

NATIONAL DEFENCE UNIVERSITY-KENYA

CHALLENGES TO CLIMATE CHANGE ADAPTATION IN SOUTHERN AFRICA DEVELOPMENT COMMUNITY (SADC): A CASE OF BEEF INDUSTRY IN BOTSWANA

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DECLARATION

I solemnly declare that this research project is my original work and has not been presented for examination towards the award of any academic qualification in any other university or college, that all sources of material used in this research project have been fully acknowledged.



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ND201/0037/2023

16/05/2024

Date

This research project has been submitted for examination with my approval as the University Supervisor.



Dr Solomon Owuoché

16th May 2024

Date

DEDICATION

I dedicate this work to my family and friends who have been very supportive during the period of the research.

ACKNOWLEDGEMENTS

I want to acknowledge the efforts made by my instructor and all the authors of the materials I have used in coming up with this proposal.

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ABBREVIATIONS

SADC: Southern Africa Development Community

PCV: Packed Cell Volume

Hb: Haemoglobin

NEFA: Non-Esterified Fatty Acid

RBC: Red Blood Cells

AST: Aminotransferase

ALT: Alanine Amino Transferase

ALP: Alkaline Phosphatase

ADH: Antidiuretic Hormone

GH: Growth Hormone

PRL: Prolactin

UNFCCC: United Nations Framework Convention on Climate Change

LRDD: Livestock Research and Development Department

WWF: World Wildlife Fund

BMC: Botswana Meat Commission

BLA: Botswana Livestock Association

NGO: Non-Governmental Organization

NPCWTNRCC: National Portfolio Committee on Wildlife, Tourism, Natural Resources and
Climate Change

LIMAC: Livestock Management Advisory Center

NAPF: National Adaptation Plan Framework

LRDD: Livestock Research and Development Department

BNASAP: Botswana National Adaptation Strategy and Action Plan

ABSTRACT

Botswana is among the countries in Southern Africa Development Community (SADC) that is greatly affected by climate change. The impact of climate change on the beef industry is more pronounced given that it is one of the largest contributors to the economy of the country. This study aimed at examining the challenges to climate change adaptation in SADC: A case of beef industry in Botswana. Specifically, the study; examined the challenges of climate change adaptation in SADC, with a focus on Botswana beef industry; investigated the effects of climate change on Botswana Beef production and explored what were the interventions for Botswana to address the challenges of beef industry to satisfy the domestic and international markets. Policy change, technological intervention and funding were some of the interventions noted from the study. However, Botswana faces a number of challenges in implementation of adaptation measures to climate change in the beef sector, these include financial challenges making supporting some of the mitigation programs difficult, cultural issues to do with land ownership and system of grazing that tends to favour communal use of land as opposed to more modest methods like fencing to avoid land degradation. Policy and institutional issues that make implementation of mitigation measures a challenge as well as government logistical issues. The study will help SADC countries and policy makers establish policies aimed at accelerating climate change adaptations through addressing the challenges faced by Botswana Beef industry as a result of climate change. The study scope was limited to Botswana beef sector and looked at climate change, its effect on the sector and the challenges and opportunities for interventions. The qualitative survey method was employed for obtaining data for the study and this involved the use of questionnaires and interviews.

CHAPTER ONE: INTRODUCTION

1.0 Introduction

This chapter presents the background to the study as well as the problem statement. Also presented in this chapter are the objectives of the study as well as the research questions. The assumptions of the study and the justification necessitating the study are laid out. The significance of the study as well as its scope and limitations are also presented.

1.1 Background

Climatic changes refers to deviation from the normal patterns of weather in a given area as seen over a long period of time and this can be linked either directly or indirectly with human activities. Changes in climatic conditions are one of the fiercest challenges that are facing many regions around the world. This challenge is made adverse by the negative impact that climate changes possess to food security, environment and the whole eco system. Agriculture and food production is greatly impacted due to droughts, flash floods, sporadic heavy rains and unpredictable weather. All these impact on the ability to produce food and maintain the normal livelihoods for a lot of people around the world (Nyoni et al., 2019).

Many communities around the world derive their livelihood from agriculture and weather related activities. Their lives are thus impacted when climate changes around them. It is estimated that by 2050, approximately 1.5 billion people in Sub Saharan Africa will depend on agriculture for food security, therefore any changes in climate affects their livelihoods directly (Nyoni et al., 2019). According to Godde et al., (2021), changes in climate conditions are shown by erratic rainfalls, increased temperatures, and wild fires, droughts that are longer than normal, flash floods, and excess irregular rainfall. These conditions have unintended consequences on the local, regional and global

economy. The ability to secure populations with food is also greatly impacted. Livestock keeping is greatly hampered when there are prolonged droughts and food derived from these herds is reduced. The crops and wild animals are affected by these climatic changes as well.

Abebe (2017) observes that climatic changes can be said to be significant deviation from regular weather patterns i.e. temperatures, wind, and precipitation over a time period of approximately 30 years. These changes have hit Sub Saharan Africa and negatively reflect on food production, including livestock keeping. These are of great concern given that in most of the parts affected by climate change, the population has less capacity to adapt and thus their lives are majorly affected. Thus in Africa, climate change is seen as one of the greatest threat to livelihoods as systems of livestock production are impacted negatively. The livestock sector contributes significantly to food security in Africa and employs millions either directly or indirectly.

The livestock production systems in many parts of Africa are affected by climate changes given that the forage production and rangelands bear the blunt of weather changes especially prolonged droughts and irregular rain patterns. These changes pose risks on regular production of beef, milk and other animal products. Not only are the livelihoods affected but also the economies that are dependent on livestock production. Cost of adaptation to these climatic changes increases and makes normal production untenable. The health of animals reared and their reproduction patterns are also negatively impacted (Abebe, 2017)

Pequeno et al., (2021) reports that about 30% of SADC region is significantly threatened by climatic variations. Climatic hazards and their various manifestations affect all spheres of the region's economy in terms of food production, economies and increased costs of adaptation. Therefore, when the issues of global climate change are addressed the region should be among the first to be aided.

Crop production contributes a great percentage of activities in African region. Livestock also employs millions and any climatic hazard impacts directly on the population. Livestock diseases are also prevalent as irregular weather patterns make it difficult to maintain normal vaccinations and other preventive measures.

There exists a nexus between food, water and energy and this relationship greatly complicates the negative impacts of climate hazards in the SADC region. Thus, any efforts to tackle issues to do with climate change needs to be multidimensional and regional not just in any one area but among nations within the region as a block. Due to climate hazards, there is reduced land for food production, both crops and animals. There is water scarcity and food insecurity. The food available to consume and sell is also greatly reduced (Pequeno et al., 2021).

In most households in SADC region, livestock keeping is the major economic activity that contributes to food security and employment and or economy. Therefore, climate hazards leave these households vulnerable to food insecurities and poverty. The livestock production systems in many African countries are not developed to adapt to climate changes and as such depend on rainfall. Any deviation from normal weather patterns has put these households at a greater risk given that food requirements are increasing in tandem with population growth in the continent (Abebe, 2017).

According to Kassie (2017) there is urgent need for livestock keepers to improve their production systems so as to enhance their capacity to deal with climate changes. Mulwa et al., (2017) posits that they need to be trained on agro ecological practices for beef livestock production that involves conservation of fodder during glut periods, reduction of herd mortality and on beef animal feeding (Mulwa et al., 2017). The poor folks in rural areas who cannot afford costly adaptive technologies in their beef production should therefore be assisted.

1.2 Statement of the Problem

Botswana is among the countries in Southern Africa Development Community (SADC) that is greatly affected by climate change. The impact of climate change on the beef industry is more pronounced given that it is one of the largest contributors to the economy in the country. A number of studies have been conducted in relation to this study phenomenon. Abebe (2017), found out that since 2019, most countries in Sub Saharan Africa including Botswana have experienced a recurring drought as a result of climate change, which presents barriers to access a competitive beef market. Pequeno et al., (2021) study established that climate change is guaranteed to cause a further decline in the quality and quantity of cattle produced in the country especially for the communal farmers where large numbers of cattle are. This leads to increase in the numbers of cattle taken to the feedlots by farmers to be fattened in order to meet the criteria of the EU market before being sold to abattoirs and other countries (SADC, 2016). Currently, there is no growth at Botswana Beef Industry due to insufficient beef supply to satisfy the demand in the market (Abebe, 2017, Godde, 2020). Most of the studies regarding this study phenomena were conducted in diverse contexts and employed different methodology from the one intended in this study. The previous studies gave little focus on climate change effects on beef industry in Botswana. It is therefore, necessary to conduct a study examining the challenges to climate change adaptation in Southern Africa Development Community (SADC): a case of beef industry in Botswana.

1.3 Objectives

1.3.1 General Objective

The general objective of the study was to assess the challenges to climate change adaptation in Southern Africa Development Community; a case of beef industry in Botswana.

1.3.2 Specific Objectives

- 1) To assess the vulnerability of different beef production systems in Botswana to extreme weather events such as droughts and floods.
- 2) To identify 5 main challenges of climate change adaptation in SADC with a focus on Botswana beef industry.
- 3) To explore the existing interventions by the Government of Botswana in addressing the challenges in the beef industry and their effectiveness.

1.4 Research Questions

- 1) What are the impacts of climate change on Botswana Beef production?
- 2) What are the challenges of climate change adaptation in SADC, with a focus on Botswana beef industry?
- 3) What interventions can Botswana use to address the climate change challenges of beef industry to satisfy the domestic and international market?

1.5 Justification

The attainment of Sustainable Development Goals (SDGs) mainly long term growth in both social and economic spheres in the face of changing climatic conditions especially in the SADC area is of great concern. Thus, this study is necessary to understand how climatic changes affect food production systems in Botswana and in the SADC region.

1.6 Significance of the Study

The study will be of great significance to SADC region given that they are faced with climate change hazards like floods, prolonged droughts, erratic rainfall and inadequate rains. The study will shed light on the challenges that this region faces and the various interventions necessary to help them adapt to climate changes. Secondly, the study will bring forth information on how beef production in Botswana is affected by climate change and what can be done by government and non-government actors to improve the situation. To the policy makers, the study will help them craft necessary policies based on current climate changes and challenges faced by the region and particularly the beef industry in Botswana. To the academicians, the study will contribute to the available body of literature relating to climate changes, adaptations to the same and challenges facing the beef industry.

1.7 Assumptions

Research assumptions are hypotheses or suppositions that the research may take for granted or assume are true, but do not have empirical data to back them up. This research took account of the following research assumptions that may have had an impact on the conclusion and recommendations. The study assumptions were that the respondents had adequate information regarding climate change in SADC region. The study also assumed that the stakeholders who were involved in this study were aware of challenges and interventions to climate change adaptations. It was also assumed that there is enough available literature documenting beef industry in Botswana. Furthermore, it is the assumption of the study that there are existing climate change adaptation practices within the beef industry in Botswana and that stakeholders in the beef industry have implemented or are aware of adaptation measures, even if not explicitly mentioned in the literature.

1.8 Scope and Limitations of the Study

The study scope was limited to the climatic changes effects and challenges as well as opportunities and intervention for climate change adaptation in Botswana. The study was carried out in Botswana. The choice of this area was appropriate given that Botswana is a leading producer of beef within SADC region and is also among the countries prone to climatic changes. The study covered the period between 2023 and 2024. Because of limited resources, the number of participants in the study was less, and taking their responses as inferences for the entire study may result in conclusions that contain some errors. The accuracy of the study outcome was significantly limited by how accurate the responses provided by the participants were. These responses also had a substantial impact on the inferences made.

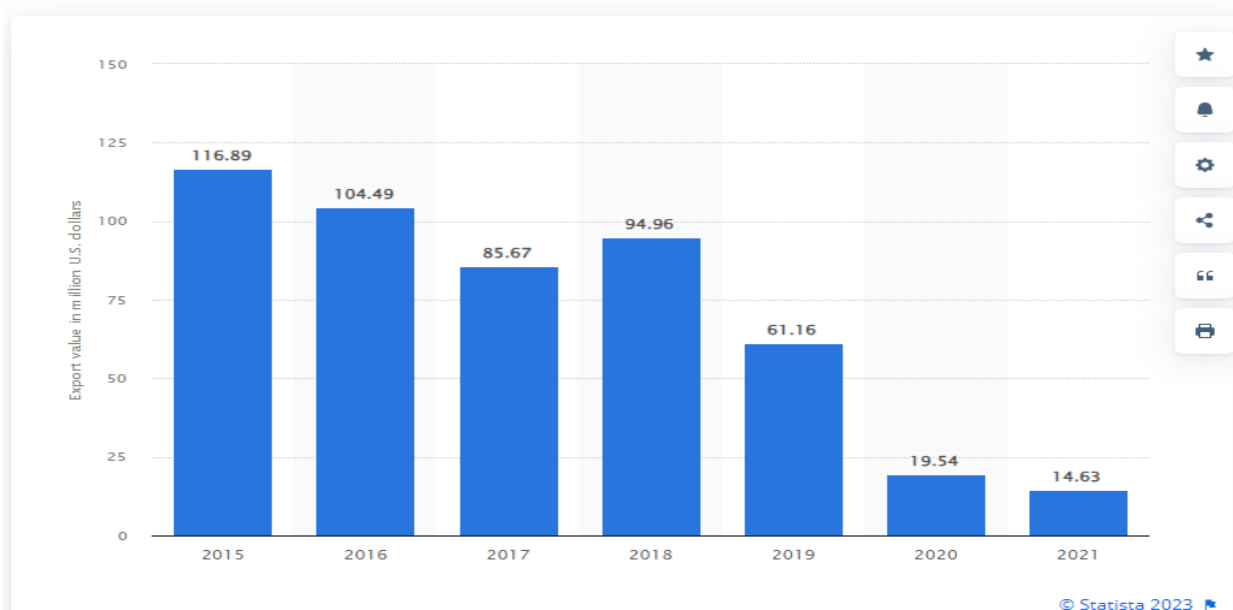
CHAPTER TWO: LITERATURE REVIEW

2.1 Empirical Review

2.1.1 Introduction

Botswana's beef business is critical to the country's economy. Beef is by far Botswana's most important agricultural export. The cattle population in the country as of 2022 was estimated to be 2.1 million (Foreign Agricultural Service, 2022). The country's livestock production surpasses domestic needs, and it has exported range-fed beef to the European Union. Despite its importance to the Botswana economy, the beef industry has started to stall and is experiencing obstacles that have threatened its viability and lowered its overall contribution to the economy. Today, the industry faces even a more intriguing threat, that of climate change (Ziwakaya & Lungu, 2021).

Figure1: Shows how the export value of meat and edible meat offal from Botswana has been decreasing over the years (Kamer, 2023).



The balance of the ecosystem is threatened by the unprecedented challenge of climate change, which affects all the species on earth. Climate change has devastating effects on the agriculture and food production systems, which could push many developing countries into severe poverty (Ziwakaya & Lungu, 2021). The livestock sector is also vulnerable to the adverse impacts of climate change. Cattle production, in particular, is one of the most sensitive sectors to the changing climate with diverse effects being seen on different production variables for livestock (Angel et al., 2018). Heat stress is an important factor affecting livestock output, particularly cattle. Heat stress occurs when animals are subjected to extreme temperatures and humidity, which impairs their capacity to regulate their body temperature and causes physiological and behavioural abnormalities (Angel et al., 2018). The increased temperatures due to the global climate change and genetic selection for higher production will further affect the reliability and survivability of livestock. Importantly, climate change will significantly impact the ability to profitably rear livestock in the event that no mitigation measures will be put in place for the foreseeable future (Angel et al., 2018). Cattle production is highly sensitive to even a slight increase in the upper critical temperature; this means that whenever temperatures get high, farmers have to come up with interventions to prevent sickness and possible death of their herd. This poses a serious challenge for the farmers to adapt. The dairy industry is bound to suffer from economic losses due to the effects of heat stress on the cows, such as lower milk production, reduced reproduction, increased metabolic disorders and poor immune function (Angel et al., 2018). This chapter examined literature that deals with the impact of climate change on livestock, more specifically cattle and the adaptive mechanisms adopted by the animals to ensure their survivability and how this affects the beef industry in Botswana.

