Davison, & Herrero, 2019). Changing protein sources to the lowest emission intensity product is one option but it would be very difficult to get all consumers to only buy the product with the lowest emission intensity, forgoing their other values. A similar scenario is found in beef, depending on the life cycle assessment and individual production systems used, where feedlot beef generally has lower emissions due to the shorter life cycle of the animal, however many consumers want grass fed or organic and will pay a premium. Pastoral enterprises in the rangelands are majority and in avertedly organic and have benefited from a consumer willing to pay a premium for these products. In the future they may need to also demonstrate that they are helping in the fight against climate change.

In the developing world, concerns about red meat production are less about the environmental effects and more about food safety and affordability. In Asia and Africa, where a majority of the population growth will come from, they are still very connected to their producers with most purchases happening in wet markets (Figure 7). As their middle class grows allowing increased spending on food it will increase demand for livestock products. This may offset a decrease in demand from consumers who refrain from eating red meat for environmental reasons. It poses a question to the industry, should the future of the red meat industry be as a commodity, aiming to get the highest volume to meet demand or as a luxury product maintaining current production levels but at a higher price point? Livestock production in the rangelands can position itself as high -value pasture-raised product that has the ability to sequester carbon but further research into carbon footprint in this environment is required. At an industry level, focusing on meeting consumers concerns and recognising that market share could change is important.

Figure 7 Wet market in Los Banos, Philippines (Source: Author)

2.2 Policy changes to combat climate change

Policy changes in response to pressure to mitigate climate change pose one of the biggest threats to livestock production in the rangelands of Australia. The contribution of livestock to GHG levels is widely publicised and causes growing resentment within the public. When visiting the Netherlands, it was evident the consumer and producer divide was growing. They are aiming to decrease their livestock numbers by 50% to meet the nitrous oxide reduction targets. With headlines such as: "*How can we make more room for houses? Get rid of the cows!*" and farmers with tractors closing roads to protest the changes creates a divide between consumers and producers ("Netherlands farmers stage tractor protest, cause huge jams," 2019).

Producer-focused policies that aim to decrease production or increase cost often result in the consumer purchasing an imported product from another country that does not have restrictive policies in place. It is just moving the nitrogen emissions from one country to

another. They are disastrous to a national industry but with minimal improvements in global emissions. Australian policy advisors need to recognise this as well, especially since 70% of Australia's red meat is exported and need to remain competitive in the global market without ignoring environmental externalities. Factoring in environmental externalities of production needs to be addressed in all industries. How to do this is a challenge for reasons including:

- Applying a monetary value on environmental externalities is difficult
- Who should pay for it?

2.2.1 Taxing red meat

Studies looking to decrease the European Union's (EU) GHG emissions have looked at taxing meat to account for the environmental externalities (Nordgren, 2012; Wirsenius, Hedenus, & Mohlin, 2011). This tax would result in a 25% increase in the price of red meat at the supermarkets. The proceeds from the levy would then be used to subsidise farmers to get into other production industries. A red meat tax and many of the other policy options put forward in the EU focus on policies that decrease all livestock production. This doesn't allow differentiation between systems and assumes all livestock production results in biodiversity loss and high emissions.

Applying a tax on emissions has been attempted in Australia but has thus far been difficult to get through parliament. The Carbon Pollution Reduction Scheme (CPRS) or carbon tax as it was colloquially known would have forced the big emitters to pay for the amount of carbon they produce. With 75% of Australia's GHG produced by 500 companies it would have increased their cost of production, which would probably have been passed onto the consumer, and agriculture would have been largely avoided in the short term. In New Zealand, a carbon tax was placed on industry, but the agricultural industry was exempt initially, despite agriculture being the biggest emitter in New Zealand. Their Labour Government now wants to include agriculture in their trading scheme and has received backlash from farmers. An agribusiness consultant the author met confirmed that whilst New Zealand agriculture is some of the most GHG efficient in the world, farmers are not concerned about measuring or mitigating their GHG emissions yet (Ford, S. Personal communication, February 2020).

