

BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE & ENGINEERING

DEPARTMENT OF DISASTER RISK REDUCTION



**AN INVESTIGATION INTO THE INFLUENCE OF CLIMATE CHANGE ON
DAIRY FEED RESOURCE AVAILABILITY AND UTILIZATION: CASE STUDY
OF SEKE DISTRICT, ZIMBABWE**

BY

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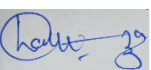
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DEDICATION

I dedicate my dissertation work to my family and friends. A special feeling of gratitude to my loving wife, Hellen, and my daughters Tavongaishe and Ropafadzo, and my son Atipaishe, and my mother, whose words of encouragement and prayers have made it possible to sail through tough times.

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ABSTRACT

Climate change poses significant challenges to the dairy sector in Zimbabwe, particularly in Seke District. The objectives of the research sought to examine how climate change affects the availability, quality, and utilization of dairy feed resources in Seke District, Zimbabwe, by assessing current feed systems, evaluating farmer challenges and adaptation practices, and proposing strategies to enhance resilience and sustainability of the dairy sector. Primary data were collected using structured questionnaires from 38 dairy farmers, 4 extension officers, and 2 pasture specialists, complemented by in-depth interviews with the extension officers and pasture specialists. The increasing costs of supplementary feed and unpredictable effects of climate change have made it difficult for farmers to sustain their operations. In Seke District, natural pastures and improved pastures are unreliable, leading to reliance on costly processed and conventional feeds. Adaptation strategies to climate change disaster risks such as diversifying forage species and using agroforestry practices are being employed to address these challenges. Dairy farming in Seke District is primarily sustained by natural pastures, improved pastures, crop residues, and agro-industrial by-products. However, over-reliance on rain-fed natural grazing systems presents challenges, as these pastures are highly vulnerable to climate change impacts. Adaptation strategies include improved storage and feed preservation techniques, diversifying feed sources, improving water management techniques, altering feeding schedules, and using climate smart agriculture practices. Mitigation strategies include improved storage and feed preservation techniques, diversifying feed sources, improving water management techniques, altering feeding schedules, and using climate smart agriculture practices. However, challenges include financial constraints, lack of machinery, and fear of failure in repayment periods. The study found that 94% of farmers anticipate decreased availability of dairy feed resources in the next ten years due to climate change-induced disasters like drought. Farmers in Seke District grow forage crops like Brachiaria species, star grass, velvet beans, lab-lab, Sunhemp, lucerne, rye grass, forage oats, and sunflower for their drought tolerance and as protein and energy sources. Infrastructure limitations, such as inadequate storage facilities and transportation challenges, hinder efficient feed utilization. The study concludes that dairy farmers in Seke District are increasingly vulnerable to climate change impacts, particularly with respect to feed resource availability. Traditional reliance on rain-fed natural pastures is no longer sufficient to meet the nutritional needs of livestock.

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LIST OF ABBREVIATIONS

BUSE – Bindura University of Science Education

CSA – Climate Smart Agriculture

DSU – Dairy Services Unit

FAO – Food and Agriculture Organization

SLF – Sustainable Livelihoods Framework

TPB – Theory of Planned Behaviour

TRANZDVC: Transforming Zimbabwean Value Chain for the Future (2019-2023)

ZADF – Zimbabwe Association of Dairy Farmers

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CHAPTER ONE: INTRODUCTION

1.1 Introduction

The chapter provides an introduction to the research, outlining the key elements of the study on the influence of climate change on dairy feed resource availability and utilization in Seke District, Zimbabwe. The chapter gives a comprehensive background of the study, highlighting the challenges faced by Zimbabwe's dairy sector due to climate-induced changes such as erratic rainfall, increased temperatures, and extreme weather events. It also presents the climate change effects on dairy production, defining the specific challenges of dairy feed scarcity exacerbated by climate change. The purpose and scope of the research are detailed through the general and specific objectives, aimed at analysing the current status of feed resources, examining adaptation strategies by farmers, and proposing mitigation measures. Additionally, the chapter outlines the research questions that will guide the study, along with the hypotheses. Definitions of key terms used in the study are provided for clarity. Finally, the chapter concludes by explaining the organization of the dissertation, guiding the reader through the structure of the subsequent chapters.

1.2 Background of the Study

Climate change has become one of the most pressing global challenges, affecting numerous sectors, including agriculture. The Intergovernmental Panel on Climate Change (IPCC) has warned that global temperature rises, shifting precipitation patterns, and increasing incidences of extreme weather events such as droughts, floods, and storms which are exacerbating the vulnerabilities of agricultural systems worldwide (IPCC, 2019). Agriculture, as both a contributor to and victim of climate change, faces significant transformations. The rising global temperatures and changing weather patterns disrupt crop production, reduce soil fertility, and alter the availability of water resources, ultimately impacting global food security (World Bank, 2020).

In the context of livestock, climate change impacts range from altered pasture and forage growth to changes in livestock health, productivity, and reproduction. Dairy farming, in particular, is highly sensitive to climate variability. As temperatures rise, dairy cattle suffer from heat stress, which reduces milk production and affects their overall well-being. Moreover, shifts in rainfall patterns and the increasing frequency of extreme weather events compromise the availability of feed resources, essential for maintaining livestock health and productivity

(Thornton et al. 2019). Globally, farmers have begun to implement adaptive measures such as improving feed management practices, utilizing more resilient forage species, and adopting water-saving technologies to cope with these challenges (FAO, 2018).

Climate-smart agriculture (CSA) has emerged as a response to the growing impacts of climate change on agriculture. CSA aims to increase productivity, enhance resilience, and reduce greenhouse gas emissions in farming systems. However, the capacity to implement CSA strategies varies across regions, depending on the availability of resources, infrastructure, and policy support (Lipper et al., 2018). In developed countries, the integration of advanced technologies, such as precision agriculture and irrigation systems, allows farmers to adapt more effectively. In contrast, developing countries, particularly in sub-Saharan Africa, face significant challenges in implementing CSA due to limited resources, weak institutional frameworks, and insufficient access to climate-related information.

1.2.1 Climate Change and Agriculture in Africa

Africa is one of the most vulnerable regions to climate change due to its dependence on rain-fed agriculture, fragile ecosystems, and limited adaptive capacity (Niang et al., 2014). According to the African Union, agriculture remains the backbone of most African economies, contributing significantly to employment, food security, and economic growth. However, the sector is increasingly threatened by climate-induced changes, which affect agricultural productivity, food security, and the livelihoods of millions of people across the continent.