2.1.2 Climate Change Impact on Cattle Growth

As already mentioned, one of the direct effects of climate change is the global increase in temperatures. This results in an overall increase in heat. Animals perceive this change as heat stress as they have to deal with temperatures that are slightly higher than their normal average values. Heat stress affects the growth and development of animals in a number of ways but most obviously by reducing their daily gain, body mass as well as body condition. Animals naturally take in more food in average and low temperatures to increase heat production in their body which comes directly from their food (Angel et al., 2018). When temperatures are high, the need for the body to produce more heat is reduced and this translates to lower food intake. Lower food intake affects growth performance (Angel et al., 2018). The production and reproduction of animals is also affected by heat stress, especially crossbred animals that are more vulnerable than indigenous ones (Angel et al., 2018). Increased temperatures (normal than the average) cause a delay in the reproduction cycle of animals. Reproduction is slowed down. Animals that are exposed to chronic heat stress have to adapt their metabolism to cope with the stress. This involves changes in their hormone function, energy use, water and electrolyte balance, acid-base balance and rumen fermentation. To add on that, heat stress also affects the body measurements and body condition of animals. The growth hormone response of animals is altered and this can actually be measured by the looking at the early signalling molecules in the growth hormone pathway of these animals (Angel et al., 2018). The overall result is that the reproduction cycle is delayed. Global warming, which has increased average daily temperatures by 2-6 °C has slowed the growth, puberty and maturity of animals (Angel et al., 2018). This means that as Botswana continues to produce and export beef, the supply in the long run will be inadequate and the sustainability of the industry may be threatened.

The traditional grazing patterns and food availability for the livestock are also important factors in the beef industry that are significantly affected by climate change. The feeding patterns

because of food availability will be altered and this has the overall effect of interfering with the normal growth pattern of livestock. As temperatures continue to rise, certain grazing regions in the country may experience drought and this may significantly affect the quantity and quality of available grazing land (Angel et al., 2018). The availability and pricing of fodder will be interfered because of disruptions in crop production caused by increasing incidence and intensity of extreme weather conditions. In Botswana particularly, the central and western areas which are dominated by the Kalahari Desert, grassland and sandy soils are more suited for livestock as opposed to agriculture (Short et al., 2017). However, these areas are within a zone of a highly variable climate that is influenced by the climatic changes that are happening across the globe and their suitability is expected to be highly compromised with time. This is the same situation in the north-central parts of the country. These and other areas that majority of the farmers depend on for their animal feed will be adversely affected with the changing climate and this will significantly contribute to cattle growth ability (Short et al., 2017). The scarcity of nutritious forage will directly affect the growth rates and overall health of cattle, leading to diminished weight gain and suboptimal meat quality.

When the weather is hotter, colder, or drier than usual, parasites and diseases (such as hoof and mouth disease) spread further in cattle. Some parasites, such as ticks, worms, and flies, are likely to multiply in warm and humid areas (Short et al., 2017). This leads to an increased prevalence of the parasites in the livestock and subsequently result in more chances of their infection. The seasons in which some parasites are active may be altered by climate change, making them even longer and exposing the livestock even more. For instance, warmer seasons may result in less mortality among parasite eggs and larvae on the soil thereby promoting a higher infection levels during cold weather. These parasites have an effect on the growth rate and reproduction ability of the livestock (Short et

al., 2017). Increased temperatures due to global warming in Botswana may make cattle susceptible to parasite attack leading to poor health, poor meat quality and reduced rates of reproduction.

2.1.3 Impact on Milk Production

Milk yield of dairy cows is significantly affected by the heat stress, especially through the feed availability. The lactating cows of the dairy farms are subjected to stress when the external temperatures exceed 35⁰C in an attempt to evade it. Heat stress from metabolism is likely among high producing dairy cows (Angel et al., 2018). Heat stress affects the feed intake, water balance and rumen fermentation leading to reduced energy used for the production of milk. Under such conditions – high ambient temperatures coupled with high levels of relative humidity as well as high body temperature – cattle will tend to eat less but drink more water (Angel et al., 2018). This negatively impacts on the quantity of milk they produce. When temperatures are warm, there is increased production of saliva as well as faster breathing among the cows to help in cooling down of the body system; this in turn decreases milk yield (Angel et al., 2018). Heat stress also causes the cows to sweat excessively thereby increasing blood circulation toward the skin which necessitates the cows to seek shades. As the cows are under the heat stress they also incur increased energy need to sustain their normal body functions which leaves less energy for milk production. Temporary or permanent decline in the level of milk production might result from long term and intense heat stress (Angel et al., 2018). This is because the early lactation cattle exposed to heat stress have the capability of reducing their whole lactation potential milk yields.

The amount and quality of milk are influenced by the hot and humid atmosphere. Heat stress inhibits mammary cell proliferation during the dry period, resulting in decreased milk output. Furthermore, heat stress during the dry period impairs the activity of the immune cell in lactating cows nearing calving and is carried over to the following lactation periods (Angel et al., 2018). This

affects the reproductivity of the animals and therefore their overall population. Inadequate milk production produces weak and unhealthy calves. Calves need specific nutrients like antitrypsin in addition to antibodies that are vital for survival and development (Angel et al., 2018). The death rate among calves may be higher, owing to lack of or insufficient amount of milk supply. Such result in a lowered calf population in general. Furthermore, low milk production can be related to the reproductive problems in cattle. If the cattle are not getting pregnant, or are having challenging pregnancies the reproductive rate for the herd decreases. This may lead to reduced rate herd growth and even population decrease over a period (Angel et al., 2018). In addition, low milk production comes with economic consequences for farmers. Low milk productivity will result in a low income from the sales of milk to farmers hence it is untenable to have huge herds. The economic pressure may force the farmers to cull or sell off their animals, thus reducing the country's total livestock. This leads to lower number of cattle hence lower beef production. The low number of cattle that will be available for butchering will also result into a smaller amount of beef production in Botswana (Angel et al., 2018). The decrease in the cattle sector may lead to indirect consequences for the area's economy, especially on the part of cattle and beef industry participants.

Addressing the factors contributing to low milk production, improving nutrition, veterinary care, and reproductive management practices can help mitigate these challenges and support a sustainable and productive cattle industry (Angel et al., 2018). This means that climate change must be addressed to counter majority of these effects on cattle.

2.1.4 Impact on Meat Production:

Climate change has negative ramifications to the quality of meat at every stage from the ranch to the table. Environmental factors, like temperature, relative humidity, and solar radiation have an

impact on the physiology, behavioural, and health traits of animals which in turn can affect the final meat quality (Angel et al., 2018). Meat quality is a function of weight of the animal, body size, coat thickness, and coat colour of the animals. When these aspects are affected, meat quality will also be compromised.

Slaughter situations significantly affect the tenderness of meat. This include how the animal was handled during transport, and how the meat stunned, and chilled. Heat causes muscle fibres to contract faster than usual during slaughter which results in tougher meat (Gollands et al., 2015). This decreased quality has implications for the market value of beef sold in Botswana and could potentially lead to decreased consumer demand for locally produced meat. Microbial contamination during handling of fresh meat also influences the tenderness and softness of meat. Pathogens associated with transfer during slaughter and processing of carcasses can produce subsequent meat borne diseases which in turn compromises the quality of meat (Angel et al., 2018). Warmer temperatures create favourable conditions for disease-carrying insects such as ticks and flies, which can transmit diseases to cattle (Mogomotsi et al., 2012). This not only affects animal health but also poses a threat to human health through food borne illnesses. Climate change therefore presents a challenge to the quality of meat supplied by Botswana in terms of its integrity and safety towards sensorial characteristics including colour, smell, flavour, and texture (Angel et al., 2018).

The meat colour and pH of beef can be affected by extreme heat stress. When the cattle are exposed to high temperature for a long time before slaughter, they experience stress and release adrenaline. This causes the blood vessels in the muscles to widen and the glycogen in the muscles to break down. This results in lower muscle pH and darker meat colour. The meat can also become tougher due to the heat shortening effect, which is caused by the high temperature and the excessive exercise of the cattle before slaughter. The heat shortening effect makes the muscle fibres contract

and loses water (Angel et al., 2018). However, high temperature can also have some positive effects on the meat quality, such as increasing the marbling and the fat deposition in the subcutaneous regions (Angel et al., 2018). The marbling and the fat deposition can improve the juiciness and the flavour of the meat.

In addition to affecting animal health directly, heat also has implications for feed availability and quality. High temperatures can result in droughts or irregular rainfall patterns which impact grazing lands for cattle (Mogomotsi et al., 2012). Hot weather increases the risk of wildfires. These incidents, often caused by dry and hot weather conditions, result in loss of grazing land and livestock. In 2013 alone, more than 6% of the total land used for livestock production was lost due to wildfires (Ndlovu & Kgosikoma, 2013). This limits the amount and quality of food available for cattle leading to malnutrition further exacerbating their vulnerability to disease.

The effects of heat on meat production extend beyond animal welfare and health. The beef industry is highly dependent on water availability for both drinking and irrigation purposes. With rising temperatures and droughts becoming more frequent due to climate change, water scarcity becomes a significant issue for cattle farmers (Bryceson et al., 2014). This presents additional challenges in ensuring the supply of feed for cattle herds.

Furthermore, heat also affects logistical operations within the beef industry. As temperatures rise, transportation of live animals becomes challenging due to stress on animals during long-distance journeys (Marasini & Gomersall, 2019). This result in delays and increased costs for farmers when selling their livestock apart from possibly affecting the tenderness of the meat as already discussed above. The cost of beef transportation can be increased due to adapting to the effects of climate change like ensuring animal welfare in transporting and finding alternative transport routes to avoid storm effects. Consumers might, therefore, end up bearing these additional costs. Climate change can

lead to more frequent and severe weather events, such as floods, hurricanes, or wildfires, damage to transportation infrastructure, including roads, bridges, and railways, disrupting the supply chain for beef transportation. This is a real scenario that Botswana's beef industry is left to grapple with (Marasini & Gomersall, 2019). Addressing the impacts of climate change on beef transportation requires a combination of adaptive strategies, including improved infrastructure resilience, changes in transportation practices, and the development of climate-resilient supply chains. Proactive measures can help mitigate the potential negative effects and enhance the overall sustainability of the beef industry in the face of a changing climate.

2.1.5 Impact on Cattle Reproduction:

Ambient temperature among other environmental elements affects the fertility and reproductive performance of cattle. Dairy cattle performance is affected negatively by heat stress, which has been identified as a significant environmental variable affecting reproduction. It is particularly noted across the tropics, sub-tropics and many parts of temperate areas (Marasini & Gomersall, 2019). Dairy cattle have altered physiology, hormone functions and behaviours in response to heat stress which also affect their reproductive functions. Some of the effects of heat stress on the reproductive functions of dairy cattle are: Heat stress decreases blood flow to the uterus and causes elevated uterine temperature that in turn disturbs the intrauterine environment. It may also hamper implantation, embryonic growth, and embryonic survival. Foetal resorption, abortions and stillbirths may also be caused by heat stress on expecting cows (Marasini & Gomersall, 2019).

Dairy cows experience heat stress that negatively affects their ovarian function and estrus cycle (Angel et al., 2018). Heat stress can inhibit follicular development, lower ovulation rate, and deteriorate the quality of oocyte. Heat stress may also disrupt the FSH and LH secretions, which are stimulants of ovary activity (Angel et al., 2018). The corpus luteum which secretes progesterone,

another important hormone for pregnancy is also affected by heat stress. Heat stress influence the behaviour, sex and milk production of heifers and adult dairy cows (Angel et al., 2018). Furthermore, it can down regulate the intensity and the length of estrous period, making it hard to perform artificial insemination (Angel et al., 2018). Natural service of the bulls can be affected by heat stress because it reduces libido and therefore affects the mating behaviour. Sperm quality and bulls' fertility are also generally affected.

Heat stress can affect the survival of the embryo in cattle. High temperatures may interfere with crucial cellular processes and increase the likelihood of abnormalities in the developing embryo (Angel et al., 2018). It can also reduce the concentration of steroids in the fluid of the large mature follicles, which are important for the development and ovulation of the oocyte (Angel et al., 2018). This can impair the aromatase activity, which is the enzyme that converts androgens to estrogens. This can further lead to early embryonic loss and lower insemination success (Angel et al., 2018). Heat stress can also indirectly affect the reproductive performance of dairy cattle by reducing their feed intake, nutrient use, estrus expression, and milk production (Angel et al., 2018). A low feed intake can result in low fertility after calving and this can significantly impact on the reproduction ability of the cattle.

2.2 Adaptation of Cattle to Increased Global Temperatures and Effect on Beef Production

2.2.1 Behavioral Adaptation:

Animals have different ways of coping with the changes in the environment that affect their performance and productivity. They show various behaviours that help them adapt to the changing environmental conditions. Some of the behaviours that dairy cattle adopt include: seeking shade, standing time, feeding, defecating and urinating frequency, water intake, lying time, and drinking

frequency (Angel et al., 2018). Seeking shade is a common behaviour that helps the animals to avoid direct sun exposure. Dairy farms usually have shade structures that reduce heat stress. When the heat stress is high, cows tend to lie down less and stand up more (Angel et al., 2018). This helps them increase their body surface area, which allows more heat loss by evaporation. It also helps them avoid the heat from the ground.

Generally speaking, when temperatures rise, the frequency of urination and defecation reduces as the body loses water through sweat (Angel et al., 2018). The body does not also require producing a lot of internal heat and therefore many physiological processes are slowed down. The rate of waste accumulation in the body is reduced and therefore the rate of excretion (Angel et al., 2018). Development of muscle mass and general body condition in cattle depend on efficient digestion and nutrient absorption. When a cow does not defecate well, it may not be using fully the available nutrients and this can affect its growth and muscle building. Poor excretion can affect the energy balance of the cow. Energy is crucial for muscle development and fat deposition, both of which contribute to the overall quality of beef. Depending on the dietary balance and health status of an animal, the chemical composition or tenderness may vary. The meat quality will also be affected. The European Union economic block is one of the main consumers of Beef produced in Botswana. One of the main preferences of the EU is High quality, lean, and full-flavoured beef that is produced by free-ranging and natural farming methods (Oliver et al., 2016). Lean beef is mostly a result of a well-balanced nutrition which cannot be achieved with unbalanced feeding habits due to extreme temperatures.

Cows under heat stress exhibit a sharp decline in the frequency of their urination. Extreme weather conditions cause cattle to limit their feed intake. When cows are fed during periods of high temperatures, their metabolic heat increment typically rises, causing them to consume less feed

overall (Angel et al., 2018). This can lower the body weight and body condition score, which represents the cattle's productive performance. In extreme weather, there is an increase in water usage. In situations of heat stress, water is essential, and cows often prefer water that is at a moderate temperature, that is, neither too hot nor too cold.