2.2.2 Pastoral leases and conservation

The author met with fourth generation beef farmers in British Columbia (BC), Canada (Figure 8). They felt the greatest risk to their ability to continue farming is their right to their natural resources. Beef producing areas of British Columbia have a similar lease structure to pastoral leases in Australia. They can have a grazing lease on nearby forests that they rely on for the cattle to graze in summer. As winter approaches, the cattle return closer to the productive farming land that are owned under freehold, usually producing hay in the summer months.

Figure 8 Ted and Andrea with their daughters Sylvie and Anna Haywood-Farmer on their property, Indian Gardens, in British Columbia, Canada (Source: Author)

The pastoral leases that cover most of the arid rangelands in Australia are similar in that they are owned by the crown and are restricted in the activities that can be carried out depending

on the state. In South Australia, leases are subject to inspections every 14 years and this review will determine if a lease is renewed in a 42-year rolling structure. Marginal lands in Australia and British Columbia both allow cattle producers to capitalise on the surplus vegetation without adding in any inputs or clearing. Marginal lands are also considered by some policy makers as the answer to increasing the areas of conservation, by restricting agriculture to the most productive areas. Pastoralists in the Australian rangelands need to ensure they can demonstrate their role in conservation whilst still producing livestock in low impact, extensive systems.

2.2.3 Carbon neutral

At the end of 2019, Meat and Livestock Australia released a peer reviewed article that outlined the possible pathways to attaining its goal of carbon neutral by 2030 (Mayberry et al., 2019). One pathway was decreasing the number of cattle finished on grass. The author is concerned that these conclusions could be the basis for future policy briefs and could be very detrimental to the pasture raised cattle industry. Looking at one environmental indicator such as methane emissions without thinking about overall food sustainability may result in inept policy decisions. Advocacy for the rangelands red meat industry needs to highlight the synergy that can be achieved through conservation and agriculture in rangeland systems to ensure their survival.

Chapter 3: Risk Management in a Risky Climate

As pastoral enterprises enter a riskier climate, they will need to ensure they understand and recognise the future risks and impacts as well as starting to put in place risk management strategies. This chapter looks at strategies that pastoralists can adopt to increase their resilience to the impacts discussed above.

3.1 Weather insurance

Insurance is one of the most common risk management tools and is present in some form in all businesses. However, insuring against weather is a new field for agriculture in Australia and especially for livestock producers. Index weather insurance allows a producer to put in a weather contract for a specific weather variable over a specified time period (Trethewey, N Personal Communication, 2020). For example, creating a contract to insure against getting <50mm rain cumulative over a 12-month period, and then insuring for the amount of an interest loan or cost of feeding cattle. The timeframe and weather variable are virtually limitless but as the likelihood of it occurring increases then the premium goes up as it does with the amount that would need to be paid out. Instead of having to submit a claim and have an insurer come up to determine if the payout should occur it runs off Bureau of Meteorology (BOM) weather station data so as soon as that time period is up if the weather variable occurred then it will be automatically paid out. The uptake has been slow with <5% of crop farmers insuring against weather derivatives and at time of writing this report there were no published cases of beef and lamb producers in the rangelands utilising it in Australia.

Longer term contracts (>12 months) would suit most red meat producers in the arid and semi-arid rangelands since cumulative rainfall is more important than timing and because of the wide array of forage it takes longer to go into drought. Working with an insurance broker to develop contracts that suit an individual business are currently the only option and, in many cases, may be the most applicable (such as Weather Index Solutions Pty Ltd).

Hillridge Technology have created an algorithm that allows producers to insure short term contracts instantly without having to go through a broker or wait for approval from the underwriters. This may be applicable in some scenarios in the rangelands such as going into

summer with minimal pasture availability. Rain would be required within a two-month window or stock would need to be fed, sold or agisted. A policy could be taken out to cover costs if rain does not fall before summer. As climatic volatility increases, these tools could become more attractive to rangeland producers. Weather index insurance could be the key to decreasing cashflow volatility in a volatile climate in the arid and semi-arid regions of Australia.

3.2 Income diversification

This report will only briefly touch on diversification as it is unique to each individual system and it comes down to a producer's passion and willingness to adapt. If a producer is attached to the production of beef rather than geographical location, they may prefer to move to a higher latitude to offset climate change effects. If they are attached to their location, they should utilise the advantages that area has. The Nuffield experience has highlighted the importance of identifying opportunities in adversity and to constantly evolve.