In Africa, climate change has been associated with increased temperatures, changing precipitation patterns, and more frequent and intense droughts, floods, and storms (FAO, 2019). These changes have profound implications for both crop and livestock production. For instance, prolonged droughts have led to the loss of crops and livestock, reduced water availability, and degraded natural resources such as soil and grazing lands (Boko et al. 2019). This, in turn, has affected food security, particularly in regions that depend heavily on agriculture for subsistence.

Livestock farming, a critical component of Africa's agricultural systems, is highly vulnerable to disasters emanating from climate change such as droughts. The availability of feed resources, which depend on natural pastures and forage production, is increasingly being affected by climate variability (Thornton et al. 2019). In many parts of Africa, including East and Southern Africa, pastoral and agro-pastoral systems rely on rain-fed pastures and are thus highly

susceptible to the impacts of changing rainfall patterns. Droughts, in particular, lead to pasture degradation, reduced water availability, and increased competition for feed resources, all of which negatively impact livestock productivity (Chaudhary et al. 2019).

To address these challenges, African countries are increasingly focusing on adaptation strategies, including the adoption of climate-resilient crops and livestock breeds, improving water management practices, and promoting sustainable land management (FAO, 2020). In Eastern and Southern Africa, there has been a push to integrate climate-smart agriculture practices, including agroforestry, conservation agriculture, and improved pasture management, to enhance the resilience of farming systems. However, limited access to resources, inadequate infrastructure, and weak institutional support continue to hinder the widespread adoption of these practices (Smit & Pilifosova, 2019).

1.2.2 The Impact of Climate Change on Zimbabwe's Dairy Sector

Zimbabwe's agricultural sector is particularly vulnerable to the impacts of climate change, with dairy farming being no exception. The country's dairy industry plays a crucial role in food security, rural development, and the national economy. However, climate-induced shifts in rainfall patterns, increasing temperatures, and more frequent extreme weather events like droughts pose significant challenges to the availability and quality of feed resources, which are critical for sustaining dairy production (Nyanga, 2021). Dairy farming in Zimbabwe primarily relies on natural grazing lands, rain-fed fodder production, and agro-industrial by-products to meet the nutritional needs of dairy cattle (Munyati, 2020). This dependence on natural resources makes the industry highly vulnerable to climate-induced disruptions.

Climate change in Zimbabwe is manifested through prolonged dry spells, erratic rainfall, and extreme weather events such as droughts and floods (Bongo et al. 2018). These climatic changes have had a profound impact on agricultural productivity, particularly for smallholder and medium dairy farmers who mostly rely heavily on rain-fed fodder production. For example, reduced rainfall and prolonged dry spells have led to decreased pasture growth and forage availability, while floods have degraded grazing lands, further compromising the quality and quantity of available feed resources (Gondo, 2017; Masama, 2016). These changes have a direct impact on dairy cattle nutrition, milk production, and overall farm profitability.

In response to these challenges, Zimbabwean dairy farmers have begun to adopt various adaptation strategies. Some farmers are diversifying their forage species, incorporating more resilient crops such as drought-tolerant grasses and legumes (Chanza & Musakwa, 2022).

Others are altering their feeding patterns and integrating more agro-industrial by-products to supplement traditional feed sources. Additionally, the adoption of water-saving technologies, such as rainwater harvesting and improved irrigation systems, is helping farmers to cope with water scarcity and ensure the consistent availability of feed throughout the year (Magwaza, 2019). Dairy farmers in Zimbabwe are increasingly adopting adaptation strategies to mitigate the effects of climate change on feed resources and maintain herd productivity. Studies by Chikodzi (2019; 2020) and Zwane (2022) document various adaptation measures, including adjusting planting dates, diversifying forage species, conserving water resources, and integrating crop-livestock systems. Agroforestry practices, such as tree planting and fodder shrub cultivation, are also gaining traction as climate-resilient feed options (Chiduza, 2021). Examples of fodder cultivation practices in Zimbabwe include the cultivation of multi-purpose trees such as *Leucaena leucocephala*.

Despite these efforts, the dairy industry in Zimbabwe continues to face significant challenges due to the limited availability of research, financial resources, and policy support to effectively address the impacts of climate change on dairy feed resources. The lack of comprehensive studies examining the specific impacts of climate change on dairy feed availability and utilization in Zimbabwe has hindered the development of effective adaptation strategies. As a result, there is an urgent need for research that investigates the influence of climate change on dairy feed resources and identifies sustainable solutions for the dairy industry in Zimbabwe (Bongo et al. 2018).

Seke District, located in the Mashonaland East Province of Zimbabwe, is a key area for dairy farming, as it comprises of all scales of dairy farmers, that is, the large, medium and smallholder dairy farmers. The district, like many other parts of Zimbabwe, is heavily reliant on rain-fed agriculture and natural grazing lands for livestock farming. Climate change has had a significant impact on the availability of feed resources in the district, with farmers experiencing more frequent droughts, reduced rainfall, and increasing temperatures (Nyanga, 2021). These changes have disrupted the traditional patterns of feed availability, leading to feed shortages and increased competition for limited resources.

The smallholder dairy farmers are particularly vulnerable to climate-induced feed scarcity. This is because many of them lack access to alternative feed sources and rely heavily on natural pastures and crop residues to sustain their herds (Munyati, 2020). However, with the changing climate, these resources have become increasingly unreliable, leading to reduced milk yields

and higher production costs. Additionally, the degradation of grazing lands due to overgrazing and unsustainable land-use practices has further exacerbated the feed scarcity problem (Masama, 2016).

Despite these challenges, some farmers in Seke District have begun to adopt climate-smart agricultural practices to improve the resilience of their farming systems. These practices include diversifying forage species, adopting drought-tolerant crops, and improving water management techniques (Chanza & Musakwa, 2021). Additionally, the integration of agroforestry practices, such as planting fodder shrubs and trees, has helped farmers to enhance feed availability while promoting environmental sustainability. However, the adoption of these practices remains limited due to financial constraints, limited access to extension services, and inadequate policy support (Magwaza, 2019).

This study is critical for several reasons. First, it aimed at filling the knowledge gap regarding the specific impacts of climate change on dairy feed resource availability and utilization in Zimbabwe. By focusing on Seke District, the study provided valuable insights into the challenges faced by smallholder dairy farmers in Zimbabwe and in the region and offered practical solutions for enhancing the resilience of the dairy industry in the face of climate change. Additionally, the study contributed to the broader discourse on climate-smart agriculture by identifying effective adaptation strategies that can be scaled up and applied in other regions of Zimbabwe and beyond.