2.2.2 Blood Biochemical Response:

The health status of the cattle can be assessed by the blood biochemical composition, which is influenced by various factors, such as nutrition, management, stress, and diseases. The blood biochemical composition includes different components, such as packed cell volume (PCV), haemoglobin (Hb), plasma glucose, albumin, total protein, total cholesterol, and non-esterified fatty acid (NEFA) (Angel et al., 2018). These components can change when the cattle are exposed to heat stress, which is a major effect of climate change. Heat stress can reduce the number and the amount of red blood cells (RBC) and Hb in the cattle, which indicate their ability to adapt (Angel et al., 2018). This is because heat stress increases the oxygen consumption of the cattle, as they breathe faster to cool down their body. This also increases the oxygen pressure in the blood, which reduces the production of new RBC and Hb. Heat stress causes an increase of the water demand in the blood stream that dilutes the blood and decreases its PCV (Angel et al., 2018). However, as a form of response to heat stress, the amount of plasma albumin goes up in the blood. Plasma albumin has an anti-oxidant role in removing heat free radicals.

When cattle are under stress, PCV and Hb decrease because they need more water in the blood system to cool down the body by diluting the blood (Angel et al., 2018). This also reduces the production of new red blood cells and Hb. Also, total cholesterol decreases when the cattle are under heat stress, because they use less cholesterol to produce hormones and other substances (Angel et al., 2018). This also reflects the reduced metabolic activity of the cattle under heat stress. The activity of

some enzymes in the blood, such as aspartate aminotransferase (AST), alanine amino transferase (ALT), and alkaline phosphatase (ALP), changes when the cattle are under heat stress. These enzymes are involved in different metabolic processes, such as amino acid metabolism, liver function, and bone formation (Angel et al., 2018). The changes in the activity of these enzymes indicate the impaired function of the organs and the tissues under heat stress.

2.2.3 Cellular and Molecular Adaptation:

Animal cells have a way of adapting to heat stress, which is expected to be caused by the changing climate. This adaptation can help the animals survive the high temperature and to become more tolerant to heat. The cells respond to the heat by changing their gene expression and their protein activity. Some of the genes that help the cells to adapt to heat are called heat shock proteins (HSPs) and other thermo-tolerant genes (Angel et al., 2018). These genes are activated by a signal called heat shock transcription factor 1 (HSF1), which is triggered by heat stress. Some cattle breeds that live in hot climates, such as Senepol, Bostaurusindicus, and Romosinuano, have different thermo-tolerant genes that help them to cope with the heat (Angel et al., 2018). These genes can be used as markers to identify and select cattle that are more tolerant to heat stress through breeding programs.

Heat resistance genes play a crucial role in mitigating the effects of heat by maintaining cellular homeostasis, regulating metabolic processes, and minimizing oxidative stress (Angel et al., 2018). However, prolonged exposure to extreme heat can disrupt the normal functioning of these genes, leading to a decrease in their efficiency. This has been the case with the changing climate and it is expected to continue if temperatures continue to rise. As a consequence, the ability of cows to cope with high temperatures may be compromised (Angel et al., 2018). From a beef quality perspective, the impact of interference with heat resistance genes or stretching their abilities can be

phenomenal to the beef quality. Heat-stressed cows may experience changes in muscle metabolism, leading to variations in meat quality attributes such as tenderness, colour, and flavour (Angel et al., 2018). Additionally, heat stress can contribute to increased fat deposition, affecting the lean-to-fat ratio in the meat. The meat from heat-stressed cows may exhibit differences in water-holding capacity and pH, potentially influencing the sensory characteristics that contribute to overall beef quality (Angel et al., 2018). Therefore, managing environmental temperatures, providing adequate shade, and implementing strategies to alleviate heat stress are essential not only for the welfare of the cows but also for maintaining the desired quality of beef in the production process.

2.2.4 Neuro-Endocrine Adaptation:

The endocrine system is one of the main systems that help the animals to adapt to heat stress. The endocrine system involves different glands and hormones that regulate the body functions and responses to stress. The hormones that are related to heat stress adaptation include glucocorticoids, catecholamines, antidiuretic hormone (ADH), thyroid hormones, mineralocorticoids, growth hormone (GH), and prolactin (PRL). When the animals are under heat stress, they activate two main pathways: the sympatho–adrenal medullary axis (SAM) and the hypothalamic-pituitary adrenocortical axis (HPA) (Angel et al., 2018). The SAM pathway stimulates the adrenal medulla to release epinephrine and norepinephrine, which are also called adrenaline and noradrenaline (Angel et al., 2018). These hormones help the animals to cope with the stress by increasing the heart rate, blood pressure, and blood sugar. The HPA pathway stimulates the adrenal cortex to release glucocorticoids, such as cortisol. These hormones help the animals to relieve the stress by reducing the inflammation, suppressing the immune system, and increasing the glucose production in the liver (Angel et al., 2018). The cortisol level in the blood increases when the animals are under acute stress,

but decreases when the animals are under chronic stress (Angel et al., 2018). The cortisol level can also be used as an indicator of heat stress in animals.

Blood concentration of glucocorticoids determines the extent of heat stress the animals face. Another hormone called aldosterone which is released from the adrenal glands assists animals in maintaining the water and mineral balance in their bodies (Angel et al., 2018). An aldosterone-mediated pathway is activated when the animals are dehydrated because of hotness and restores the water and electrolytes (Angel et al., 2018). The other hormone that is involved in the heat adaptation of the animals is known as thyroid hormone. The thyroid hormone controls the amount of heat produced by the body and is also a marker for assessing heat tolerance of the animal. Heat distress lowers blood levels of thyroid hormone like T3 or T4 and also lowers milk levels of these hormones for cows (Angel et al., 2018). Heat stress also leads to the reduction of the activity of pituitary thyroid axis that controls the secretion of thyroid hormones in the steers. The low energy production rate and tolerance towards the thermal stress further slows their ability to produce less heat (Angel et al., 2018).

Climate change will mainly involve increased temperature often affect neuro-endocrine adaptation in beef production thereby altering beef quality. Due to limited abilities to control its body temperature when it gets hot, this phenomenon triggers a neuro-endocrine response towards restoring equilibrium within an individual. In particular, it is important to note that most of these systems are based on the neuro-endocrine system, which is involved in most of these processes including the hypothalamus, pituitary gland, and adrenal glands, among others.

2.2 Theoretical Framework

Theoretical frameworks are intellectual tools that are composed to provide a basis for understanding the dynamics or factors that affect different issues or subjects of discussion. When applied to the Botswana beef industry, the frameworks offer a conceptual roadmap for understanding the intricate interactions between climate change and the ecological, social, and economic aspects of Botswana's beef industry. This chapter critically engages with established theoretical frameworks, each offering a unique perspective on the interplay between climate change and the Botswana beef industry.

2.3.1 Environmental Systems Theory:

The Ecological Systems Theory was first put forward by Urie Bronfenbrenner. It is normally useful in explaining how human and animal development is influenced by different levels of environmental systems, from the immediate surroundings to the broader societal structures (Bennett & Chorley, 2015). Bronfenbrenner broadly categorizes these systems as the microsystem, the mesosystem, the exosystem, the macrosystem, and the chronosystem with each system representing a different level of environmental influence on human and animal behaviour and interactions. This theory can be applied to understand how climate change affects the beef industry in Botswana as below:

The microsystem is the first and most influential level of the ecological systems theory. It consists of the direct and immediate environments and relationships that the individual interacts with, such as family, friends, school, and work (Mogomotsi, Nyangito & Tsopito, 2016). For the beef industry in Botswana, the microsystem includes the cattle ranches, feed, parasites, and clean water amongst other factors that directly affect the well-being of cattle. These factors are directly affected

by climate change, and this translates to a direct impact on the well-being of the cattle. Climate change affects the health and productivity of the cattle, which reduces the quantity and quality of beef that the farmers can produce and sell. Mogomotsi, Nyangito and Tsopito found that climate change reduced the body weight, carcass weight, and fat thickness of cattle in Botswana through their study on *Climate change and variability: smallholder farming communities in Botswana* (Mogomotsi, Nyangito & Tsopito, 2016). This therefore affected the meat quality and profitability of the farmers. The microsystem also involves the bi-directional interactions and influences among the actors, which can either enhance or hinder their adaptation to climate change. For example, supportive and cooperative relationships among the farmers, their families, their employees, their customers, and their suppliers can help them cope with the challenges and opportunities of climate change, such as sharing information, resources, and strategies. On the other hand, conflictive and competitive relationships can undermine their adaptation and resilience to climate change, such as hoarding.

The mesosystem is the second level of the ecological systems theory (Bennett & Chorley, 2015). It looks at the interactions and connections between different microsystems. In the case of the Botswana's beef industry, the mesosystem includes the linkages and networks among the different actors and stakeholders involved in the production, processing, marketing, and consumption of beef, such as the farmers, the processors, the traders, the retailers, the consumers, the regulators, and the researchers. These actors and stakeholders are interdependent and influence each other through their actions and decisions regarding the beef industry. Climate change affects the mesosystem by creating challenges and opportunities for the coordination and collaboration among the actors and stakeholders (Bennett & Chorley, 2015). For example, climate change can create supply and demand shocks, price fluctuations, quality standards, and market access issues that require the actors and stakeholders to adjust and adapt their practices and policies. Climate change can also create

opportunities for innovation, diversification, and integration that can enhance the efficiency and sustainability of the beef industry. For example, a study by Mogomotsi et al., found that climate change stimulated the adoption of improved breeds, feed supplements, water harvesting, and conservation agriculture among the cattle farmers in Botswana, which improved their productivity and resilience (Mogomotsi, Nyangito & Tsopito, 2016).

The third level of the ecological systems theory is the exosystem and it refers to the external environments and relationships that affect the individual (in this case, the animals) although they do not directly interact with them (Bennett & Chorley, 2015). The exosystem therefore in this case deals with those factors that will be changed or affected by climate change in Botswana and indirectly affect the reproduction capacity, growth or beef quality obtained from cattle in the country. These factors can include the government, the media, the economy, and the culture. For the beef industry in Botswana, the exosystem includes the national and international factors and forces that shape the context and conditions of the beef industry, such as the political, economic, social, and environmental factors and forces. In the beef industry, climate change creates opportunities and threats for development and competitiveness. For example, climate change can create policy and regulatory changes, trade and market changes, consumer and societal changes, and natural and ecological changes that affect the beef industry. A changing climate can also provide opportunities to promote and recognize the beef industry as a source of income, food, and employment. For example, a study by Mogomotsi et al. found that climate change increased the demand and preference for Botswana beef in the international market, especially in the European Union, due to its high quality, lean, and full-flavoured characteristics, which are produced by free-ranging and natural farming methods (Mogomotsi, Nyangito & Tsopito, 2016).

The fourth level of the ecological systems theory is the macrosystem. This focuses on those abstract things that can be influenced by climate change and in turn influence the beef industry in Botswana. These can include ideologies, culture and beliefs. The macrosystem for the beef industry encompasses history, culture and other external forces or phenomena that have an influence on the culture and identity of the beef industry which includes practices or behaviours, rituals or symbols associated with cattle herding, ranching and beef production (Bennett & Chorley, 2015). Macrosystem is affected by climate changes that make it have challenges/provide opportunities in the beef being preserved and transformed as a legacy of pride for the nation (Mogomotsi, Nyangito & Tsopito, 2016). For instance, climate change would have led to cultural and sociological changes among these people that have affected their perceptions and attitude about beef production thereby leading them to lose interest in animal husbandry or embrace other diets (Mogomotsi, Nyangito & Tsopito, 2016). The beef industry may be able to revitalize and innovate its culture and identity since it is linked with climate change to become one source of cultural heritage for the country. For instance, they could improve quality and variety by coming up with new products or markets.

The last and fifth division of the ecological system theory is the chronosystem. This includes the contextual features of the environment in which the person lives and events like changes, transitions and trends occurring along the time axis (Mogomotsi, Nyangito & Tsopito, 2016). The chronosystem consists of the past, present, and future elements and influences that determine the path of development of the beef industry in Botswana. Chronic system is further affected by climate change by introducing both the uncertainty and a possibility to reshape it by the beef industry of the future (Mogomotsi, Nyangito & Tsopito, 2016). This could include climate change that brings about unexpected harsh or severe weather, including famine and flash flooding, excessively high temperature and torrential storm, thereby affecting the quality of beef, among other things.

Additionally, climate change may result in chronic changes like the increase or decrease of climate attributes including precipitation and temperatures which impacts on the availability of suitable land, water, and pasture for livestock production (Mogomotsi, Nyangito & Tsopito, 2016). Climate change can also offer chances for beef adaptations and mitigations concerning climate change through incorporation of new improved technologies, practices, and policies which minimize vulnerability and maximize durability of the beef industry.

The Ecological Systems Theory is a useful framework to understand how climate change affects the beef industry in Botswana, which is one of the main sources of income and food security for the country. The theory shows how climate change affects different levels of environmental systems that influence the behaviour and interactions of the actors and stakeholders involved in the beef industry, from the immediate surroundings to the broader societal structures. The theory also shows how climate change creates challenges and opportunities for the adaptation and resilience of the beef industry to climate change, as well as for the development and competitiveness of the beef industry in the national and international markets. The theory can help to identify and address the problems and potentials of the beef industry in Botswana, and to design and implement effective and sustainable solutions and strategies for the beef industry in the context of climate change.

2.3.2 The Adaptation and Resilience Theory

The Adaptation and Resilience Theory may be used to understand and mitigate the effects of climate change on the beef industry based on the manner in which the actors and stakeholders will absorb, adapt, or evolve into new behaviours as a result of climate change (O'Connell, 2015). The theory focuses on the adjustments that can be made by different stakeholders to ensure sustainability, in this case of beef production, in the wake of the changing climatic conditions.