Looking at diversification through 'The Boston Model' improves the resilience of an operation by maintaining current markets and creating new markets (Morrison & Wensley, 1991). The Boston Model is a four-quadrant model used by investment firms and it can be adapted to primary production systems (Figure 9).

1. ***Dogs*:** do not make much money and may be in a slow growth market. Ideally do not want to invest heavily but they may have other benefits that aren't directly to cashflow.
2. ***Cash cows:*** make good returns in a well-established market and are less risky. In livestock systems these would be the traditional sales routes or for a big company like Apple, it is their iPhone. They provide the returns to invest in other areas.
3. ***Stars***: need a lot of investment and are often in new markets and are hopeful of turning into the next cash cow and not a dog. This is potential new markets, such as carbon farming or starting a new brand.
4. ***Question marks:*** are uncertain, they often require higher investment and may not provide any returns, but they could turn into the next star!

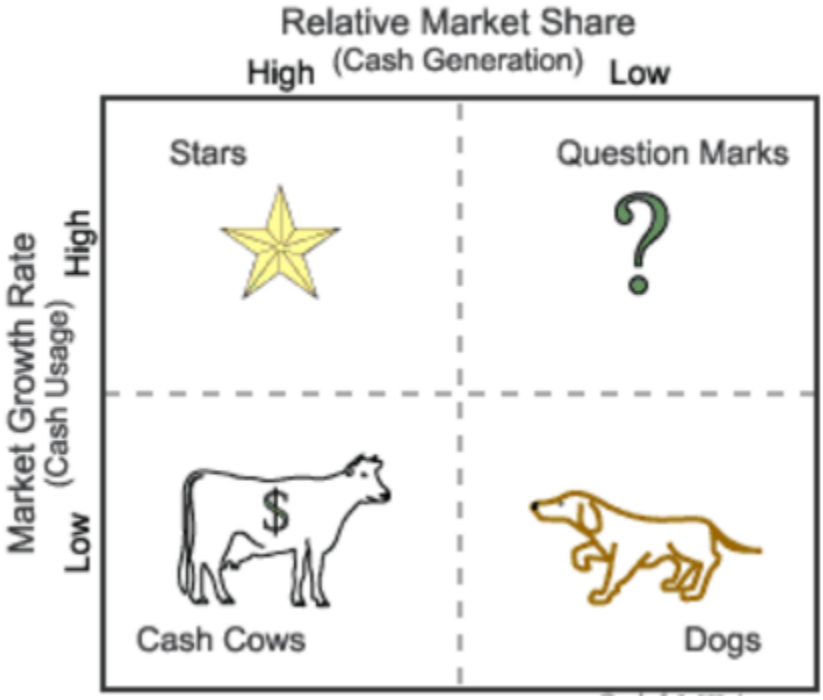

Figure 9 The Boston Cash Cow Model ***http://www.quickmba.com/strategy/matrix/bcg/***

Pastoral production systems must evolve to decrease their vulnerability to a changing landscape. This may be through an infinite number of options that are unique to each business but the Boston model provides a framework for how pastoralists can think about their business structure.

3.3 Production systems thriving in harsh environments

The following case studies were developed from visits undertaken by the author over the duration of the research. They have been chosen as they exemplify the future of rangeland red meat production. All production systems are working in harmony with their environment/climate to find opportunities despite their challenging landscapes.

3.3.1 Case study 1: Venator Ranch, Hudsons Hope, British Columbia

Christoph and Erica Weder together with their children Pasco, Nero, Oro and Luna farm 1,800 Angus cross cows, 350 Bison cows and 1,000 yearling beef and bison young stock on 8,000 acres of deeded and 10,000 acres of grazing license in northeast British Columbia in Canada (Figure 10). The weather can range from >35 degrees Celsius in summer to -40 in winter. Winter routinely last up to five months. Summer and spring are spent cutting pasture hay and preparing to survive the winter, similar to how the summer is approached in arid Australia.