The findings of the study are also important in influencing livestock production policies in Zimbabwe. By providing evidence-based recommendations, the study informs policymakers, extension services, and agricultural stakeholders about the necessary interventions to support dairy farmers in adapting to climate change. These recommendations are crucial for developing climate-smart policies and programs that promote sustainable dairy farming practices and enhance the resilience of Zimbabwe's agricultural sector.

Climate change poses significant challenges to the global, African, and Zimbabwean agricultural sectors, with dairy farming being particularly vulnerable due to its dependence on natural resources for feed. In Zimbabwe, the impacts of climate change on dairy feed resource availability and utilization are already being felt, particularly in districts like Seke District. However, despite the growing challenges, there is a lack of comprehensive research and policy support to address these issues effectively. This study sought to investigate the influence of climate change on dairy feed resources in Seke District and proposed adaptation strategies that

can enhance the resilience and sustainability of the dairy sector. The insights gained from the research will contribute to the broader efforts of promoting climate-smart agriculture in Zimbabwe and ensuring the long-term viability of the country's dairy industry.

1.3 Justification of the Study

The dairy sector is crucial for Zimbabwe's food security and rural economy, and the adverse effects of climate change are threatening its sustainability. Given the challenges posed by climate change, including erratic rainfall, prolonged dry spells, and rising temperatures, understanding its impact on dairy feed resources is essential for developing effective adaptation strategies (Gusha, 2020). While several studies have explored climate change's broader impacts on agriculture, limited research specifically addresses the dairy sector, particularly in relation to feed resources in Zimbabwe. This research seeks to fill that gap by providing insights into the specific challenges faced by dairy farmers in Seke District and offering strategies to enhance the sector's resilience.

1.4 Problem Statement

The increasing costs associated with dairy feed, coupled with the unpredictable effects of climate change, have made it challenging for farmers to sustain their operations using traditional methods. Climate change has significantly altered the availability and quality of feed resources, which are critical for maintaining dairy cattle nutrition (Gondo, 2016). In regions like Seke District, Zimbabwe, farmers face numerous challenges in accessing sufficient feed due to changing precipitation patterns, increased frequency of droughts, and extreme weather events like floods (Bongo et al. 2018). Despite these challenges, there is a lack of comprehensive research that specifically addresses the impact of climate change on dairy feed availability and utilization in this district. Thus, there is a pressing need for a study that explores these challenges and identifies sustainable solutions for the dairy industry in Zimbabwe.

1.5 Aims & Objectives

The primary aim of the study was to investigate the influence of climate change on dairy feed resource availability and utilization in Seke District, Zimbabwe. Specific objectives of the study sought:

- i. To assess the current status of dairy feed resource availability and utilization in Seke District.

- ii. To analyse the impacts of climate change on the quality and quantity of dairy feed resources in Seke District.
- iii. To identify adaptation strategies employed by dairy farmers to mitigate the effects of climate change on feed resources.
- iv. To evaluate the challenges faced by dairy farmers in accessing and utilizing feed resources under changing climatic conditions.
- v. To suggest strategies to enhance the resilience and sustainability of the dairy industry in response to climate change.

1.6 Research Questions and Hypotheses

1.6.1 Research Questions

This study addressed the following key research questions:

1. How is climate change impacting the availability and quality of dairy feed resources in Seke District, Zimbabwe?
2. How are current practices and patterns of dairy feed resource utilization changing in response to evolving climatic conditions?
3. What adaptation strategies are dairy farmers in Seke District adopting to mitigate the effects of climate change on feed resources?
4. What are the challenges faced by dairy farmers in accessing and utilizing feed resources under the influence of climate change?

1.6.2 Research Hypothesis

H₀ There is no significant difference in the influence of climate change on dairy feed resource availability and utilization in Seke district due to climate change.

H₁ There is a significant difference in the influence of climate change on dairy feed resource availability and utilization in Seke district due to climate change.

1.7 Definition of Terms

Climate Change is the long-term changes in temperature, precipitation patterns, and other atmospheric conditions that affect natural ecosystems and human livelihoods.

Dairy Feed Resources refers to the forage, pastures, and other feedstuffs used to nourish dairy cattle.

Adaptation Strategies are actions or approaches taken to adjust to new climatic conditions, aimed at reducing vulnerability and improving resilience.

1.8 Organization of the Study

This dissertation is structured as follows:

Chapter One provides the background, problem statement, aims, objectives, research questions, and justification of the study.

Chapter Two reviews existing literature on climate change and its impact on dairy feed resources, highlighting key findings from recent studies.

Chapter Three outlines the methodology used in conducting the study, including the research design, data collection methods, and analysis techniques.

Chapter Four presents the findings of the research, detailing the influence of climate change on dairy feed resource availability and utilization in Seke District.

Chapter Five discusses the results, drawing conclusions and offering recommendations for policymakers, stakeholders, and dairy farmers.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Climate change has emerged as one of the most significant challenges impacting agricultural productivity and food security globally. The dairy sector, in particular, is vulnerable to changes in climate patterns, especially in regions where natural resources play a critical role in sustaining livestock. This literature review examines the influence of climate change on dairy feed resource availability and utilization, focusing on its impact on dairy farming in Zimbabwe, particularly in Seke District. By reviewing existing studies and frameworks, this chapter provides a theoretical and conceptual foundation for understanding the interplay between climate change and dairy feed resources. The review will highlight relevant literature for each research objective, demonstrating how previous research has informed this study while identifying gaps that necessitate further investigation.

2.2 Theoretical Framework

2.2.1 Sustainable Livelihoods Framework (SLF)

The Sustainable Livelihoods Framework (SLF) is a holistic approach to understanding how households manage their resources and sustain their livelihoods in the face of various external stressors such as climate change. This framework provides an essential foundation for analysing the impacts of climate change on dairy farming, particularly the availability of feed resources. According to the SLF, the sustainability of a household's livelihood depends on access to five types of capital: natural, human, financial, social, and physical (Ellis, 2000). These resources interact within broader socio-economic and environmental contexts, and their availability and quality are mediated by policies, institutions, and processes that either facilitate or hinder resource access and management (Scoones, 2015). In the context of dairy farming, feed resources fall under the natural capital category, making them a critical component of livelihood strategies for livestock dairy farmers.