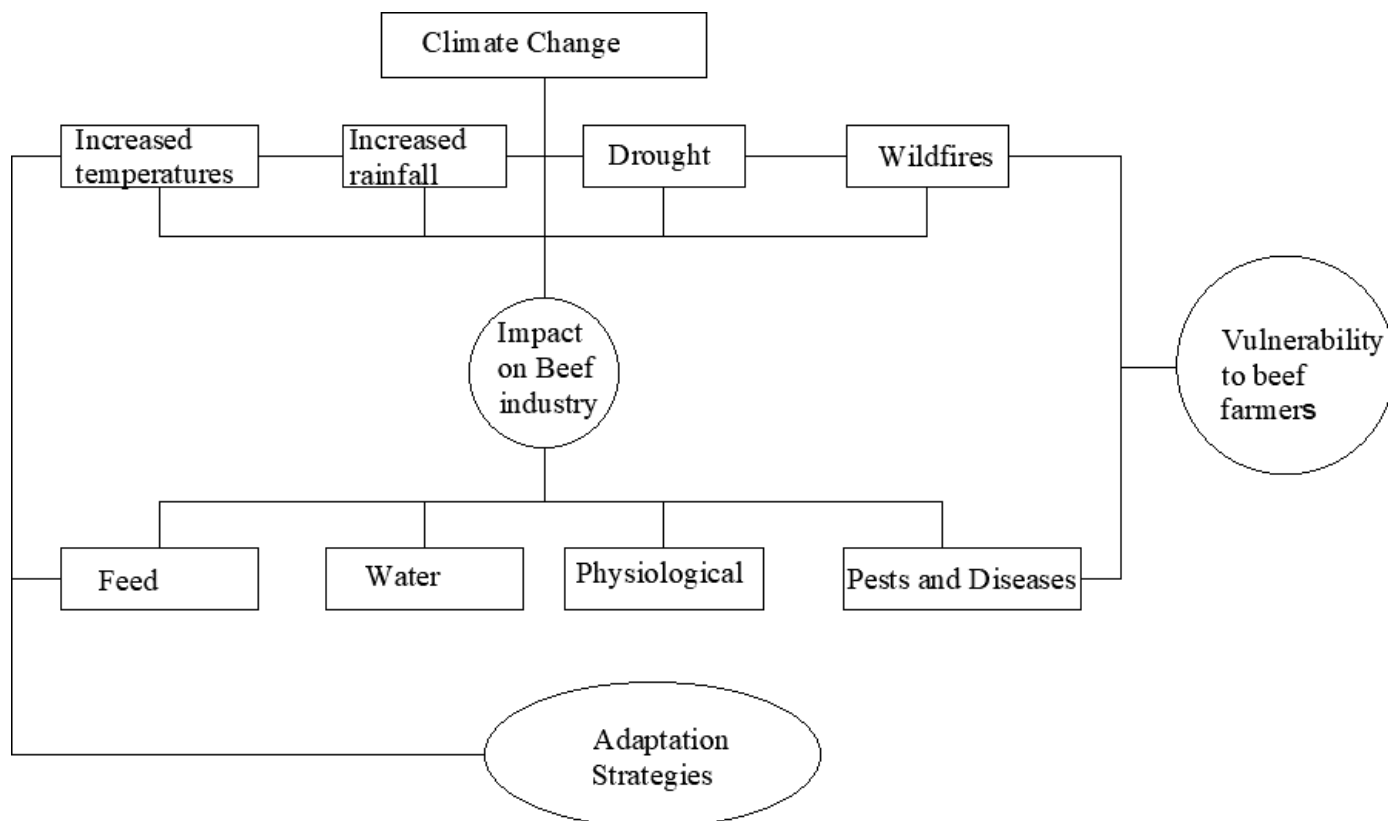
Adaption as already noted constitutes modification of behaviour by the actors and other stakeholders involved with a purpose of minimizing their susceptibility and enhancing their adaptive capacity to climate change. For example, the cattle farmers can adopt improved breeds, feed supplements, water harvesting, and conservation agriculture for higher productivity and resilience. The supply and demand shocks, price fluctuations, quality standards, and market access problems associated with climate change can be addressed by processors, traders, and retailers through the appropriate adjustments of their practices and policies (O'Connell, 2015). Thus, the beef industry can be supported by the consumers, regulators as well as researchers through information, resources and ways for improvement respectively.

Resilience is about the ability and capability of the involved parties to take stock, adjust and still prosper under climate change conditions (O'Connell, 2015). For instance, according to the theory, the cattle farmers can increase their resilience through diversification of income sources, improved social networks, as well as insurance and credit facilities. Innovative products and services, integrated supply chain system, and partnerships among processors, traders, and retailers will enhance their resilience (O'Connell, 2015). To improve its resilience, the beef industry should promote its values, benefits, and potentials, as well as create and implement successful and sustainable solutions and strategies, which may also be helpful for consumers, regulators, and researchers.

The Adaptation and Resilience Theory can help to identify and address the problems and opportunities of the beef industry in Botswana, and to design and implement effective and sustainable solutions and strategies for the beef industry in the context of climate change. The theory can also help to recognize and appreciate the historical and cultural factors that shape the identity and meaning of the beef industry, and to preserve and transform the beef industry as a source of pride and heritage for the country.

2.3 Conceptual Framework

The conceptual framework revolves around a multidimensional analysis incorporating climate change aspects, their impact and the adaptive strategies employed as illustrated below:



The specific changes in climate majorly include increased temperatures and rainfall. Drought episodes and wildfires will be discussed. These changes impact cattle productivity in terms of the quality and quantity of feed availability, water availability, Physiological wellbeing and vulnerability to pests and diseases. Elevated temperatures, erratic rainfall patterns, and intensifying droughts will be the mains aspects of climate change in Botswana discussed on this conception framework. Climate change necessities adaptation from farmers, who must strategize across diverse scenarios. Increased rainfall, initially viewed as positive, can bring destructive flash floods damaging infrastructure and endangering livestock. Rising temperatures accelerate evaporation, parching grazing lands and

stressing animals. Droughts, becoming more frequent and severe, leave pastures barren and water sources scarce, pushing herds to the brink. These contrasting yet interconnected climate changes inform Botswana's beef farmers' adaptation strategies on multiple levels as will be detailed in the following chapters of the essay.

Summary

In summary, the Ecological Systems Theory and the Adaptation and Resilience Theory can both be related to climate change and beef production. The Ecological Systems Theory describes how climate change influences the beef sector through various levels of environmental systems ranging from the micro system to chronosystem and the way these actors and stakeholders interact and influence one another at these levels. The adaptation and resilience theory explains how the actors and stakeholders of the beef industry contend with, resist, turnaround and strengthen themselves to survive during climate changes. The theories can be used in understanding what are the challenges and opportunities for beef productions against its environment under the impacts of climate change. The paper will use these two theories as the conceptual and analytical frameworks to conduct the research on the challenges to climate change adaptation in the beef industry in Botswana. This will guide the research in making conclusions of scientific basis and backing and therefore provide room for inferences that can be backed with existing data and facts. Through the analysis conducted from collected data and archival studies, the research will provide a conclusion that will be based on evidence and also necessary recommendations.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

Methodology provides directions, legitimacy, and authenticity which the research needs. It is in a sense the heart of the research process, comprising the various steps involved as well as their approaches and rules. It involves selecting appropriate ways of gathering and presenting data in such a way that the reader can comprehend the steps followed and the outcome of the steps. Weighing of the options precedes any particular type of study. Also, it is worth noting that methodology is not rigid but flexible with regard to changing circumstances. In carrying out their studies, researchers must specify issues about each step – what was done in designing a study, how the data were

collected, how the results were analysed, and how the findings were interpreted (Kazdin, 2016). The methodology serves as a shield against prejudices, errors, and misconceptions so that it is highly probable that the findings are credible enough to be duplicated and generally accepted. Researchers use methodology to obtain information for supporting an idea or responding to vital questions or issues concerning human beings, the environment or different aspects of the environment (Kazdin, 2016). Any research, be it scientific inquiry, social analysis, or humanities scholarship requires a strong methodology for the credibility and authenticity of results.

This section discusses about the methods used to obtain data for the research as well as the design to be adopted. The study discusses what population is going to be researched on, the design of the study, the method used in obtaining samples, number of sample, kinds of instruments which should be employed, validity and reliability of these instruments, procedure of gathering data, procedure of analysis and ethics considered in the process of collecting and using data.

3.2 Research Design and Area of Study

A qualitative survey approach was employed for this study case study. A qualitative survey approach pries deeper than traditional surveys, seeking rich descriptions and personal narratives over mere numbers. Open-ended questions and smaller, targeted groups unlock the "why" and "how" behind opinions, experiences, and perceptions. While not statistically generalizable, this method excels at uncovering underlying motivations, identifying new themes, and informing effective interventions. Its flexibility allows for adjustments based on emerging ideas, but demands careful analysis to mitigate potential subjectivity and time-intensiveness. This approach allowed me to gain a rich understanding of farmer experiences, practices, and challenges within specific geographical

contexts of Botswana. By triangulating qualitative and quantitative data, I was able to paint a nuanced picture of adaptation strategies and their effectiveness.

Qualitative Data Collection:

Semi-structured interviews: In-depth interviews were conducted with a purposefully selected sample of beef farmers and officials in the agricultural industry in Botswana. The interview guide will explore the following themes: perceived climate impacts, implemented adaptation strategies, decision-making processes, and challenges faced. Open-ended questions will encourage rich narratives and detailed explanations of individual experiences.

Focus group discussions: To foster group synergy and explore shared perspectives, focus group discussions were conducted with farmers within each selected region. These discussions sought to get answers to the following prompts: collective adaptation efforts, knowledge sharing mechanisms, and perceived effectiveness of different strategies. This approach allowed for identification of shared challenges and community-based coping mechanisms.

Quantitative Data Collection:

Farm surveys: A standardized survey was administered to the participating farmers, gathering quantitative data on their farm. This data was further contextualized for the qualitative findings and allowed for statistical analysis to identify potential correlations between farm characteristics and specific adaptation choices.

Secondary data analysis: Existing data from government agencies, agricultural organizations, and meteorological services were leveraged to provide additional information on the qualitative data collected. This data included rainfall patterns, temperature changes, drought frequency, and

government policies related to agriculture and climate change. This enriched the research by providing a broader context for understanding the external factors influencing farmer adaptation decisions.

Data Analysis and Triangulation:

Qualitative data from interviews and focus groups was transcribed and analyzed thematically, identifying recurring patterns and meanings within and across narratives. Quantitative data from the farm survey and secondary sources was statistically analysed to explore associations and trends. The triangulation process was then performed weaving together the quantitative and qualitative insights, offering a comprehensive understanding of how farmers adapt to climate change within their specific contexts.

This mixed methods case study approach allowed for a conversant exploration of beef farmer adaptation in Botswana. The combination of in-depth interviews, focus groups, and surveys provided the depth and breadth necessary to capture the diverse experiences, strategies, and challenges faced by farmers navigating a changing climate. Through triangulation and rigorous analysis, this research strived to offer valuable insights for policymakers, extension services, and development agencies aiming to support the long-term sustainability and resilience of Botswana's vital beef industry.

The study areas was Botswana, which is a country located in Southern parts of Africa. The country is renowned for its thriving beef farming industry. Botswana's favourable climate, vast ranches, diverse vegetation, and robust economic activities contribute to its success in this sector (World Bank Climate Change Knowledge Portal., 2023)

Botswana's climate is predominantly semi-arid, characterized by hot and dry conditions. The country experiences distinct wet and dry seasons. The wet season occur between the months of

November and March and is mainly characterized by heavy rainfall (World Bank Climate Change Knowledge Portal., 2023). The dry season usually occurs from April to October, with little to no precipitation. This climate as such is well-suited for growth of natural pasture and that has been one of the main driving factors for the successful beef industry in Botswana.

Extensive ranches characterize the South East, the North West and Central District areas of Botswana. These ranches are typically vast, covering large areas of land where cattle are free to roam and graze on the abundant vegetation (World Bank Climate Change Knowledge Portal., 2023). The government of Botswana has implemented policies to promote sustainable ranching practices, ensuring the preservation of the natural environment while supporting the beef industry.

The vegetation in Botswana has also greatly contributed to the success of cattle farming. It mainly consists of a variety of grasses and shrubs that serve as essential food sources for cattle (World Bank Climate Change Knowledge Portal., 2023). The country's diverse flora includes species such as *Themodatriandra*, *Aristida* spp., and *Cenchrusciliaris*, which are highly nutritious for grazing animals (World Bank Climate Change Knowledge Portal., 2023). The availability of such vegetation ensures that the cattle raised in Botswana receive a balanced diet, contributing to the high quality of the country's beef products.

Beef farming is one of the main economic activities in Botswana and plays a crucial role in the country's economy (World Bank Climate Change Knowledge Portal., 2023). The beef industry contributes significantly to employment, export earnings, and food security. The government has implemented policies to support the growth of the sector, including investing in infrastructure such as abattoirs and cold storage facilities. These initiatives aim to improve the efficiency of beef production, enhance product quality, and expand market access (World Bank Climate Change

Knowledge Portal., 2023). This study will therefore focus on analysing how climate change is changing the beef industry in Botswana by collecting data whilst guided by the three research questions of what the challenges of climate change adaptation in SADC are, with a focus on Botswana beef industry, what the effects of climate change on Botswana Beef production are and the kinds of interventions Botswana can use to address the climate change challenges of beef industry to satisfy the domestic and international market.

3.3 Data Collection

Botswana was considered for the study because it has been one of Africa' leading producers of beef for the past few years. Climate change has been experienced throughout the world with its effects varying depending on a region's economic activities and the environment amongst other factors. Since Botswana has been producing beef for the past couple of years and for commercial purposes, it is expected that the biggest impact of climate change on the beef industry will be featured in the country and, as such, our research will be able to pick out on some of the indicators through the research design as described.

The research design determined the strategy for collecting and analysing data and interpreting results. It shaped all the elements of the study. This research design considered several key components that gathered meaningful information on the impact of climate change on the beef industry in Botswana. To gather qualitative data, questionnaires were used with structured questions that focused on particular responses. Interviews were also conducted to gather current information on the issue. Information gathered from all sources was analysed to produce meaningful inferences for the study using weighting scales. Furthermore, archival analysis of relevant reports, policies, and

climate change effects were conducted to gain insights into what will be the effect of climate change on the beef industry in Botswana. In such a modern study, archival data has three different functions.

Archival data is particularly useful in adding “empirical depth” to the subject under study. This can aid in assessing the historical or current effects of climate change not only to the beef sectors but other sectors that may have been impacted significantly. This data is normally analyzed from a triangulation point of view. The process of triangulation involves considering different information available and coming up with one point of convergence regarding the ideas being expressed with the information sorted. Denzine 1989 categorized triangulation into four basic perspectives: data triangulation (comparing multiple sources of data), investigational triangulation (use of many researchers), theoretical triangulation (evaluation of varying theories over the same data) and methodological triangulation (utilization of diverse methods for research). The fourth category of triangulation implies bringing together interview and archival data in order to qualify the interview responses as well as the response to the questionnaires (Zelčāne & Pipere, 2023). One way of getting round some of the problems with interview information is through archives. In general, archival materials are more trustworthy than interview data and questionnaires in three ways: these techniques are comprehensive, less invasive, and autonomous.

Archival data can be used to provide a more comprehensive understanding of a project by generating new types of data and enabling the verification of theoretical explanations based on other data sources (Zelčāne & Pipere, 2023). In this case, archival data can help evaluate the effects of climate change on the beef industry and future expectations. The data can be arranged systematically to give a systematic record of how the climate has been changing over the years and the effects that have been recorded. As will be shown in the discussion section of the project report, archival data

can be used to challenge established theories and create new theoretical models. The time component, which adds another layer of analysis, opens up new avenues for application and contemplation.

This research was guided by three main research questions which are:

- 1) What are the impacts of climate change on Botswana Beef production?
- 2) What are the main challenges of climate change adaptation in SADC, with a focus on Botswana beef industry?
- 3) What interventions can Botswana use to address the climate change challenges of beef industry to satisfy the domestic and international market?

To get insights on the first question, the following questionnaire items were used:

2.2.2 Climate change poses a significant threat to the beef industry in Botswana?

2.2.3 To what extent has climate change impacted each of the following aspects of beef production in Botswana?

Feed availability

Water availability

Increased pests and disease

Animal Physiological well being

6.1.1 To What extent do you believe climate change will impact the beef industry in Botswana in the next 5-10 years?

Further insights on the first research question were obtained from questionnaire items:

2.2.5 Please specify any particular climate change impacts you are aware of that affect the beef industry in Botswana.

4.1.1 What specific climate-related challenges do you observe in the beef industry in Botswana?

More insight on the same were gotten from interview question 11b

11. b Given the unique climate challenges in Southern Africa, particularly in Botswana, how has the beef industry experienced changes in temperature and precipitation patterns, and what implications does this have for cattle farming?

The second question was also answered through the questionnaire question 3.2.1 and Interview questions. The prompt in the questionnaire required the respondents to indicate on a scale of 1 to 5 how significant the provided common challenges were to the implementation of mitigation strategies in the Beef industry in Botswana.

Insights for the third research question were obtained from questionnaire prompt

5.1.1 How involved are various stakeholders (government, private sector, NGOs, local communities) in climate change adaptation efforts within the beef industry?

5.2.1 Are there challenges in collaboration between different stakeholders in implementing climate change adaptation strategies?