Pasture hay is baled with biodegradable Sisal string made from cactus. This enables them to leave hay in paddocks and when stock consume the hay in winter, they trample the organic matter back into the soil. They do this to ensure they are not taking nutrients away from the soil and increase soil fertility. They focus on improving the productivity of their land without external inputs such as fertilisers or buying in fodder. Increased productivity means that they do not need to clear forests to create more productive land instead they utilise the pastures they already have. They receive no 'ecosystem payment' for the native forests (which have never been logged) and the abundant biodiversity on their property. The family understands the inherent value of their environmental work.

Figure 10 Inspecting the fields at Venator and picking wild strawberries growing amongst the cow pastures with Christoph Weder (Source: Author)

The Bison are perfectly adapted to the harsh conditions of winter as in the cold they decrease their metabolic rate so require less feed to do well through the winter. This is in stark contrast to bovines that require their metabolic rate to increase during cold stress to offset the heat loss. Back in Australia the use of *Bos Indicus* genetics or Senepol cattle that are better adapted to the high ambient temperatures should be considered by pastoralists in the southern arid rangelands (Huson et al., 2014). The Weder's have recognized the benefits of having livestock that are well adapted to their environment, however the Bison market is relatively small so they have started their own Bison brand, 'Frontier Bison'. Their brand is used to market their herd, connect with consumers and ensure they are working within their environment. The Angus cattle provide a lower risk income, although they are more subject to the environmental pressures, they have a secure market and can offset the risk of a new venture like the Bison brand. Erica Weder also writes for a farming journal in her home country of

Switzerland that also helps to connect farmers and people living in an urban environment with farming system.

Species	Temp., °C	Jan	Feb	March
Yak	20 0 -30	128.2 123.4 146.2	111.7 137.2 150.1	143.5 164.2 181.8
Bison	20 0 -30	118.2 117.9 90.7	105.3 124.0 104.6	160.4 168.6 135.4
Hereford	20 0 -30	138.7 146.5 186.2	141.8 152.0 186.1	155.7 174.2 259.8
Highland	20 0 -30	109.0 127.9 137.4	116.6 133.7 136.8	132.9 144.7 171.3
Mean monthly temperature,°C		-10.2 (-42.0 to 7.8)[2]	-8.5 (-29 to 10)	-5.6 (-34 to 11)

Table 2 Metabolic rate response to temperature of different bovines

https://www.bisoncentre.com/resources/resource-library/bison-research/physiology/comparative-winter-bioenergetics-american-bison-yak-scottish-highland-and-hereford-calves

Figure 11 Bronson the Bison coming over to check the visitor to the farm (Source: Author)

Initially, it may be difficult to see similarities between Northern Canada and Australian rangelands but they are both very unique and fragile ecosystems within an unforgiving environment. As a result, it is imperative that the production systems are well adapted and identify the strengths of their environment. For the Weder's that has been through developing Frontier Bison, a brand built in response to their environment.

3.3.2 Ol Pejeta, Kenya

Ol Pejeta is a fantastic example of creating synergy between conservation and agriculture. Over the 90,000 acres there are elephants, buffalo, rhino, lions and many more making up the 12 to 13,000 wildlife, this is also home to 7,500 cattle. The cattle are herded across the property in 150 cow units by herders from pastoralists families and each night they are placed in a Boma (yard) to be kept safe from predators (eg lions). Boran cattle are a breed that originates from Kenya and are well adapted to the environment with a strong herding instinct, making them easier to graze over the pastures and easier to manage at night.

Figure 12 Boran cattle grazing with their herder (Source: Author)

The high-density short duration of roaming cattle across the property promotes new grass growth, fertilises the area and in times of drought encourages the break-up the hard soil. Anecdotally, other conservancies that do not have livestock have found it difficult to maintain the plant diversity required for a healthy ecosystem. Losses to the lions are generally around 1% pa and they feel this loss is acceptable for the other benefits they are seeing. Whilst the cattle only provide around 25% of the income in the years that tourism fails, the cattle are still a reliable income. Grazing cattle also has social benefits as they provide job opportunities for the herders from pastoral families and in Kenya it is often viewed by locals that land without livestock is wasted.

Figure 13 Elephants that live in harmony with the cattle enterprise (Source: Author)

This case study highlights to the author that land used for agriculture and/or conservation does not have to be exclusive. Ruminants, when grazed correctly, can have many ecological benefits that work synergistically with conservation efforts to increase biodiversity. Ol Pejeta demonstrates how to capitalise on the advantages in the environment. For them, that includes economical and abundant labour which makes cattle herding achievable and helps

to offset some of the disadvantages such as political instability that can have a negative impact on overall tourism revenue.