The SLF became relevant to this study because dairy farmers in regions such as Zimbabwe's Seke District heavily depend on natural feed resources, such as grazing lands and water, which are directly affected by climatic variability. The framework emphasizes how different forms of capital, natural in this case, interact with the other capitals. For instance, access to financial capital may allow a farmer to purchase supplemental feed during times of drought, while human capital, such as knowledge of climate-resilient practices, can facilitate better

management of feed resources in the face of climate change (Chanza & Musakwa, 2021). The SLF provides a structured way to examine how farmers draw upon multiple resources to sustain their dairy operations and make strategic decisions to adapt to external pressures such as climate variability.

This theory particularly became pertinent to the study as it highlighted the need for a diversified asset base in maintaining livelihood resilience. Dairy farmers relying solely on natural grazing may face greater vulnerabilities to climatic shocks compared to those who integrate financial capital, for example purchasing feed, or human capital for example training in climate-smart agriculture. SLF advocates for understanding how policies and institutional processes can either strengthen or weaken farmers' ability to manage feed resources sustainably (Nyanga, 2021). For example, access to agricultural extension services or subsidies for climate-resilient feed options can greatly improve the capacity of farmers to adapt. Therefore, this study leverages the SLF to explore how these various forms of capital can be mobilized to address the challenges posed by climate change on feed resource availability.

Moreover, the SLF framework also accounts for the vulnerability context, which includes trends, shocks, and seasonality. Climate change represents both a trend and a shock within the SLF as it causes long-term shifts in weather patterns and introduces sudden disruptions, such as droughts and floods, which affect feed availability (Bongo et al., 2018). These shifts in the vulnerability context force farmers to adopt coping mechanisms and strategies that influence how they manage natural resources such as grazing land. The SLF's emphasis on adaptive strategies makes it an ideal theoretical foundation for this study, which investigates how dairy farmers in Zimbabwe respond to the changing availability and quality of feed resources.

The justification for employing SLF in this study is grounded in its broad applicability to agricultural livelihoods in resource-constrained environments. Dairy farming in Seke District is highly dependent on rain-fed grazing, which makes it susceptible to climatic stressors such as droughts and long dry spells. By utilizing the SLF, this research sought to uncover how various forms of capital (especially natural and financial) are utilized to mitigate the effects of climate change on feed availability. Additionally, the SLF's ability to highlight the role of policies and institutions provides insights into how local governments and agricultural institutions can support farmers in sustaining their dairy livelihoods (Scoones, 2015). As climate change intensifies, the interaction between these capital assets and the external

environment becomes crucial for designing interventions that strengthen resilience among dairy farmers.

The SLF also introduces the concept of livelihood outcomes, which are the results of how households manage their assets and respond to stressors. In the context of dairy farming, positive livelihood outcomes might include maintaining or increasing milk production despite climatic challenges, which in turn leads to sustained income and food security (Munyati, 2020). The SLF allows for the evaluation of these outcomes by considering the extent to which dairy farmers have successfully adapted to the impacts of climate change. For example, farmers who adopt climate-resilient forage species may experience better livelihood outcomes compared to those who do not. Therefore, the SLF not only helps in understanding the dynamics of resource use but also provides a means to measure the success of adaptation strategies.

2.2.2 Theory of Planned Behaviour (TPB)

The Theory of Planned Behaviour (TPB) is a psychological model that explains how individuals make decisions about adopting specific behaviours. In the context of this research, the TPB is used to understand how dairy farmers decide to adopt or resist climate-resilient feed management practices. The TPB posits that human actions are guided by three core beliefs: behavioural beliefs, normative beliefs, and control beliefs (Ajzen, 1991). Behavioural beliefs refer to an individual's attitude toward the behaviour in question, which in this case could be the perceived benefits or drawbacks of adopting drought-resistant forage crops or other adaptive strategies. Normative beliefs reflect the social pressures or expectations surrounding the behaviour, such as whether other farmers in the community are also adopting new practices. Lastly, control beliefs are about the individual's perceived ease or difficulty in performing the behaviour, which could be influenced by access to resources such as seeds, water, or knowledge.

The TPB became relevant to this study as it provided a framework for understanding the cognitive processes behind farmers' decisions to adapt to climate-induced feed scarcity. In Zimbabwe, the decision to adopt climate-resilient practices such as planting drought-tolerant forage species may not only depend on a farmer's perception of the benefits but also on external factors such as the availability of these resources or the presence of supportive agricultural extension services (Zwane & Mutami, 2018). The TPB helps to conceptualize how farmers weigh these factors when deciding whether to adopt new feed management strategies.

Additionally, TPB allows for the examination of the social dynamics involved in decision-making. For example, farmers may be influenced by what their neighbours or community leaders are doing regarding feed management practices, thereby reinforcing or discouraging behaviour change.

A critical aspect of the TPB in this context is the role of control beliefs. For many farmers, especially smallholder dairy farmers in Seke District, access to climate-resilient feed options may be limited due to financial constraints, lack of technical knowledge, or inadequate institutional support. Control beliefs, therefore, become central in understanding the adoption of new practices. If farmers perceive that they do not have the necessary resources or institutional backing to adopt new feed strategies, they may be less likely to change their behaviour, even if they recognize the benefits of doing so. This aspect of the TPB underscores the importance of ensuring that adaptation strategies are not only beneficial but also feasible for farmers to implement.

The justification for using the TPB in this research lies in its focus on decision-making processes. Unlike more structural theories, which emphasize external factors like policies or institutions, the TPB provided a deeper understanding of the psychological and social factors that influence farmers' behaviour. This is particularly important in the context of climate change adaptation, where individual decisions about adopting new practices can make a significant difference in mitigating the impacts of climate variability on dairy production (Mupangwa et al. 2021). The TPB helps explain why some farmers might be more willing to adopt drought-tolerant forage crops or water-saving technologies, while others may resist, even when both groups face the same external environmental conditions.

Additionally, the TPB highlights the role of perceived behavioural control in decision-making, which is especially relevant in the context of climate change. Dairy farmers may feel that they lack control over certain factors, such as erratic rainfall or rising feed costs, which can discourage them from adopting adaptation measures (Nyanga, 2021). However, by improving access to resources, such as climate-resilient seeds or water-saving technologies, and by offering targeted extension services, policymakers and agricultural stakeholders can increase farmers' perceived control, thereby encouraging the adoption of climate-smart practices. The TPB thus offers actionable insights into how interventions can be designed to support behavioural change in response to climate challenges.