6.2.1 What recommendations do you have for enhancing climate change adaptation in the beef industry in Botswana?

And interview questions

11. g Given the international nature of the beef industry, how does Botswana collaborate with neighbouring countries and global partners to address shared climate challenges and promote sustainable practices?

11. i How can government agencies, industry stakeholders, and local communities collaborate more effectively to overcome the challenges posed by climate change in the Botswana beef industry, and what specific initiatives or partnerships would be beneficial in this regard?

The answers from the aforementioned survey were utilized to support the study's descriptive survey methodology. As such, a descriptive survey was the most common type. The goal of descriptive survey research is to methodically and precisely characterize a population, phenomena and circumstance. Since this research aimed at collecting both qualitative and quantitative data, the most accurate approach for the study was going to be the descriptive survey. The approach guaranteed that information gathered via both quantitative and qualitative methods was evaluated and contrasted in order to appropriately weight the data and ascertain their impact on the research.

3.4 Target Population

The study's main population was farmers and officials in the beef industry sector in Botswana. The farmers are the principal causalities of climate change on their cattle farming. Officials oversee the producers' daily operations on the beef market. Therefore, they occupy a unique position in this industry that makes them perfect for understanding what obstacles the industry experiences due to climate adaptation. The officials also are in a position to experience challenges posed by climate change in the industry by virtue of their day to day activities and this makes them very valuable in providing insights on the subject under study.

Animal health officials for instance provided important insights on the impact of climate change on animal health. According to literature, climate change has led to an increase in the prevalence of diseases such as tick-borne fever and heart water disease. These diseases can have a significant impact on animal health and productivity, leading to increased production costs and reduced profitability and it will therefore be very vital to get the views of the officials on the same or otherwise for the case of Botswana.

The study as noted employed an equal number of male and female participants. The use of an equal sex ratio (male/female) guaranteed the representativeness of gender in this case, the sample. This greatly helped to reduce the possibility of bias in the study (Lakens, 2022). Also, the fact that men and women may have different perspectives, experiences and challenges on the research topic based on gender made it important to get insights from both parties. By including both genders in the study, the research captured these differences and gained a more comprehensive understanding of the issues at hand (Lakens, 2022). This was important because the conclusions and decisions from the study are going to affect the general population around. Furthermore, if this was not properly managed, the research would have become gender biased resulting in unbinding decisions. Take for instance a study that includes only the male participants, then the findings might not be applicable to females. This bias can perpetuate stereotypes and limit our understanding of various issues.

3.5 Determination of Sample Size

Determining the appropriate sample size for a research study was a crucial step in ensuring accurate and reliable results (Lakens, 2022). A sample size that is too small can lead to biased results, while a sample size that is too large can lead to unnecessary resources being expended. Sample size determination is influenced by various factors, such as the research question, the size of the

population, the desired level of precision, and the chosen statistical test (Lakens, 2022). There are several methods for calculating sample sizes that entails including power analysis, sample size formulae, and simulation studies (Lakens, 2022). Each method has its advantages and limitations, and the choice of method depends on the specific research question and study design and also the type of data that is needed. In this section, a methodology for determining the sample size for the study will be discussed together with the relevance. For this study, the factors below were considered for determination of sample size.

- **Confidence Level:** The confidence level expresses the likelihood that the survey results will fall inside a given range. 95% is the most commonly used confidence level, meaning that there is a 95% chance that the survey findings are accurate. The selected population size will therefore enable the determination of the degree of confidence in this study a confidence level of 90% will be adopted.
- **Population Size:** A larger population usually requires more samples. For populations that are noticeably large, as this one will be, using a small portion of the population as a sample, however, might be adequate. The opinions of a small number of people will be gathered to represent the views of all Botswana citizens. Time and money limitations are just two of the many reasons for this.
- **Margin of Error:** The phrase "margin of error" (EE) refers to the allowable range within which the true population parameter is expected to fall. If there is a smaller margin of error, a larger sample size is needed (Lakens, 2022). Because the population being utilized does not constitute a significant representative sample of the population as a whole, it will not be feasible to attain an extremely tiny margin of error in this instance.

- Variability in the Population: When the population is more variable, a larger sample size is required to produce representative results.
- Objectives of the Study: The specific goal of the study is to determine the effect on climate change on the southern development region specifically in Botswana (Lakens, 2022).

Glenn 1992 provided two tables that could be used in the determination of the sample size, (Tables 1 and 2) (Glenn, 1992).

Table 1. Sample Size for $\pm 5\%$ and $\pm 10\%$ Precision Levels where Confidence Level is 95% and $P=0.5$.

Size of Population	Sample Size (n) for precision (e)	
	$\pm 5\%$	$\pm 10\%$
500	222	83
1,000	286	91
2,000	333	95
3,000	353	97
4,000	364	98
5,000	370	98
7,000	378	99
9,000	383	99
10,000	385	99
15,000	390	99
20,000	392	100
25,000	394	100
50,000	397	100
100,000	398	100
>100,000	400	100

Table 2. Sample Size for $\pm 5\%$ and $\pm 10\%$ Precision Levels where Confidence Level is 95% and $p=0.5$.

Size of Population	Sample Size (n) for Precision (e) of:	
	$\pm 5\%$	$\pm 10\%$
100	81	51
125	96	56
150	110	61
200	134	67
250	154	72
300	172	76
350	187	78
400	201	81
450	212	82

Glenn made the assumption that the sample sizes in the tables represent the number of responses received based on the mailed surveys and interviews (Israel, 1992). Secondly, Table 2's sample sizes are predicated on the notion that the attributes under examination are either normally distributed or almost so. It could be necessary to conduct a survey of the whole population if this premise is not true.

In consideration of the above table, this study targeted 50 officials in the beef industry sector in Botswana and 50 farmers who have specialized in cattle rearing. Therefore a total of 100 participants were recruited. These participants were selected randomly to ensure that the sample was a representative of the population. The population size of 100 participants was determined based on table 1 above that recommends a minimum of this sample size on a population greater than 100000. This will guarantee a precision level of ± 10 at a 95% confidence level. Also, recruiting and managing a larger sample could be challenging and expensive. A sample of 100 was more manageable and cost-effective, allowing for in-depth data collection and analysis with focused sampling strategies.

The participants that took an interview were not required to fill the questionnaire as the information sought from the interviews was almost the same as that sought in the questionnaires. 20 officials were interviewed and the rest requested to fill the questionnaire.

The study targeted only those individuals who have attained the legal age so that their details can be used with their consent. According to International Law, adults are people of legal age who have the capacity to make decisions and give their consent. Obtaining informed consent is among the main principles of any modern research with human subjects. This therefore requires one to have cognitive knowledge about participation decision of the participants recruited. Adults have the power to make their own decision on how they would handle any activity or study. Therefore, they can understand complex research protocols, possible risks, and implications of their participation. This is another reason why only adults will be involved in the research. Such comprehension is essential in achieving correctness as well as accuracy in research findings.

3.6 Sampling Techniques and Procedures

As already stated, the sampling style was random sampling. The procedure below was adopted.

1. Defining the Population: The population was specified first. In this case it was the total number of officials in the beef industry in Botswana.
2. Ascertaining the Sample Size: A sample size of 100 was chosen for this particular case and was adopted. The sample size was sizable and manageable and also statistically okay as was demonstrated.
3. Assigning a Special Number: Each member of the population was assigned a unique identification in form of a serial number.

4. Selecting the sample: Simple Random Sampling: All the available officials were given a number and random numbers were chosen to make the sample from the population.
6. Notifying and Gathering participants: The selected individuals were informed of the intention to have them as part of the sample for the study. All the necessary information about the study was also given to them.
7. Evaluating the sample: The samples were evaluated of their availability and willingness to participate in the study and provide honest opinions about the issues being discussed.

For the data to be collected, individuals were first approached and asked of their willingness and availability to undertake the questionnaire or interview questions. As already noted, these officials were randomly sampled in the various government departments and Non-governmental agencies in the Botswana beef industry as well as specialized cattle farmers. In order to guarantee that the sample taken from the population was representative of the entire population, random sampling was used. Taking samples at random indicated that the sample's features were probably going to reflect those of the broader group from which it was taken. If samples were not randomly collected, results may have been distorted or prejudiced and may not have fairly represented the population. Random sampling was required in order to draw reliable statistical conclusions about the population. Because of this randomness assumption, statistical tests and analyses could be used to draw conclusions from the sample for the whole study. The results of this study would not be valid if random selection of the participants, in this case the officials, was not used.

3.7 Data Collection Instruments/Tools

3.7.1 Questionnaire

During the research, a questionnaire was given to the participant. It included both closed-ended and open-ended survey questions. Open-ended questionnaires are a valuable research instrument because they can efficiently study the link between two or more variables, according to Chandra (2004). They promote more reflective and evocative answers that explore people's values, feelings, and past experiences. This foundation promotes empathy and understanding among people (Chandra & Fisher, 2009). Open-ended questions can help people think critically, participate more actively, and also improve their capacity to evaluate a variety of sources of information. Because they produce a comprehensive set of qualitative data that is unconstrained by the narrow range of alternatives of closed questions, open-ended research questions are advantageous. As a result, the researcher can come across intriguing new information and developing patterns that illuminate the true nature of complex events (Chandra & Fisher, 2009). In addition, open-ended inquiries can stimulate creativity in circumstances requiring problem solving. These inquiries frequently encourage critical thinking by pushing people to consider opposing viewpoints and potential solutions. This kind of approach generally gives people a sense of freedom, which is the primary premise of this study.

The options available to the respondent in closed-ended inquiries are restricted, such as a list of options, a numerical response, or a Yes/No response. Responses are therefore clearer in terms of quantification. There will be some closed-ended questions on the survey as well. This clarity will assist in preventing contradictory interpretations of the gathered data. Because closed-ended questions are quick to answer, they will save you important time when conducting the interview and completing the questionnaire. Any data gathered was quantified because these questions were to yield answers that are precise, countable, and measurable.

3.7.2. Interviews

As already stated, interviews were conducted for selected official in the beef industry in Botswana. Interviews, as opposed to questionnaires, offer an alternative viewpoint for responding. These were beneficial due to: The interviewing procedure enabled a thorough examination of the subjects. The main distinction between surveys and interviews is that the former are primarily composed of closed-ended questions, while the latter give respondents the chance to express their thoughts and feelings in greater detail.

Interviews also provided the opportunity to probe. It was easier to get clearer answers to the research questions (Chandra & Fisher, 2009). Additionally, interviews yielded incredibly detailed information about individual accounts of perceptions, attitudes, and experiences. Such qualitative data is crucial for any sociological research project or analysis of a "soft" phenomenon. Furthermore, significant non-verbal clues can be used in conjunction with these kinds of inquiries. Face-to-face interviews allow researchers to observe nonverbal clues such as tone of voice, body language, and facial expressions (Chandra & Fisher, 2009). These cues could reveal parts of the participants' emotions that they would not have otherwise been captured through a questionnaire.

3.7.3. Archival Analysis

As already noted, archival analysis was important in getting past information on climate change effects on cattle as well as the beef industry in general. This was critical in the systematic presentation of the information obtained during the research.

3.8 Instrument Piloting, Validity, and Reliability

Because of time and strained resources, pilot studies were not conducted for this research. The main research was undertaken immediately the permit was obtained and samples identified. The integrity of the results obtained through deliberate statistical undertakings. For instance, the sample

size was selected based on Glenn's table 1 therefore satisfying the requirement of population to sample size ratio. The research also was designed such that a confidence limit of 90% can be achieved. The results statistical bearings therefore made conclusions from the research validity. Responses were rated on a Likert scale. The Likert scale is typically a five, seven, or nine-point agreement scale used to measure respondents' agreement with various statements (Chandra & Fisher, 2009). Each response on the scale was awarded points as follows: Somewhat agree = 1, Agree = 2, strongly agree = -3, somewhat disagree = -1, Disagree = -2 and Strongly Disagree = -3. The responses were then analysed to produce quantifiable data to drawing conclusions.

3.9 Data Collection Procedure

As already noted, the data for this research was obtained by two main methods. That is by analyzing filled questionnaires and also responses as obtained from interviews. The procedure for collecting the data involved first establishing the sample and then acquiring the necessary legal requirements to conduct the research. Participants were notified of interview dates and datelines for submitting questionnaires which was 7 days. Participants were required to provide as much honest feedback as they could on the various questions posed, and filling out the questionnaire was voluntary. Before the exercise started, each participant received clarification on the same.

3.10 Data Processing Analysis and Interpretation

Data processing and analysis were conducted once all of the questionnaires had been returned. Data was examined for insufficient or unnecessary responses during processing, and it was determined whether an appropriate return rate was attained in respect to the instruments that were distributed. Responses were categorized and indexed into common themes in order to examine qualitative data. The analysis used the respondents' exact quotes to bolster particular points of

contention. Excel and Power BI were used to analyse all of the quantitative data derived from the Likert scale rating. Data entered in Excel was exported into BI for additional analysis and visualization. Descriptive and inferential statistics were employed in the analysis. The results were presented in tables and figures and interpreted in light of the study objectives, reviewed literature, and theoretical and conceptual frameworks.

3.11 Ethical Considerations

This research had careful consideration of ethics when collecting and analyzing data from every participant involved. It also acknowledged the right and interest of the local community as well as those who are affected with regard to the research outcome. Moreover, ethical practices such as informed consent and transparency were sought from the farmers, the factory workers, and other population members participating in the study. The researchers were also conscious of the possible issues that would arise if the results were published or shared. Because the study was done in an anonymous manner, participants' identities were never connected to the data or responses they provided, this ensured their privacy and lowered the possibility of negative social or professional outcomes.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the findings of the study based on the methodology discussed in chapter three. The chapter starts with descriptions of respondents, followed by interpretation and discussions

of findings. The purpose of the study was to establish challenges to climate change adaptation in Southern Africa Development Community (SADC): A case of beef industry in Botswana. Data included for analysis are only those from items that were answered; unanswered questions were omitted and classified as “missing system”. The analyses are presented thematically according to the research objectives. First, descriptive analyses are presented followed by inferential analysis. The research questions raised in chapter one are answered and discussions made to link the study findings with the existing body of knowledge. Data are presented in tabular and figural form.

4.2 Impacts of Climate Change on Botswana Beef Production

A total of 80 participants filled the questionnaires that prompted them on their views on the impact of climate change in Botswana’s beef industry. These included 50 farmers, and 30 officials in the Ministry of Agricultural Development and Food Security in Botswana.

The specific questions that sought insight into this research question were:

2.2.1 Climate change poses a significant threat to the beef industry in Botswana?

2.2.2 To what extent has climate change impacted each of the following aspects of beef production in Botswana?

Feed availability

Water availability

Increased pests and disease

Animal Physiological well being

2.2.3 What other ways has climate change affected the beef industry in Botswana?

6.1.1 To What extent do you believe climate change will impact the beef industry in Botswana in the next 5-10 years?

The response rate was 100% with all the participants returning their filled responses on the prompts.

The responses were rated on a Likert scale and the following results were obtained.

All the 80 (100%) participants strongly agreed that climate change posed a significant threat to the beef industry.

Aspect of Beef Production	Great Extent (%)	Somewhat (%)	Very Little (%)	Not at All (%)
Feed Availability	25 (31.25%)	30 (37.50%)	15(21.25%)	10(5.00%)
Water Availability	20 (25.00%)	40 (50.00%)	17(21.25%)	3(3.75%)
Increased Pests and Disease	35(43.75%)	25(31.25%)	15 (18.75%)	5 (6.25%)
Animal Physiological Well-being	18 (22.50%)	32 (40.00%)	20(25.00%)	10(12.50%)

The data reveals crucial insights into the perceptions of officials in the ministry of agriculture and food security in Botswana and farmers, particularly regarding the impact of climate change on various aspects of beef production. Notably, a substantial 50% of participants perceive a "somewhat" significant impact on water availability, indicating a prevalent concern within the industry. The lower but still considerable 25% who perceive a "great extent" impact on water availability suggests that a quarter of participants view water scarcity induced by climate change as a major challenge for the beef production sector.