3.3.3. Fair Game brand, Beaufort, South Africa

Africa is renowned for its big cats. They conjure support for their conservation from people all over the world. To the local farmer trying to maintain a business or feed a family with their sheep and cattle, big cats can be the cause of a lot of anguish. The Landmark Foundation is a conservation charity recognising the benefits of merging agriculture and conservation, resulting in greater biodiversity.

Figure 14 Kraal site pictured above is 12 months post-use, so has been through one growing cycle, Can see that there are more grasses in the old Kraal site in comparison to the more shrub covered exterior.

In the Karoo, an area native to Leopards, they have established a production system that works alongside these natural predators without any lethal control methods. They have 1,750 Dorper sheep and 350 cattle all herded together over the rangelands. The herders walk with them throughout the day and they are then put in a Kraal (yard) at night (Figure 14). At each Kraal they stay for seven nights and move on. They have found that the grasses return in

around three months and the shrubs return in 12 months, but recovery times are highly dependent on rainfall. There is much higher nitrogen in the Kraal site from the animal faeces and it is noticeably greener after rain and attractive to herbivores. Often the Kraal site is placed on areas of erosion to improve the soil quality from the extra nutrients provided by the animals.

Livestock are processed at a nearby town and sent to Cape Town where the final product goes to butchers, restaurants and high-end consumers. This product is sold under an accreditation scheme that ensures to its buyer that no predators have been harmed in its production: Fair Game Pty Ltd. Joining this accreditation scheme gives the producers a premium for their product by recognising the role they are playing as custodians of the land. The aim is to get more farmers to join the scheme and recognise the value of protecting these species whilst continuing to farm.

Figure 15 Herding Dorpers into the Kraal at night in the Karoo (Source: Author)

Chapter 4: Opportunities from Climate Change

With all challenges comes opportunities and the climate change challenge is no exception. The primary producer must evolve to meet the changes in consumer expectations and natural resources. The greatest opportunity coming from extreme weather events and the loss of natural habitats is that ecological services are no longer taken for granted. As with all supply and demand principles as the supply of ecological services decreases and the urban population feels the effects of high emissions, they become more valuable.

4.1 Payments for ecosystem services

Rangelands are a unique farming area in Australia and the world where the natural ecosystem is relatively intact and there has been minimal clearing or invasion of exotic pests. Payments for ecosystem services (PES) are based on the theory that the undersupply of ecosystem services is due to a lack of monetary benefit and environmental externalities can be decreased with market-based solutions (Muradian et al., 2013). In Brazil, they have been used to decrease deforestation, giving payments per acre of forest preserved that is greater than the reward for clearing to farm cattle or crops. In the EU the Common Agricultural Policy (CAP) provides subsidies to offset some of the production loss from the environmental restrictions it places on producers such as fencing off riparian areas. In the 2020 review of the CAP they hope to move towards more results based environmental payments to ensure that producers are rewarded for their contribution. Government funding for PES is quite restricted in Australia and presents a significant barrier to their implementation. In France, Nestle Waters, a large private sector spring water company funded a PES program to ensure the quality of their water. The program works with farmers to decrease nutrient contamination into the water supply, the program took many years to develop and highlighted that just monetary reward is not enough, social issues must also be addressed when trying to get producers to adopt these programs (Perrot-Maître, 2006).

The Burren project is a successful PES program in Ireland the author visited that rewards farmers for the important role grazing plays in maintaining biodiversity on the limestone outcrops that have been farmed for over 6,000 years (Williams, Parr, Moran, Dunford, & Conchúir, 2009). The Burren project (Figure 16) is a results-based payment with the land

scored in summer based on plant diversity and then if successful the farmer is paid. If they do not score well there are grants available to assist them in adopting new management practices that will benefit biodiversity. The Burren project also identified that it is not just monetary rewards that are required to get producers involved but just as importantly it needs to address:

- education and technological support; and
- acknowledgement of producer successes amongst peers.

This is a successful example of results-based PES and the framework could be adopted to other ecosystems.