A key strength of the TPB in this study was on its applicability to interventions aimed at promoting climate-resilient agriculture. For example, if behavioural beliefs are found to be a significant barrier to adopting new feed practices, targeted awareness campaigns could be developed to shift farmers' attitudes toward these practices by demonstrating their benefits (Zwane & Mutami, 2018). Similarly, if normative beliefs are a barrier, community-based programs that involve local leaders and peer learning could be implemented to shift social norms around the adoption of climate-resilient practices. Lastly, if control beliefs are the main constraint, then policies that improve farmers' access to financial resources, inputs, and technical knowledge could be prioritized to empower farmers to make the changes necessary for sustaining their livelihoods in a changing climate.

The TPB also allows for the exploration of the intention-behaviour gap, which refers to situations where individuals intend to adopt a particular behaviour but fail to do so due to practical constraints. In the context of this study, even farmers who recognize the importance of climate-resilient feed management practices may fail to implement them due to barriers such as the cost of seeds, lack of access to water, or limited technical knowledge (Munyati, 2020). The TPB provides a useful lens for identifying these barriers and developing strategies to close the intention-behaviour gap. For instance, financial incentives, such as subsidies for drought-tolerant forage seeds, could be introduced to reduce the cost barriers that prevent farmers from acting on their intentions.

In a nutshell, both the Sustainable Livelihoods Framework (SLF) and the Theory of Planned Behaviour (TPB) provide robust theoretical foundations for understanding how dairy farmers in Seke District manage feed resources in the face of climate change. The SLF emphasizes the importance of accessing and managing multiple forms of capital to sustain livelihoods, while the TPB focuses on the psychological and social factors that influence farmers' decisions to adopt climate-resilient practices. Together, these frameworks offer a comprehensive approach to analysing the complex dynamics of adaptation in the dairy sector, highlighting both the structural and behavioural dimensions of decision-making.

2.2.3 Conceptual Framework

The conceptual framework for this study is a key visual representation that illustrates the relationship between climate change, dairy feed resource availability, and the adaptation strategies that farmers can employ to enhance resilience. This conceptual framework serves as

a tool to visualize and understand the complex interactions between climate change and dairy farming, guiding research and policy-making to support sustainable and resilient dairy production systems. The climate change drivers like increased temperatures, altered rainfall patterns, and extreme weather events have to be countered by employing sustainable adaptation strategies and perspectives to have a positive impact on the dependent feed resource availability and feed quality in dairy farming.

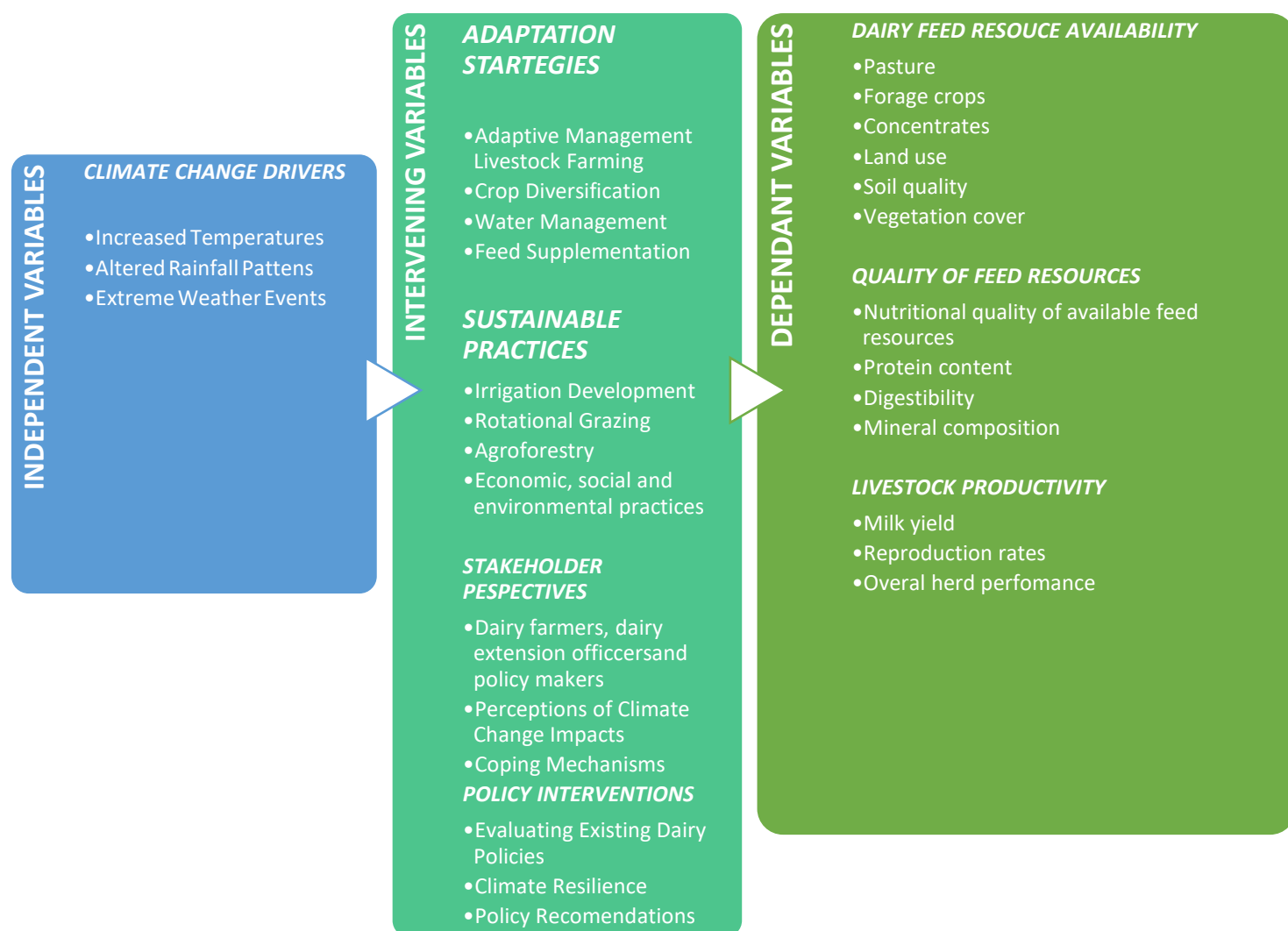


Figure 2.1: Conceptual Framework: Influence of climate change on dairy feed resource availability and utilization

Climate Variability and Change

This includes the primary stressors such as rising temperatures, erratic rainfall patterns, prolonged dry spells, and extreme weather events like droughts and floods. These climate-induced stressors directly affect natural resources, particularly feed resources necessary for

dairy farming (Nyanga, 2021). Climate change is the independent variable in this framework, initiating changes in feed availability.