The findings also underscore the pervasive influence of climate change on pest and disease prevalence, with a combined 75% of participants acknowledging its significant impact. Of this, 43.75% perceive a "great extent" impact, signaling a potential threat to animal health and overall productivity. The recognition of climate change as a key factor affecting pest and disease

prevalence suggests the need for adaptive strategies to mitigate these challenges and ensure the sustainability of the industry.

In contrast, while still concerning, the perceived impacts on feed availability and animal well-being are comparatively lower. Approximately 30% of participants identify a "great extent" impact on feed availability, indicating a moderate level of concern. Similarly, 22.5% perceive a "great extent" impact on animal well-being. These lower percentages may suggest that while these aspects are recognized as impacted by climate change, they may not be perceived as immediate and severe threats compared to water scarcity and increased pests and diseases.

The data highlights the complex web of challenges faced by the beef production industry in Botswana, with water scarcity and heightened pest and disease prevalence emerging as primary concerns. This information is pivotal for policymakers and stakeholders in developing targeted strategies to address these challenges and bolster the resilience of the industry in the face of climate change.

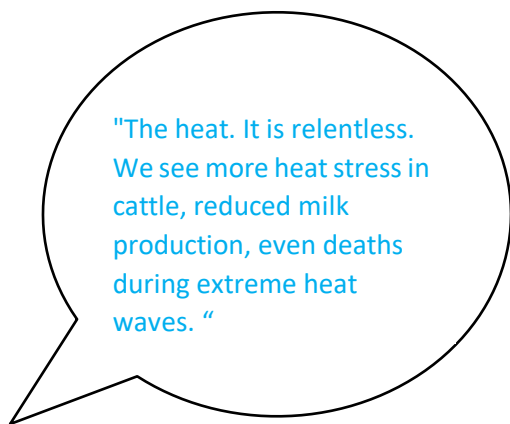
On what other ways that the climate had impacted Botswana's beef industry, important insights were noted. Notably, majority of the farmers spoke of dwindling vegetation cover, exposed and eroding soil, and the relentless advance of desertification. This shrinking canvas of grazing land directly impacted animal nutrition and the number of cattle they can support. Although this was a direct impact of increased drought, it was important to see that the farmers were keen on the immaculate issues that resulted from the drought with regards to feeding their cattle.

The farmers also noted that extreme weather events disrupted production and transportation, leading to market turmoil. Prices for agricultural produce including beef fluctuated and keeps doing so in the local and international markets, leaving farmers grappling with uncertainty and potential

losses. One farmer particularly noted that he was forced to sell cattle at a fraction of its normal market value due to a sudden drought that threatened his herd's survival.

According to some of the sampled farmers, the rising heat and water scarcity were demanding more labour and manpower to manage their herd. This meant more logistical and financial expenses. Farmers spoke of the constant need to water animals, find alternative grazing areas, and provide additional care during heat waves. This increased workload adds pressure on already strained manpower, impacting both family farms and larger operations.

Interviewed officials were also opined on how the beef industry experienced changes in temperature and precipitation patterns, and what implications it had for cattle farming? In general, they noted that the shifting temperature and precipitation patterns are no longer abstract concerns, but tangible challenges demanding immediate attention. From "unusually hot" to "unbearably scorching," was how several officials described the recent temperature increases. These extended heat waves pose a significant threat to animal health, stressing cattle and reducing their ability to graze and gain weight. One official likened the impact to watching milk production plummet during peak heat periods.



“Erratic” and “unpredictable” were recurring adjectives regarding rainfall patterns. The officials lamented the shift from reliable seasonal rains to

sporadic downpours followed by lengthy droughts. This unpredictability makes pasture management a gamble, forcing farmers to scramble for alternative feed sources when natural forage dries up.

The implications for cattle farming were numerous, and officials expressed varying degrees of concern. Increased disease outbreaks: Rising temperatures create breeding grounds for pests and diseases, leading to higher veterinary costs and potential herd losses. Degradation of grazing land: Erratic rainfall patterns disrupt natural grass growth cycles, leading to overgrazing and soil erosion, further limiting available pasture. Water scarcity: Droughts exacerbate the existing water challenges, forcing farmers to invest in expensive solutions like boreholes and trucking water, impacting profitability.

While acknowledging the severity of the situation, officials stressed the need for collaborative action. Increased research on heat-resistant breeds, government support for infrastructure development in remote areas, and financial incentives for adopting sustainable practices were seen as crucial steps. Overall, the message was clear: climate change is reshaping the beef industry, demanding adaptation and innovation. Officials, along with farmers and communities, stand at the frontline, their voices a clarion call for action to preserve this vital sector and ensure its future in a changing climate.

4.2 Challenges Facing the Implementation of Mitigation Strategies

4.2.1 Financial Challenges

The participants were asked to rate the severity of some given barriers to implementing mitigation strategies to climate change in Botswana as obtained from archival literature (Masike & Urich, 2008). The challenges listed were: Financial Barriers, Knowledge and Capacity Barriers, Institutional and Policy Barriers, Social and Cultural Barriers. The responses were as follows.

Barrier	Avg. Rating	Little(1)	Somewhat(2)	Major (3)	Critical (4)	Not at all(5)
Financial Barriers						
- Low household income	3.8	8 (10%)	16 (20%)	28 (35%)	20 (25%)	8 (10%)
- Limited access to financing	4.2	4 (5%)	12 (15%)	24 (30%)	24 (30%)	16 (20%)
- Uncertain ROI	3.5	12 (15%)	20 (25%)	24 (30%)	16 (20%)	8 (10%)
Knowledge & Capacity Barriers						
- Lack of awareness/knowledge	3.2	16 (20%)	24 (30%)	24 (30%)	12 (15%)	4 (5%)
- Insufficient extension services	4.1	4 (5%)	8 (10%)	20 (25%)	32 (40%)	16 (20%)
- Difficulty accessing climate data	3.6	12 (15%)	20 (25%)	28 (35%)	16 (20%)	4 (5%)
Institutional & Policy Barriers						

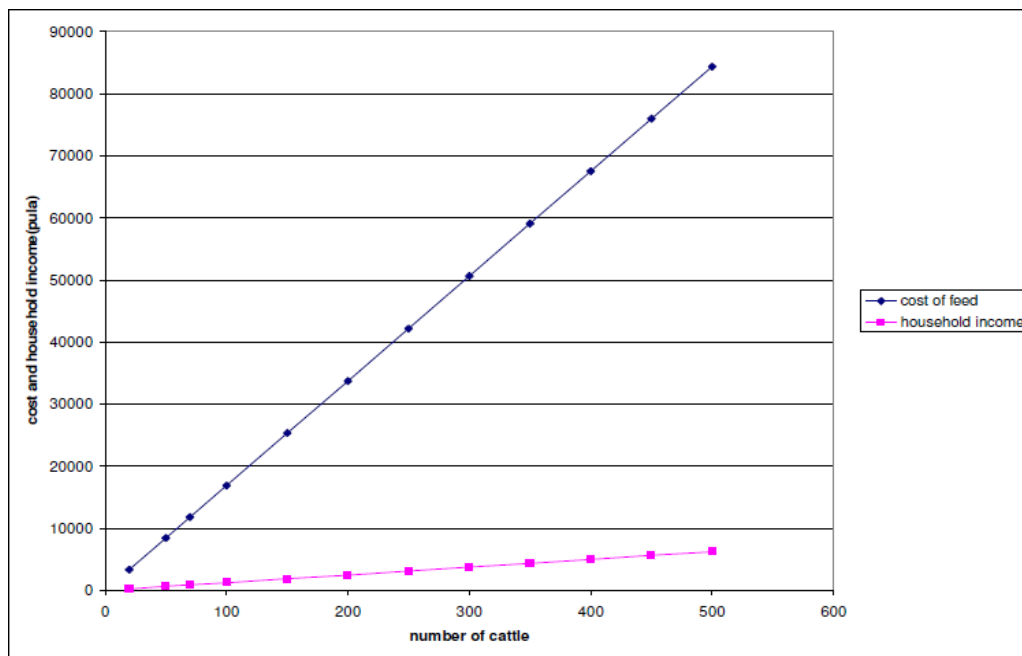
- Lack of clear policies	4.0	8 (10%)	12 (15%)	24 (30%)	24 (30%)	12 (15%)
- Conflicting regulations	3.7	12 (15%)	16 (20%)	28 (35%)	20 (25%)	4 (5%)
- Unfavorable market structures	3.3	16 (20%)	24 (30%)	24 (30%)	12 (15%)	4 (5%)
Social & Cultural Barriers						
- Resistance to change	3.1	20 (25%)	14 (17.5%)	34 (42.5%)	8 (10%)	4 (5%)
- Land tenure insecurity	3.9	8 (10%)	12 (15%)	24 (30%)	24 (30%)	12 (15%)
- Limited community involvement	3.4	16 (20%)	24 (30%)	24 (30%)	12 (15%)	4 (5%)

A significant 35% of participants identified Low household income as a major barrier to climate change mitigation implementation (rating 3) and another 25% finding them a critical obstacle (rating 4). Access to financing, particularly for long-term investments in combating climate change effects remains limited, with 30% of participants rating it as a major barrier and 20% a critical one. The general response from the interviews on this particular issue pointed to a severe lack of enough financial resources to implement possible mitigation strategies. According to an official (Name withheld for anonymity), one of the ways these financial challenges affect the industry is being an

impediment to the implementation of climate-smart solutions like acquiring and feeding drought-resistant breeds, installing water-efficient irrigation systems in animal feed farms, and using renewable energy. These often require significant initial investments. Small-scale farmers who form the backbone of the industry have been the most impacted financially, leaving them hesitant to adopt new practices even if they recognize their long-term benefits. He also noted that even for farmers that are convinced of the importance of these measures, securing the necessary funds remains a big challenge in Botswana. Traditional lenders often consider climate-friendly interventions risky due to perceived uncertainties, making them reluctant to offer loans (African Union report, 2023). This leaves farmers scrambling for alternative financing options, which are often limited or come with high interest rates, further straining their finances. The long-term nature of many climate mitigation strategies also poses another hurdle. While the benefits of improved water management or drought-resistant breeds may be evident over time, farmers often grapple with immediate financial needs and shorter-term return expectations. This uncertainty discourages investments that require waiting for future payoffs (Masike & Urich, 2008). To add on that, he observed that the financial deficit hinders collaboration between key stakeholders. Limited resources restrict the government's ability to offer significant financial support or initiate large-scale demonstration projects showcasing the viability of climate-smart practices (Masike & Urich, 2008). This missed opportunity for collective action and knowledge sharing impedes the development of innovative solutions and slows down the adoption of successful strategies across the industry.

These results concur with the findings of Masike and Urich (2008) in their study of the vulnerability of traditional beef sector to drought and the challenges of climate change. They noted that the farmer's ability to pay for supplementary feeds during drought was highly compromised because of their low income as a result of low off take rates given that majority of them are small

scale farmers as shown in the figure below (Masike & Urich, 2008). These farmers prefer to practise low cost farming even though this is always very vulnerable to drought. Rural household income for cattle farmers they note, is determined by cattle sales (Masike & Urich, 2008). During droughts, the cattle lose weight and therefore fetch lower market value. Many small scale farmers also look to destock due to their inability to afford supplementary feeds during this period and this creates an excess supply in the market reducing prices. Small scale famers own 80% of Botswana’s cattle and mostly market through informal sector channels (Masike & Urich, 2008). As such, the cattle industry becomes vulnerably exposed to climate change effects with the financial issue playing a significant role as captured in this paper.



Relationship between household income and cost of supplementary feeding for farmers in sampled village of Kglteng in Botswana as reported by Masike and Urich (2008)

On large scale financing, Botswana also seems to have a problem in terms of finding willing donors or bilateral funding for climate change adaptation. As reported by Alec Crawford in his review of the current and planned adaptation action in Botswana, while several donor countries supported Botswana's climate change initiatives between 2011 and 2013, most funding was not exclusively dedicated to adaptation (Crawford, 2016). Instead, it targeted broader environmental protection and disaster preparedness programs where adaptation played a secondary role. Sweden, the most consistent supporter, discontinued its funding in 2013 (Crawford, 2016). Also, Botswana's strong development progress has led to decreased international funding in recent years. As of April 2015, it only received approval for \$3.6 million in climate finance, none of which directly focused on adaptation (Crawford, 2016). A portion of a grant for national reports to the UNFCCC was assigned to indirectly support adaptation, while the remaining funds targeted a mitigation project. Notably, Botswana is among the few sub-Saharan African countries receiving no dedicated adaptation funding from international climate funds (Crawford, 2016).

However, Botswana recently established a National Environmental Fund to support environmental activities, particularly through civil society. Whether this fund will include dedicated resources for adaptation remains unclear but it promises to be a great avenue for funding climate change adaptation efforts in the beef sector of the country (Masike & Urich, 2008).

These findings underscore the need for financial support mechanisms like grant programs, subsidies, and loan guarantees to ease the burden on farmers, especially small-scale producers. Building financial literacy and exploring alternative financing models can also be beneficial to Botswana farmers in the long run especially in the anticipation of further changes in weather.

4.2.2 Knowledge and Capacity Barriers

The survey reveals a concerning lack of awareness and knowledge about effective adaptation practices. 30% of participants identified this as a major barrier, while another 15% considered it critical. This suggests that many farmers may not be fully aware of the available options or their potential benefits, hindering their adoption. This lack of knowledge could stem from various factors, including inadequate extension services, limited access to training programs, and information dissemination materials not tailored to local contexts. The data further highlights the inadequacy of extension services essential for bridging the knowledge gap. 40% of participants rated this as a major barrier, indicating a significant need for improvement. Extension services play a crucial role in providing farmers with practical guidance, technical assistance, and knowledge tailored to their specific needs and local conditions. Limited access to such support can leave farmers feeling overwhelmed and unsure of how to implement adaptation strategies effectively.

Climate data plays a critical role in informed decision-making regarding adaptation strategies. However, 35% of participants identified difficulty accessing climate data as a major barrier, and another 5% considered it critical. This lack of access could be due to various factors, such as limited internet connectivity in rural areas, inadequate data infrastructure, or user-unfriendly data platforms. Without readily available and understandable climate data, farmers struggle to make informed choices about resource management, drought preparedness, or selecting suitable crop varieties.

The African Union in its report on Country Food and Agriculture Delivery Compact noted that, in Botswana, the deep cultural roots of cattle farming often present a hurdle to adopting modern techniques that could boost profitability and sustainability (African Union report, 2023). Many communal farmers view their herds not just as assets but as an embodiment of their heritage and way of life. This results in traditional approaches to animal husbandry, where priorities

sometimes differ from maximizing output. The key challenge lies in bridging the gap between these ingrained practices and the potential for commercial success (African Union report, 2023). While tradition holds immense value, modern methods can optimize herd management, from selecting better quality inputs to sustainably managing pastures and land. These advancements, if understood and adapted, can significantly improve the lives of farmers and secure the future of cattle farming in Botswana (African Union report, 2023). One path to progress lies in education and awareness (African Union report, 2023). Empowering farmers with knowledge about profitable farming practices is crucial. Public initiatives, led by the government or international partners, can play a vital role in this (African Union report, 2023). Educational programs should clearly explain the various production methods, highlighting their pros and cons in the context of individual circumstances and goals. By understanding the potential for increased income and the long-term viability of their herds, farmers are more likely to embrace change (African Union report, 2023). This does not necessarily mean abandoning tradition entirely. Instead, it is about finding a harmonious balance where modern techniques enhance, rather than replace, existing practices. For instance, workshops could demonstrate improved breeding strategies that preserve local breeds while enhancing their productivity (African Union report, 2023). Similarly, training on rotational grazing techniques can be presented as a way to protect pastures, ensuring their sustainability for future generations.