Figure 16 The Burren project in Ireland, the cattle graze the limestone flats in winter

In the Karoo in South Africa, a similar landscape to the Australian semi-arid and arid rangelands, they are working to create greater synergy between agriculture and conservation. An example of this is the endangered riverine rabbit, found in land that has been farmed for

over 200 years. The Endangered Wildlife Trust (EWT) based in South Africa are supported by the private sector and support producers to adopt sustainable land management through educational days, financing and grants. Pressure from finance institutes to support ecologically conscious systems may be a driving factor in the development of the value of ecosystem services, especially in developed countries. Recognition of the value of natural capital is being explored by the big banks in Australia (Wackernagel & Rees, 1997) and this area will continue to develop.

Environmental offsets are already used extensively in Australia by the private sector, especially the mining companies to offset the degradation caused by their activities. Recognising that an area can be grazed in a way that preserves its environmental value would be a huge benefit as it would allow the private sector to fund sustainable land management through measures they are currently already doing by buying environmental offsets. The National Farmers Federation see PES as a significant future revenue stream for farmers, aiming to get the market worth $5 Billion by 2030 (NFF, 2019). Whilst these schemes are still in development, they present an exciting opportunity for rangelands producers that are poised ready to capitalise on their natural capital.

4.2 Carbon farming

Carbon farming presents an attractive alternative income stream for pastoralists during times of increased volatility in livestock returns. Carbon farming works on two principles - either the amount of carbon dioxide equivalents sequestered into the soil or trees, or the amount of carbon dioxide equivalents reduced through increased efficiencies (Macintosh & Waugh, 2012). Commonly used methodologies in Australia are:

- **Reforestation**, increasing canopy cover of native plants over 2m in height through manipulating grazing management, feral animals and /or exotic species. This is the most appropriate method for the rangeland systems and is measured using satellite imagery.
- **Soil sequestration**, these methods are difficult to measure and not commercially viable in the rangelands yet but is a growth area if the methodology can be improved. It is used in more productive areas or where swap from cropping to permanent pasture or shrubs is possible.

- **Improved beef herd efficiencies to decrease methane**, such as improving daily weight gain that results in a shorter life cycle thus less methane emitted.

(Van Oosterzee, 2012)

Over the 12 month period the amount of GHG sequestered is determined and calculated back to a number of carbon credits, so these can then be traded. Emission trading schemes (ETS) are present in various forms across the world, however currently carbon cannot be traded internationally and so the prices per tonne vary significantly between countries. For example, at time of writing this report, Australian carbon credits are trading at AUD $16 per tonne and in New Zealand it is AUD $26 per tonne. In New Zealand, the most commonly adopted carbon farming methodology is reforestation through tree planting. It provides a good revenue stream in the areas of the farm that are underperforming from a production perspective and can also be done retrospectively from 1990. Despite these advantages its uptake has still been slow with <1% of New Zealand farmers farming carbon (Personal communication with Stuart Ford, The Agribusiness Group). Majority of projects are set up with a third party that quantifies the amount sequestered each year and then sells the credits either into a contract or on the open market.

This area is still open to a lot of development and is being investigated as a potential new revenue stream by farming groups across the world. For example, in the United Kingdom, farmers are working together to identify the amount of carbon already being sequestered along their hedgerows in an effort to lobby for back paying of these credits. In California, carbon farming is just starting to be recognised by governmental policy and still at the beginning in the private sector. Premiums from companies for carbon neutral products along their supply chain is another way that carbon farming may benefit. Companies such as Patagonia that require a carbon neutral product will supply a premium. Australian rangeland producers should recognise the benefits of the carbon farming initiative as it supplies an alternative income source and meets consumers concerns. Further research into the ability of soils in the arid and semi-arid rangelands to sequester carbon is required by the industry.

4.3 Community supported agriculture

Consumers want to feel they are helping to mitigate climate change. There is growth of community supported agriculture (CSA) programs and farm to table initiatives that aim to give the consumer more trust in the origins of their products (Brown & Miller, 2008). CSA works on developing a relationship between the consumer and producer, the more traditional form is the consumer pays a monthly stipend and receives a box of what is available at the time. It gives the farmer constant cash flow despite climate volatility or market conditions and the consumer is also not faced with price fluctuations and can choose who they want to support. It transfers some of the risk from the producer to consumer, which is a huge benefit in a changing climate change. However, consumer uptake can be slow and although the eco conscious consumer is more likely to adopt a CSA, these business models are still in their infancy in Australia.