Feed Resource Availability and Quality

As a consequence of climate variability, the availability and quality of feed resources, such as natural pastures, cultivated forages, and agro-industrial by-products, become compromised. This directly affects the dairy sector's productivity by reducing both the quantity and nutritional content of available feed resources (Gusha, 2020). This represents a dependent variable, which is influenced by the changing climatic conditions.

Dairy Production

The availability and quality of feed resources significantly affect the overall productivity of dairy farms, including milk yields, cattle health, and economic viability. Reduced feed availability can lead to nutritional deficiencies, lower milk production, and decreased profitability (Bongo et al. 2018). Dairy production thus forms another dependent variable in the framework, influenced by both feed resources and adaptation strategies.

Adaptation Strategies

This is a mediating factor between climate variability and dairy production. Adaptation strategies encompass practices aimed at mitigating the negative impacts of climate change on feed resources and dairy productivity. These strategies include:

Diversification of forage species where dairy farmers may plant drought-resistant forage varieties to ensure consistent feed availability throughout the year (Mupangwa et al. 2021).

Water management practices where efficient use of water resources, such as rainwater harvesting and irrigation, helps sustain forage growth during dry periods (Chanza & Musakwa, 2021).

Use of agro-industrial by-products where farmers can supplement natural pastures with by-products like maize bran and cottonseed cake in a total mixed ration (TMR) to fill feed gaps (Munyati, 2020).

Feed preservation techniques where feed preservation methods such as ensiling (silage making), haylage and haymaking can be adopted to store feed for use during the dry season (Nyanga, 2021,).

Institutional and Policy Support

This factor influences how effectively farmers can adopt and implement adaptation strategies. Institutional support includes access to agricultural extension services, climate-smart knowledge, financial resources, and government policies that promote sustainable dairy farming practices (Magwaza, 2019). The availability of this support enhances the adaptive capacity of farmers, influencing the success of adaptation strategies.

The conceptual framework starts with climate variability, which affects the availability and quality of feed resources. This, in turn, impacts dairy production negatively by reducing the quantity of milk produced, harming livestock health, and increasing the economic burden on farmers. The framework then introduces adaptation strategies as a mitigating factor, which can alleviate some of the negative impacts of climate variability by improving feed resource management. For example, by diversifying forage species, farmers can enhance the resilience of their feed systems, ensuring more stable production even under adverse climate conditions (Chanza & Musakwa, 2022).

The framework also recognizes the role of institutional and policy support in facilitating the implementation of adaptation strategies. Farmers who have access to extension services, financial resources, and technical knowledge are better equipped to adopt practices like water management and feed preservation, which help stabilize dairy production (Magwaza, 2019). Through focusing on these interactions, the framework allows the study to explore how dairy farmers in Seke District can improve their resilience to climate-induced feed scarcity. It identifies adaptation strategies as the key area where interventions can be targeted to support sustainable dairy farming. The relationships illustrated in the framework guide the methodology and analysis of this research, helping to evaluate the effectiveness of adaptation strategies in sustaining dairy production amidst climate variability.

This conceptual framework can be visualized as a diagram with climate variability influencing feed resource availability, dairy production being the outcome variable, and adaptation

strategies acting as the moderating factor. Institutional and policy support is positioned as an external factor influencing the success of adaptation strategies.

2.3 The current status of dairy feed resource availability and utilization

Globally, climate change has had profound implications for agricultural systems, especially livestock production. The dairy sector, in particular, is highly dependent on feed resources, the availability of which is directly influenced by climatic conditions. Dairy feed resources typically consist of natural pastures, cultivated forages, crop residues, and industrial by-products. However, changes in precipitation patterns, rising temperatures, and increased frequency of extreme weather events such as droughts, floods, and heatwaves are threatening the availability of these resources (Thornton et al. 2019).

Natural pastures form the backbone of dairy feed systems in many parts of the world, particularly in regions where extensive livestock farming is practiced. However, climate change has increased the unpredictability of pasture growth due to erratic rainfall and extreme temperatures (FAO, 2018). Studies have shown that the productivity of natural pastures declines significantly during prolonged dry spells, reducing the availability of high-quality forage for dairy cattle. In some cases, extreme heat also accelerates the degradation of plant matter, leading to a loss of nutritional value in pastures (IPCC, 2019). These climatic changes have forced dairy farmers worldwide to rethink their strategies for feed management, often leading to an increased reliance on supplemental feed sources, such as cultivated forages and industrial by-products (World Bank, 2020).

Globally, the use of agro-industrial by-products, such as maize bran, cottonseed meal, and soybean hulls, has grown as a strategy to counteract the limitations imposed by natural pastures and to ensure year-round feed availability. These by-products are particularly important during the dry season or in areas where pastures are insufficient to meet dairy cattle's nutritional needs (FAO, 2018). However, the high cost of procuring these by-products, especially in developing countries, limits their widespread adoption. Moreover, climate change-induced crop failures have further strained the supply of agro-industrial feed, making it both scarce and expensive for many dairy farmers worldwide.

Efforts to adapt dairy feed systems to climate change have increasingly focused on integrating sustainable practices. The Food and Agriculture Organization (FAO) and other international

bodies have promoted climate-smart agricultural practices, including the use of drought-tolerant forage species, improved pasture management techniques, and efficient water use systems. These practices are designed to mitigate the impact of climate variability on feed resources, while improving the overall resilience of dairy farming systems (Lipper et al. 2018).

However, adaptation to climate change remains uneven across different regions, particularly in developing countries where resources are scarce. For instance, while large commercial dairy farms in developed nations may have access to advanced technologies and diversified feed sources, smallholder dairy farmers in developing countries often lack the financial and technical resources to implement such strategies (Thornton et al. 2019). As climate change continues to affect global agriculture, the need for equitable access to adaptation resources becomes increasingly pressing.

Africa is one of the most vulnerable continents to climate change due to its reliance on rain-fed agriculture, limited resources, and inadequate adaptive capacity (Niang et al. 2014). Dairy farming plays a crucial role in the livelihoods of millions of Africans, contributing to food security, rural employment, and economic growth. However, the sustainability of dairy farming is being severely compromised by the impact of climate change on feed resources, particularly natural pastures and forages (Herrero et al. 2016).