Ultimately, the success of transformative efforts hinges on respectful engagement. Approaching farmers as partners, understanding their priorities and concerns, and tailoring educational programs accordingly will increase receptivity and encourage them to explore new possibilities. By bridging the gap between tradition and modern expertise, Botswana can chart a course for its cattle farming sector that honors its heritage while ensuring its long-term prosperity.

Through knowledge, collaboration, and a willingness to adapt, the future of cattle farming in Botswana can be both culturally rich and economically sound.

4.2.3 Institution and Policy Barriers

Institutions that govern the issues of climate change adaptations play a significant role in the adaptive measures taken up. This part of the research explored whether these institutions were effective in Botswana in guiding livestock farmers in adapting to effects of climate change or mitigating against them altogether. These institutions, which in this case will include the government of Botswana, have the responsibility of formulating progressive policies that allow farmers to quickly access mitigation measures and possible solutions to the challenges they face because of climate change. Policies can be local, regional or international and the research did not confine itself to any specific policies provided they impacted the beef industry in Botswana and had an effect on how farmers were adapting to climate change. For this case, the research was looking to find out whether there were clear policies, conflicting regulations or unfavourable market structures that impeded the activities of beef farmers in Botswana.

Majority of the participants noted that lack of clear policies was a major barrier to climate change mitigation measures, average rating of 4.0. 45% of respondents (30% rated 3 and 15% rated 4) believe the absence of clear and comprehensive policies creates uncertainty and discourages investment in mitigation efforts. Nearly a third (35%) of respondents identified conflicting regulations as a major obstacle to implementing climate mitigation measures in Botswana's beef industry. This pervasive challenge stems from inconsistencies and contradictions in policies related to land use, grazing rights, and potentially environmental management. These conflicting regulations create confusion and uncertainty, discouraging ranchers from investing in long-term adaptation strategies due to fear of non-compliance. One official interviewed lamented: "*Farmers*

want to be sustainable, they want to adapt," he continued, "but how can they invest in new practices when the rules might change overnight? It's like building a house on shifting sand." This is a clear indication of the lack of clear policies guiding the beef industry in Botswana.

Implementing well-designed and comprehensive policies that incentivize mitigation, support adaptation, and are implemented in a coordinated and inclusive manner, Botswana can create an environment that enables its beef industry to thrive in a changing climate. This however seems to be missing at the moment going by the findings of the responses in the research. In Botswana, climate change issues are majorly taken care by the National Portfolio Committee on Wildlife, Tourism, Natural Resources and Climate Change (NPCWTNRCC), stakeholders have however raised concerns about its effectiveness (Crawford, 2016). Established to provide continuous guidance and drive national action, the committee reportedly only convenes sporadically, primarily around UN climate conferences (Crawford, 2016). This infrequent engagement suggests a low national priority for climate change, leaving the committee unable to fulfil its intended role. It remains uncertain how the upcoming climate legislation and policies will affect the committee's function and efficacy. The trickle-down effect is the lack of clear policy guidelines on the mitigation measures that beef farmers can adopt in climate change response.

4.2.4 Social & Cultural Barriers

This research also sought to find out whether there were any social or cultural barriers that would hinder the implementation of climate change mitigation measures. It was hypothesized that if the majority of the famers in Botswana preferred to rely on traditional farming practises in rearing their cattle then it would be a challenge to adopt mitigation measures that would address challenges due to climate changes in the beef industry. The information from interviewed officials was to supplement what the famers had noted in their questionnaires. To get particular responses, the

participants were asked to rate resistance to change, land tenure insecurity and limited community participation as whether they thought were critical barriers to implement climate change mitigation measures or not. 42.5% of respondents considered resistance to change a major barrier to climate action in Botswana's agriculture while 10% considered it a critical barrier. Only 5% of the respondents thought that this was not the issue at all. The study sought to understand how this issue was affecting climate change mitigation measures from archival analysis and the following insights were noted:

Across 80% of Botswana's agricultural landscape, cattle reign supreme (Adams et al., 2003). Unlike profit-driven commercial farms, the traditional sector, practiced on tribal land by 97% of the cattle population, views livestock as a cornerstone of their way of life (Adams et al., 2003). Cattle are not just commodities; they embody security, social status, and a vital safety net in a land prone to erratic droughts (Adams et al., 2003). They serve as "banks" for school fees, dowries, and cultural ceremonies, while providing draught power and a potent symbol of prestige. This close link between cattle and cultural identity presents the first hurdle to implementing climate mitigation strategies. Stricter grazing management practices, like rotational grazing or reduced herd sizes are normally perceived as threatening this ingrained way of life. Farmers who view their herds as insurance against drought may be hesitant to adopt changes that could potentially jeopardize their social standing and economic resilience (Adams et al., 2003). In rural Botswana, where formal employment opportunities are scarce, cattle represent a lifeline for thousands of families (Adams et al., 2003). Any potential reduction in herd size, even if presented as beneficial in the long run, might be met with resistance due to the immediate implications on household income and food security (Adams et al., 2003). As already noted in this paper, small scale farmers complained of very low off take prices in the market during periods of drought when they are forced to destock, nevertheless, they destock to avoid losing

their herd altogether because of lack of supplementary feed. This is in the name of keeping as many herds of cattle as possible for cultural reasons already mentioned.

Land tenure insecurity, with an average rating of 3.9 and 30% of respondents deeming it significant, presented another cultural hurdle. Uncertain land ownership rights have created a precarious environment for long-term investments in land improvements associated with climate adaptation (Chatibura, 2023). Farmers hesitate to make necessary changes when secure ownership hangs in the balance. The disconnect between top-down approaches and cultural values of community involvement emerges as a critical barrier, with an average rating of 3.4 and 30% of respondents highlighting its importance (Chatibura, 2023). Traditional decision-making processes emphasize participation and collective action. Imposing solutions from above can clash with this deeply ingrained value, leading to limited buy-in and ownership of climate initiatives.

Unlike confined commercial systems, traditionally cattle are grazed freely across vast communal lands in Botswana with the tribal land system (Adams et al., 2003). In fact, there are three categories of land tenure: tribal land, state land (crown land before independence) and freehold land. Today, tribal land comprises 71% of the land area; freehold about 4.2% and state land 24.8% (Adams et al., 2003). Thus, the policy in Botswana has been to increase the area of tribal land at the expense of both state and freehold ownership (Adams et al., 2003). Tribal land is distributed by lands board under the Tribal Lands Act, while state land is majorly urban. Free hold land is the land that was neither used for urban development of farming and was therefore free for grazing (Adams et al., 2003). This free-ranging approach, while deeply interwoven with the pastoralist lifestyle, contributed significantly to environmental degradation. Overgrazing depletes grassland cover, exposing the soil to erosion and reducing its ability to trap carbon. This vicious cycle amplifies the impacts of climate change, leading to decreased pasture quality and exacerbated drought severity.

Proposing fencing and controlled grazing patterns clashes with this deeply ingrained cultural practice as demonstrated here (Crawford, 2016). Yet, this is one of the main interventions in view of the changing climate and the ability to rear healthy productive animals in a given space of land. The free-ranging system holds symbolic value, representing traditional land use rights and a sense of freedom for both the people of Botswana (Masike & Urich, 2008). Moreover, the social fabric built around cattle rearing extends beyond individual families. Sharing herds, exchanging resources, and collaborating on grazing management are cornerstones of community cohesion and cultural expression. Top-down solutions that fail to acknowledge these intricate social dynamics risk alienating stakeholders and jeopardizing the very communities they aim to help as unraveled in this research.

Water also forms another aspect of consideration in view of how it has traditionally been viewed and used versus how it is intended that it is used in the face of the changing climatic conditions, especially in consideration of how this can affect beef farming in the country. Water is a precious resource in Botswana, and cultural norms around water usage, such as communal ownership and customary rights, can make it challenging to implement water conservation measures. Traditional practices, such as using water for ceremonial rituals or agricultural activities, may place additional strain on water resources, particularly in the context of climate change-induced water scarcity. Balancing cultural values with sustainable water management practices is essential for addressing this challenge.

Gender roles and norms also influence cattle farming practices in Botswana. While men may be responsible for herding and decision-making related to cattle, women often play crucial roles in tasks such as milking, processing dairy products, and managing household water and fuel wood needs. Climate change-induced shifts in weather patterns have exacerbated these gender disparities,

further complicating efforts to promote sustainable cattle farming practices (Crawford, 2016). Gender-responsive approaches that empower women as decision-makers and provide them with access to resources and training are essential for addressing these challenges. Gender roles and norms also influence cattle farming practices in Botswana. While men may be responsible for herding and decision-making related to cattle, women often play crucial roles in tasks such as milking, processing dairy products, and managing household water and fuel wood needs (Crawford, 2016). Climate change-induced shifts in weather patterns can exacerbate these gender disparities, further complicating efforts to promote sustainable cattle farming practices. Gender-responsive approaches that empower women as decision-makers and provide them with access to resources and training are essential for addressing these challenges.

Fortunately, opportunities exist to bridge these cultural divides and foster a more sustainable future for Botswana's agriculture. Community-driven adaptation empowers local communities to take ownership of solutions, building upon existing knowledge and practices. Engaging communities in their own languages and through trusted channels allows for culturally sensitive communication, building trust and ensuring messages resonate with their values.

4.3 Interventions Botswana Can Use To Address Climate Change Challenges of Beef

Industry to Satisfy the Domestic and International Market

The research also sought to know whether farmers and also officials in the beef industry thought that different stakeholders were involved in climate change mitigation measures in the beef industry. The results were as follows:

Stakeholder	Not Involved (Number & Percentage)	Involved (Number & Percentage)	Very Involved (Number & Percentage)	Total
Government	5 (6.3%)	40 (50.0%)	35 (43.8%)	80 (100.0%)
Private Sector (Meat processing/retail)	10 (12.5%)	35 (43.8%)	35 (43.8%)	80 (100.0%)
Private Sector (Ranchers/Farmers)	15 (18.8%)	40 (50.0%)	25 (31.3%)	80 (100.0%)
NGOs (Environmental/Sustainability)	2 (2.5%)	25 (31.3%)	53 (66.3%)	80 (100.0%)
Local Communities (Rural populations)	8 (10.0%)	42 (52.5%)	30 (37.5%)	80 (100.0%)

While a small segment (6.3%) believes the government plays a minimal role, a sizeable portion (50%) sees them actively involved, and a significant share (43.8%) even views them as leading the charge. This suggests growing government engagement, potentially through policy or partnerships. Botswana's National Adaptation Plan Framework (NAPF) and Nationally Determined Contributions (NDCs) serve as key policy documents outlining their climate change commitments. Both documents specifically consider the beef industry, recognizing its vulnerability and identifying

strategies for adaptation (Darkoh, 2002). These include promoting drought-resistant forage varieties, improving rangeland management practices, and encouraging water conservation measures. Several government agencies are also playing crucial roles. The Department of Livestock Production and Veterinary Services (DLPVS), for instance, implements programs promoting sustainable grazing practices and disease control (Darkoh, 2002). The Department of Agricultural Research (DAR) researches drought-resistant forage options and disseminates knowledge to farmers. Additionally, the Department of Meteorological Services provides climate data and early warning systems, crucial for adapting livestock management to changing weather patterns. The government has also allocated funds for initiatives like the Livestock Development Program (LDP), which supports farmers in adopting climate-smart practices (Darkoh, 2002). Additionally, the National Adaptation Fund invests in projects addressing climate change vulnerabilities in various sectors, including agriculture. To add on that, Botswana actively collaborates with international organizations like the World Bank and the Food and Agriculture Organization (FAO) on climate change initiatives within the beef industry (Darkoh, 2002). These partnerships provide additional resources, expertise, and opportunities for knowledge sharing. These findings concur with the responses obtained from participants that the government was actually being involved in climate change adaptation measures.

The private sector was also gauged of its involvement. Both meat processing/retail and ranchers/farmers show few who see them as uninvolved (12.5% and 18.8%, respectively). Interestingly, both the private sector and government show similar proportions involved and highly involved (around 43.8% each), hinting at diverse levels of engagement within each sector. Some companies might be taking proactive steps, while others navigate their individual responsibilities.

Leading meat processing and retail companies are taking concrete steps by sourcing cattle raised using environmentally friendly practices, reducing packaging waste, and investing in

renewable energy. At the farm level, a growing number of ranchers and farmers are adopting climate-smart practices such as rotational grazing, improved pasture management, and water conservation techniques (Darkoh, 2002). Additionally, participation in sustainability certification programs incentivizes them to further adopt environmentally responsible methods.

Industry associations like the Botswana Meat Commission (BMC) and the Botswana Livestock Association (BLA) play a crucial role in supporting these efforts (Darkoh, 2002). The BMC promotes sustainable practices among its members and conducts research on climate-resilient livestock production. The BLA, on the other hand, provides training and resources to farmers on adapting to climate change and adopting sustainable practices (Darkoh, 2002).

However, collaboration between public and private entities further amplifies the impact. Partnerships between the BMC and organizations like the World Wildlife Fund demonstrate the effectiveness of joint efforts in promoting sustainable cattle ranching. Additionally, blended finance mechanisms that combine public and private funds help overcome financial constraints and support climate-smart investments in the industry (Darkoh, 2002).

Environmental NGOs stand out as potential leaders, with two-thirds viewing them as highly involved (Crawford, 2016). Their expertise and advocacy position them for significant impact. However, a small gap remains, suggesting potential outreach needs or opportunities for collaboration. While government policies and private sector initiatives form the backbone of climate mitigation efforts in Botswana's beef industry, this research shows that NGOs (Non-Governmental Organizations) add an essential layer of engagement (Crawford, 2016). The research also sought to know how involved these NGOs were and the common responses revolved around, acting as bridges between the government and the farmers, connecting communities, fostering knowledge sharing, and advocating for sustainable practices. NGOs leverage their established relationships and trust with

rural communities to effectively engage and empower local stakeholders in climate adaptation strategies (Crawford, 2016). This includes workshops, training sessions, and demonstration projects that equip communities with the knowledge and skills to implement sustainable practices like improved rangeland management, water conservation techniques, and adopting climate-resilient livestock breeds. NGOs play a crucial role in bridging the gap between scientific research and its practical application within communities. They translate complex scientific findings into easily understandable information and share best practices across regions (Crawford, 2016). Additionally, some NGOs directly support research initiatives led by local communities and contribute to documenting and disseminating traditional knowledge for climate adaptation. For instance, in Okavango Delta, the World Wildlife Fund (WWF) partners with the Botswana Meat Commission (BMC) on sustainable cattle ranching promoting best practises to farmers (Crawford, 2016).