The key to successful CSA and farm to table deliveries are education, the consumer and producer need to have a constructive and continual dialogue so they can reach a shared goal. This is imperative to prevent the growing mistrust in the current food system and it is the role of every producer to ensure they have a system they are proud of and a story they are willing to share. Pastoralism is a fantastic story that the author feels is underrepresented in Australia, probably due to a combination of the isolation of these systems and a reluctance of producers to engage. Connecting with consumers will help to decrease the socio-political impacts of climate change and is the responsibility of every producer.

Conclusion

Climate change will result in increased time in drought and pose a significant threat to the productivity of pastoralism in the arid and semi arid rangelands.

Rangeland production systems have historically had to be prepared for climate extremes and this will be an advantage going into a future with greater extremes. Ensuring good land condition through sustainable management practices will increase the resilience of pastoralism.

Evolving and innovative business models will have greater resilience to climate change then static production systems.

Climate change effects in the rangelands will not be restricted to environmental impacts.

Changing consumer demands and policy responses to climate change will have an impact on rangeland-based livestock production systems, but pastoralists are poised to capitalise on the opportunities that arise from a more ecologically engaged society.

Advocacy for the role of pastoralists as custodians of the land must continue and be further developed through engaging in recognised ecosystem services and industry support. Farming is not just about food production and as the industry enters an era where consumer demand for healthy ecosystems grows, this will become even more evident.

Recommendations

The following recommendations identify how pastoralists in the arid and semi-arid rangelands can increase their resilience to the effects of climate change.

- Scientific evidence is growing that there will be increased periods of drought. Pastoralists need to recognise this and make plans to increase their businesses resilience.
- More extensive industry research into GHG emissions and sequestration of extensive rangeland production systems needs to be undertaken.
- Increase consumer understanding of rangeland production systems and promote the positive impact livestock can have on ecosystems. This is every producer's responsibility and despite long distances from urban areas, these positive stories should be shared.
- Collaboration with both other industries and production systems should be used to connect with the consumer. It should not be a competition between feedlots versus pasture-based systems but working together to build trust in the whole food system.
- Advocacy for the role pastoralists play as custodians of the land are imperative to establishing a monetary return for ecosystem services.

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Plain English Compendium Summary

Project Title:	Name of project: COMPLETE
Nuffield Australia Project No.: Scholar: Organisation: Phone: Email:	1910 Ellen Litchfield WIlpoorinna station, Marree, South Australia 0438 757 792 litchfielde10@gmail.com
Objectives	• Study the role of livestock in climate change • Climate modelling of the impacts on arid and semi-arid rangelands • Research how other producers have decreased risk on marginal lands • Investigate risk management tools that can be utilised on the rangelands • Identify any opportunities that may come from climate change
Background	Moving back to the family cattle and sheep station in northern Australia, the author was concerned about how climate change will impact the business. This report identifies the environmental and socio-political impacts of climate change on the rangelands and looks at ways to ensure the ongoing profitability of pastoral enterprises.
Research	This report highlights how producers in harsh climates across the world are working to ensure they have a system that works in harmony with their environment and capitalises on the benefits they bring to industry. Research was undertaken in China, The Philippines, Hong Kong, Germany, Ireland, UK, Italy, Canada, USA, Kenya and South Africa.
Outcomes	Climate change will result in increased time in drought and pose a significant threat to the productivity of pastoralism in the arid and semi arid rangelands. Climate change effects will not be restricted to environmental impacts. Changing consumer demands and policy responses to this difficult time will have a marked impact on production systems. Different production systems across the industry need to collaborate rather than compete against each other to meet the consumer and the environmental concerns. Farming is not just about food production and greater recognition between the synergy of agriculture and conservation is needed.
Implications	Climate modelling suggests increased time in drought for the semi arid and arid rangelands. Recognition of the role pastoralists play in managing and improving these fragile ecosystems will be pivotal in developing their resilience to climate change.