In sub-Saharan Africa, natural pastures remain the primary feed resource for dairy cattle, especially among smallholder farmers. These pastures are typically reliant on seasonal rainfall, making them highly vulnerable to climate variability. The Intergovernmental Panel on Climate Change (IPCC) reports that prolonged dry spells, erratic rainfall patterns, and higher temperatures are already affecting pasture growth in many parts of Africa (IPCC, 2019). As a result, forage availability during the dry season has become increasingly unpredictable, leading to significant feed shortages for dairy cattle (Thornton et al. 2019).

Moreover, the nutritional quality of natural pastures in Africa is declining as climate change accelerates the degradation of grazing lands. Rising temperatures, combined with erratic rainfall, lead to increased evapotranspiration and reduced soil moisture, which in turn affects plant growth and forage quality (FAO, 2019). In many cases, pasturelands have become less productive, forcing dairy farmers to rely more heavily on supplemental feeds, which are often expensive or unavailable (Muller, 2017).

In response to these challenges, African dairy farmers are increasingly adopting agro-industrial by-products as a means of supplementing natural pastures. By-products such as maize bran, cottonseed cake, and wheat bran are commonly used to fill the gap left by poor pasture growth during the dry season (Chaudhary et al. 2019). These supplements provide essential nutrients to dairy cattle, helping to maintain milk production levels even when natural feed resources are scarce. However, the use of agro-industrial by-products remains constrained by their cost and availability, especially in rural areas (Murendo et al. 2019).

To mitigate the impact of climate change on dairy feed resources, several African countries have begun to implement climate-smart agricultural practices. These include the cultivation of drought-tolerant forage species, such as Napier grass and legume-based pastures, which are more resilient to erratic rainfall and high temperatures (Chiduzo, 2021). Additionally, water management practices, such as rainwater harvesting and drip irrigation, are being promoted to support forage growth in arid and semi-arid regions (Chanza & Musakwa, 2021). Despite these efforts, the adoption of climate-smart practices is still limited by financial constraints, lack of technical knowledge, and weak institutional support across much of Africa (Thornton et al. 2019).

In Eastern and Southern Africa, where dairy farming is a key economic activity, climate change is exacerbating the challenges faced by farmers. For example, in countries like Kenya, Tanzania, and Zimbabwe, prolonged droughts have significantly reduced the availability of feed resources, leading to decreased milk yields and higher production costs (Chikodzi, 2019). These challenges are particularly pronounced in regions where smallholder dairy farmers rely on rain-fed pastures and have limited access to supplemental feeds (Murendo et al. 2019).

Zimbabwe's dairy sector is crucial to the country's food security, rural livelihoods, and economic development. However, the sector is highly vulnerable to the impacts of climate change, particularly in terms of feed resource availability. Dairy farming in Zimbabwe primarily relies on natural grazing lands, rain-fed forages, and agro-industrial by-products. Over the past few decades, climatic changes have increasingly disrupted the availability and quality of these resources, making it more difficult for farmers to sustain dairy production (Nyanga, 2021). The main feed resources for dairy farmers in Zimbabwe are natural pastures and cultivated forages, which are highly dependent on seasonal rainfall. However, the increasing frequency of droughts, erratic rainfall, and rising temperatures has led to a significant decline in pasture productivity in many parts of the country (Bongo et al. 2018). In

Seke District, for instance, farmers have reported that prolonged dry spells and unpredictable rainfall patterns have made it difficult to maintain adequate forage supplies, especially during the dry season (Nyanga, 2021). As a result, many dairy farmers face feed shortages, which negatively affect milk production and cattle health.

Despite these efforts, the adoption of climate-smart practices remains limited in Zimbabwe due to financial constraints, lack of access to extension services, and weak institutional support (Murendo et al. 2019). Smallholder farmers, in particular, face significant barriers to adopting new technologies and practices that could improve their resilience to climate change. Furthermore, there is a lack of comprehensive research on the effectiveness of different adaptation strategies, making it difficult for farmers to make informed decisions about how to manage their feed resources in the face of climate variability (Magwaza, 2019).

Therefore, climate change is having a profound impact on dairy feed resources globally, and this is particularly evident in vulnerable regions such as Africa and Zimbabwe. Natural pastures, which are the primary feed resource for dairy cattle, are being degraded by erratic rainfall, prolonged droughts, and rising temperatures. As a result, farmers are increasingly relying on agro-industrial by-products to supplement natural pastures, although the high cost and limited availability of these by-products remain significant challenges. In Zimbabwe, dairy farmers are adopting climate-smart agricultural practices, such as the diversification of forage species and improved water management, to mitigate the impact of climate variability on feed resources. However, financial and institutional barriers continue to hinder the widespread adoption of these practices, highlighting the need for targeted interventions to support the resilience of the dairy sector in the face of climate change.

2.4 The impacts of climate change on the quality and quantity of dairy feed resources

2.4.1 Changes in Temperature and Rainfall Patterns

Globally, climate change has led to significant alterations in temperature and rainfall patterns, which directly impact the availability and quality of feed resources for dairy farming. The rise in global temperatures, as reported by the Intergovernmental Panel on Climate Change (IPCC), has been accelerating over the last few decades, resulting in more frequent heatwaves and prolonged droughts (IPCC, 2019). In many parts of the world, particularly in temperate and tropical regions, this increase in temperature reduces the growth of natural pastures and forage crops, which are essential for dairy cattle nutrition. The ability of pastures to regenerate and

maintain their nutrient content declines when subjected to extreme temperatures and erratic rainfall (Thornton et al. 2019).

In addition to rising temperatures, changes in rainfall patterns are leading to both waterlogged conditions and extended dry spells, both of which are detrimental to forage crops (World Bank, 2020). Excessive rainfall leads to waterlogging, which depletes the oxygen available to plant roots, resulting in stunted growth and reduced forage quality. On the other hand, dry spells and droughts decrease the availability of water, which is crucial for the photosynthesis and growth of forage crops like grasses and legumes. These factors collectively reduce the productivity of natural pastures, forcing dairy farmers to seek alternative feed resources.

2.4.2 Declining Forage Quality

Climate change also affects the nutritional content of forage crops, which are vital for maintaining milk production in dairy cattle. Studies have demonstrated that heat stress, resulting from prolonged periods of high temperatures, can cause forage crops to lose essential nutrients, such as proteins and carbohydrates, as well as micronutrients like calcium and magnesium (Lipper et al. 2018). The nutritional degradation of forage crops leads to poor feed quality, which in turn results in nutritional imbalances in dairy cattle. These imbalances can cause significant declines in milk yields and negatively affect cattle health, particularly during critical lactation periods (Thornton et al. 2019).