Local communities, representing rural populations, show a positive trend. Only 10% of the participants see them as uninvolved, while over half (52.5%) feel that the local communities are engaged, 37.5% view them as actively leading or participating. This highlights their potential for valuable contributions and collaboration (Shackleton et al., 2015). Local communities possess generations-old knowledge about the land, weather patterns, and livestock management. Sharing and integrating this knowledge with modern scientific approaches strengthens adaptation strategies. Local groups can design and implement climate-resilient projects tailored to their unique needs and contexts (Shackleton et al., 2015). This ownership fosters long-term sustainability and ensures solutions resonate with community realities. Including communities in planning and decision-making processes ensures adaptation strategies address their concerns and priorities, leading to more effective and equitable outcomes. Examples of community involvement include: Farmer-managed grazing

associations. Groups establish rules and manage communal grazing lands, promoting sustainable resource use and conflict resolution.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

This research sought to find whether there were challenges to climate change adaptation in South African countries with the case study of Botswana beef industry. There were financial, cultural and policy challenges that still impede the implementation of long lasting solutions with regards to climate change adaptation in Botswana. This research also sought to pick up recommendations from the local population on how well to address these issues. These and inferential recommendations are presented as below.

On the financial challenges, the government needs to explore the establishment of targeted grant programs to subsidize the adoption of climate-smart technologies and infrastructure, such as drought-resistant breeds, water-efficient irrigation systems, and renewable energy solutions. Additionally, grants can support the development of demonstration farms showcasing successful mitigation practices. Also, recognizing the limited access to financing, the government needs to collaborate with financial institutions to explore loan guarantee schemes and interest rate subsidies specifically for climate-friendly investments in the beef industry. This will incentivize lenders and make borrowing more affordable for farmers. Apart from that, the government needs to actively seek partnerships with private sector entities to leverage their expertise and resources in developing innovative financing models tailored to the needs of our farmers. This could include blended finance solutions, impact investing, and carbon credit trading schemes. The financial deficit hinders

collaboration between key stakeholders. Limited resources restrict the government's ability to offer significant financial support or initiate large-scale demonstration projects showcasing the viability of climate-smart practices. This missed opportunity for collective action and knowledge sharing impedes the development of innovative solutions and slows down the adoption of successful strategies across the industry. Financial constraints also limit the resources available for crucial capacity building initiatives. Training farmers on new technologies, providing technical assistance, and offering financial literacy programs all require funding, which can be scarce. This delays the transfer of knowledge and skills necessary for effective adaptation, creating a knowledge gap that further slows down progress. The government therefore needs to take up the financial issue as a major impediment that needs to be addressed.

To improve the technological knowhow of the famers, the government needs to strengthen extension services by providing the agricultural officers with the necessary training and resources. This will help to effectively advise farmers on available financial options and guide them through the application process for grants and loans as well as latest technology for sustainability. This will ensure that the famers implement cattle rearing methods that not only ensure maximization of profits but also sustainability of their farming activities.

On addressing policy issues, the government of Botswana can dedicate climate units within relevant ministries, staffed with skilled personnel and adequate resources to champion targeted action on climate adaptation. Fostering seamless communication and collaboration across government agencies, research institutions, and industry stakeholders is crucial for crafting and implementing coherent policies. Equipping extension workers with the expertise and resources they need to effectively train and support farmers in adopting climate-smart practices is pivotal for wider implementation. Regularly reviewing and updating existing policies and regulations will also ensure

that the government addresses current climate challenges and supports adaptation efforts effectively. Implementing financial incentives, such as subsidies for drought-resistant forage varieties or water conservation equipment, can encourage farmers to adopt sustainable practices. Exploring carbon pricing schemes or other market-based mechanisms can create economic incentives for reducing greenhouse gas emissions within the industry. Furthermore, supporting research on climate-resilient livestock breeds, drought-resistant forage options, and improved grazing management practices can provide valuable solutions for farmers. Establishing effective communication channels to share research findings, best practices, and success stories with farmers and other stakeholders is crucial for wider adoption. Recognizing and incorporating the wealth of traditional knowledge held by local communities into adaptation strategies can enhance their effectiveness and cultural sensitivity. Finally, collaborating with industry players, NGOs, and research institutions can leverage diverse expertise, resources, and networks to scale up adaptation efforts. Ensuring active participation of local communities in planning, decision-making, and implementation processes leads to more inclusive and sustainable adaptation strategies. Sharing knowledge and experiences with other countries facing similar challenges and exploring opportunities for international support can further accelerate progress.

To address these cultural challenges, the first step lies in establishing trust and fostering open communication. Engaging communities through trusted local leaders and utilizing local languages is crucial. Dispelling myths and disseminating accurate information tailored to the cultural context are essential. For instance, a study by the Center for Applied Research in Botswana highlights the importance of using "local knowledge, terminology, and metaphors" to resonate with communities (2005). By collaborating with trusted local organizations like MAKATSA (Maatla a Sechaba Trust),

which works directly with farmers on sustainable practices, effective communication channels can be established (Shackleton et al., 2015).

Moving beyond top-down approaches, co-creating solutions with communities is paramount. This involves actively engaging farmers in developing and implementing climate-smart practices that align with their cultural realities. Sharing best practices and fostering knowledge exchange across communities, similar to the model adopted by the Livestock Management Advisory Center (LIMAC), can accelerate widespread adoption (Crawford, 2016). As Dr. Nyang'ombe, a researcher at the Botswana University of Agriculture and Natural Resources, emphasizes, "involving communities in decision-making and implementation increases ownership and sustainability of initiatives" (Crawford, 2016).

Tailoring incentives to resonate with existing cultural values and address key concerns is critical. While financial incentives have their place, exploring alternatives that align with cultural priorities can be more effective. For instance, promoting drought-resistant forage varieties like Boma Rhodes grass, which requires less water and offers higher nutritional value, can address concerns about herd size reduction while enhancing productivity. Additionally, supporting community-managed water points in strategic locations can alleviate pressure on grazing lands and reduce herding distances, echoing the traditional system of sharing resources.

Investing in knowledge sharing is crucial to equip communities with the tools they need to adapt. Strengthening extension services through local champions can bridge the gap between traditional knowledge and scientific understanding. Developing culturally appropriate educational materials, translated into local languages and utilizing visuals like info graphics, can enhance knowledge retention and facilitate adoption of new practices. The Livestock Research and Development Department (LRDD) already employs community-based para-veterinarians who play a

vital role in disseminating knowledge and building trust, and their role can be further strengthened with additional resources and training.

The journey towards a sustainable future for Botswana's cattle industry necessitates respecting cultural traditions while fostering innovation. Exploring grazing management alternatives that improve land use, such as rotational grazing systems adapted to communal contexts, can be pursued without disrupting the free-range ethos. Building upon existing community initiatives, like those implemented by NGOs like World Vision, which promote regenerative grazing practices while preserving communal land use, can provide valuable insights and models for wider adoption (Crawford, 2016).

Ultimately, bridging the culture-climate gap requires a collaborative approach. Bringing together scientists, policymakers, local leaders, and communities around a shared vision is key. Platforms for dialogue and knowledge exchange, such as farmer field schools and community-based monitoring programs, can foster mutual understanding and facilitate solutions that work for everyone. Initiatives like the Botswana National Adaptation Strategy and Action Plan (BNASAP) offer important frameworks for collaboration and action, but ensuring community participation and cultural sensitivity in their implementation is crucial (Crawford, 2016).

In conclusion, addressing the cultural barriers to climate action in Botswana's cattle industry necessitates a multifaceted approach that fosters trust, empowers communities, aligns incentives with values, bridges the knowledge gap, and respects tradition while embracing innovation. By collaborating across sectors and engaging stakeholders meaningfully, a path towards a more sustainable future for both the environment and the people who depend on it can be paved. This journey requires commitment, investment, and a willingness to learn from each other, but the rewards – a thriving cattle industry and a resilient landscape – are worth the effort.

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APPENDICIES

Appendix 1: QUESTIONNAIRE

Section 1: Respondent Information	
1.1. Demographic Information:	
1.1.1	Name (Optional):
1.1.2	Position/Title:
1.1.3	Organization/Company:
1.1.4	Contact Information:
1.1.5	Background Information:
1.1.6	How many years of experience do you have in the beef industry?
1.1.7	What is your role in the beef industry in Botswana?
Section 2: Climate Change Awareness and Understanding	
1.2 Climate Change Awareness:	
1.2.1	How would you rate your awareness of climate change issues affecting the beef industry in Botswana? (Low, Moderate, High)
2.2. Understanding of Climate Change Impacts:	

2.2.1 Climate change poses a significant threat to the beef industry in Botswana?

Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree

[Please mark your response with a √]

2.2.2 To what extent has climate change impacted each of the following aspects of beef production in Botswana?

	To a great extent	Somewhat	Very Little	Not at all
Feed availability				
Water availability				
Increased pests and disease				
Animal Physiological well being				

2.2.3 What other ways has climate change affected the beef industry in Botswana?

Section 3: Current Adaptation Measures

3.1. Adaptation Strategies:

3.1.1 What adaptation measures are currently in place within the beef industry in Botswana to address climate change impacts?(List as many as you can think of)

3.1.2 How effective do you perceive these adaptation measures to be? (List as many as you can think of)

3.2. Barriers to Implementation:

While adapting to climate change is crucial for the beef industry's future, implementing these strategies faces hurdles. Below are some common challenges. Please indicate how significant you believe each is (on a scale of 1-5, where 1 is not a significant barrier and 5 is a major obstacle):

Financial Barriers:

1. High upfront costs of new technologies and infrastructure (e.g., water systems, drought-resistant breeds)
2. Limited access to financing for small-scale farmers
3. Uncertain long-term return on investment for adaptation strategies

Knowledge and Capacity Barriers:

4. Lack of awareness and technical knowledge about effective adaptation options
5. Insufficient availability of extension services or training programs for farmers
6. Difficulty accessing and interpreting relevant climate data

Institutional and Policy Barriers:

7. Lack of clear and consistent government policies supporting adaptation
8. Conflicting regulations hindering implementation of adaptation measures
9. Unfavorable market structures not rewarding sustainable practices

Social and Cultural Barriers:

- 10. Resistance to change due to traditional practices and cultural norms
- 11. Land tenure insecurity discouraging long-term investments in adaptation
- 12. Limited community involvement and collaboration on adaptation strategies

Additionally, please mention any other significant barriers you perceive and suggest potential solutions to address these challenges.

Section 4: Specific Challenges in Botswana

4.1. Climate-Related Challenges:

4.1.1 What specific climate-related challenges do you observe in the beef industry in Botswana?

4.1.2 Water Scarcity:

4.1.3 How has water scarcity, influenced by climate change, affected the beef industry in Botswana?

4.1.5 What measures, if any, are in place to mitigate the impact of water scarcity on the industry?

Section 5: Stakeholder Involvement and Collaboration

5.1. Stakeholder Engagement:

5.1.1 How involved are various stakeholders (government, private sector, NGOs, local communities) in climate change adaptation efforts within the beef industry?

5.2. Collaboration Challenges:

5.2.1 Are there challenges in collaboration between different stakeholders in implementing climate change adaptation strategies?

Section 6: Future Outlook and Recommendations

6.1. Anticipated Changes:

6.1.1 To What extent do you believe climate change will impact the beef industry in Botswana in the next 5-10 years?

To a great extent, Somewhat, Very little, Not at all

[Please mark your response with a √]

6.2. Recommendations:

6.2.1 What recommendations do you have for enhancing climate change adaptation in the beef industry in Botswana?

Section 7: Additional Comments

7.1. Open-Ended:

7.1.1 Please provide any additional comments or insights regarding the challenges to climate change adaptation in the beef industry in Botswana.

Thank you for participating in this survey! Your input is valuable for understanding and addressing the challenges faced by the beef industry in the context of climate change in Southern Africa.

Appendix 2: INTERVIEW QUESTIONS

Interview Questions

1. Personal Information:

- What is your full name?
- Can you provide a brief background on your professional experience within the Botswana beef industry?

2. Position and Role:

- What is your current position within the Botswana beef industry?
- Could you describe your primary responsibilities and role in the industry?

3. Organizational Affiliation:

<ul style="list-style-type: none"> ○ Which organization or company do you represent within the Botswana beef industry?
4. Experience in the Industry:
<ul style="list-style-type: none"> ○ How long have you been involved in the Botswana beef industry?
<ul style="list-style-type: none"> ○ Can you share some key milestones or projects you've been involved in?
5. Educational Background:
<ul style="list-style-type: none"> ○ What is your educational background, especially as it pertains to the beef industry?
6. Current Challenges:
<ul style="list-style-type: none"> ○ From your perspective, what are the current challenges facing the Botswana beef industry?
7. Awareness of Climate Challenges:
<ul style="list-style-type: none"> ○ How aware is the industry, from your standpoint, of the challenges posed by climate change?

8. Previous Adaptation Efforts:
<ul style="list-style-type: none"> ○ Have there been any specific climate change adaptation initiatives or strategies implemented by the Botswana beef industry in the past?
9. Stakeholder Collaboration:

- How does your organization collaborate with other stakeholders, both within the industry and beyond, to address common challenges?

10. Expectations from the Interview:

- What are your expectations from this interview, and how do you envision the information shared contributing to the industry's resilience against climate change?

11. Detailed response questions

- How has the Botswana beef industry historically adapted to climate variability and what are the key challenges faced in this adaptation process?

- Given the unique climate challenges in Southern Africa, particularly in Botswana, how has the beef industry experienced changes in temperature and precipitation patterns, and what implications does this have for cattle farming?

- Can you elaborate on specific instances where extreme weather events, such as droughts or floods, have impacted the Botswana beef industry, and how has the industry coped with these challenges in the past?

- In terms of infrastructure and resource management, what are the main obstacles hindering effective climate change adaptation within the Botswana beef industry?

<ul style="list-style-type: none">○ How is the Botswana beef industry currently incorporating sustainable and climate-resilient practices into its operations, and what barriers exist to the widespread adoption of such practices?
<ul style="list-style-type: none">○ Considering the socio-economic aspect, how are local communities and stakeholders within the Botswana beef industry affected by climate change, and what measures are in place to address these impacts?
<ul style="list-style-type: none">○ Are there any existing policies or regulatory frameworks in Botswana that support climate change adaptation within the beef industry, and what improvements or additions would be beneficial?
<ul style="list-style-type: none">○ Given the international nature of the beef industry, how does Botswana collaborate with neighbouring countries and global partners to address shared climate challenges and promote sustainable practices?
<ul style="list-style-type: none">○ What role do technological innovations play in enhancing climate resilience within the Botswana beef industry, and how accessible are these technologies to different stakeholders, including small-scale farmers?
<ul style="list-style-type: none">○ How can government agencies, industry stakeholders, and local communities collaborate more effectively to overcome the challenges posed by climate change in the Botswana beef industry, and what specific initiatives or partnerships would be beneficial in this regard?

Appendix 3: BUDGET

Budget Item	Description	Estimated Cost (in KSH)
Personnel Costs	Interviewer Fees	20000
	Data Entry Personnel	8000
Materials and Supplies	Printing of Questionnaires	8000
	Paper, Pens, and other Stationery	1000
	Interview Recording Equipment	
Travel Expenses	Travel to Interview Locations	220000
	Accommodation and Meals for Interviewers (if necessary)	150000
Communication	Phone Calls/Cellular Charges for Interviews	2000
	Internet and Email Communication	
Incentives and Gifts	Incentives/Gifts for Participants (if applicable)	10000
Miscellaneous	Contingency Fund for Unforeseen Expenses	10000
Total Estimated Cost		429000

Appendix 4: WORK PLAN

Activity No.	Activity	Duration
1	Prepare Survey tools& request and wait for approval for research	4 weeks
2	Travel	2 days
3	Recruit participants	2 weeks
4	Schedule Interviews/give out questionnaires	1 week
5	Data collection: Conduct interviews & collect questionnaires	1 week
6	Compile a report	1 month
	Total	3 months