Furthermore, as the growing season for forage crops shortens due to increasing temperatures and erratic rainfall, dairy farmers are left with less time to harvest high-quality feed for their livestock. This reduction in growing season length leads to early harvesting, which often produces less mature forage with lower nutrient content (FAO, 2019). Consequently, dairy farmers face both reduced quantity and quality of feed resources, making it challenging to sustain milk production at optimum levels. The effects of climate change on feed quality are thus a key driver of declining productivity in the global dairy sector, particularly for smallholder farmers who depend heavily on natural pastures.

2.4.3 Increasing Reliance on Supplementary Feeds

The growing impacts of climate change on natural pastures and forage crops have forced dairy farmers worldwide to increasingly rely on supplementary feeds, such as maize bran, soybean

meal, and cottonseed cake (FAO, 2018). These agro-industrial by-products are essential in providing the necessary nutrients that natural pastures may lack, particularly during periods of feed scarcity. However, the high cost and limited availability of these supplementary feed resources present challenges, especially for smallholder dairy farmers in low-income countries (World Bank, 2020).

In developed countries, farmers have access to advanced technologies and infrastructure, which allow them to mitigate the impacts of climate change on feed resources more effectively. Practices such as precision agriculture, feed storage, and improved water management have helped commercial dairy farms maintain feed availability throughout the year (Thornton et al. 2019). However, in developing countries, limited access to financial resources and technical knowledge often makes it difficult for farmers to afford these supplementary feeds, leading to unsustainable farming practices and reduced dairy productivity.

2.4.4 Impact of Rising Temperatures and Erratic Rainfall

Africa is one of the regions most affected by climate change due to its reliance on rain-fed agriculture and limited adaptive capacity (Niang et al. 2014). In sub-Saharan Africa, dairy farming is a key livelihood activity, providing food security and income to millions of households. However, climate-induced changes in temperature and rainfall are increasingly threatening the availability of feed resources for dairy cattle. Rising temperatures across the continent have led to more frequent heatwaves, which significantly reduce the productivity of natural pastures and cultivated forages (FAO, 2019).

Erratic rainfall patterns, characterized by prolonged dry spells and intense, short-duration rainfall, have also had detrimental effects on forage crops in Africa (Herrero et al. 2016). For instance, in the Sahel region and parts of East Africa, increasing rainfall variability has resulted in the desertification of grazing lands, making it difficult for pastoralists to find sufficient forage for their cattle. In Southern Africa, countries like Zimbabwe, Botswana, and Namibia are experiencing more frequent droughts, which have reduced water availability for crops and degraded pasturelands (Chikodzi, 2019). These climatic shifts are causing widespread feed shortages, especially during the dry season when natural pastures are typically sparse.

2.4.5 Declining Nutritional Value of Forage Crops

The nutritional quality of forage crops in Africa is declining due to the combined effects of rising temperatures and changing rainfall patterns. Research shows that heat stress can reduce the protein content of grasses and legumes, while also decreasing the concentration of essential nutrients such as phosphorus and calcium (Chaudhary et al. 2019). These reductions in nutrient levels lead to nutritional deficiencies in dairy cattle, which can have serious implications for milk production and overall herd health.

Moreover, prolonged dry spells in Africa are shortening the growing seasons of forage crops, which forces farmers to harvest immature forage that lacks the necessary nutrients for optimal cattle nutrition. In countries like Kenya and Tanzania, where dairy farming is critical to rural livelihoods, the decline in forage quality is contributing to lower milk yields and increased susceptibility to diseases among livestock (Murendo et al. 2019). The deterioration of grazing lands and forage crops under climate stress is, therefore, a significant challenge for maintaining dairy production across the continent.

2.4.6 The Role of Agro-Industrial By-Products

To compensate for the declining quality and quantity of natural pastures, many African dairy farmers are turning to agro-industrial by-products as supplementary feeds. By-products such as maize bran, wheat bran, cottonseed meal, and sunflower cake provide essential nutrients to dairy cattle, particularly during periods of feed scarcity (FAO, 2020). These supplements help mitigate the effects of poor-quality forage and ensure that cattle receive adequate nutrition for milk production. However, the high cost and limited availability of these by-products, particularly in rural areas, present significant barriers to their widespread use (Muller, 2017).

In East and Southern Africa, smallholder dairy farmers often struggle to access these supplementary feeds due to financial constraints and poor infrastructure (Chikodzi, 2019). Additionally, climate change-induced crop failures, such as maize and soybean crop losses, further strain the availability of agro-industrial by-products, making them both scarce and expensive (Chaudhary et al. 2019). As a result, many smallholder farmers in Africa are forced to reduce their herd sizes or sell cattle during periods of feed scarcity, leading to a decline in dairy production and household income.

2.4.7 Adoption of Climate-Smart Agricultural Practices

In response to the growing challenges posed by climate change, African dairy farmers are increasingly adopting climate-smart agricultural (CSA) practices to enhance the resilience of their farming systems (FAO, 2020). CSA practices, such as the cultivation of drought-tolerant forage species, improved water management techniques, and feed conservation strategies, aim to mitigate the impact of climate variability on feed resources. For instance, in Kenya, dairy farmers are planting legume-based pastures and drought-resistant grasses like Napier grass to ensure consistent feed availability throughout the year (Chiduza, 2021).

Water management practices, including rainwater harvesting, drip irrigation, and the construction of water reservoirs, are also being promoted to support forage growth during dry periods (Thornton et al. 2019). These strategies help improve pasture productivity and ensure a stable supply of feed for dairy cattle, even in arid and semi-arid regions. In addition, feed conservation methods, such as silage making and haymaking, are being used to store forage during the wet season for use during the dry season (Chanza & Musakwa, 2022).

Despite the progress made in adopting climate-smart practices, there are still significant barriers to their widespread implementation in Africa. Limited access to financial resources, technical knowledge, and institutional support continues to hinder the ability of smallholder farmers to adopt these practices at large scale (Murendo et al. 2019). Moreover, the lack of research on the effectiveness of different CSA practices in specific agro-ecological contexts makes it difficult for farmers to make informed decisions about how to manage their feed resources in the face of climate change (Chikodzi, 2019).

2.4.8 Rising Temperatures and Feed Scarcity

In Zimbabwe, climate change is already having a significant impact on dairy farming, particularly in terms of feed resource availability. Dairy farmers in Zimbabwe rely heavily on natural pastures and rain-fed forage crops to sustain their herds. However, rising temperatures and increasingly erratic rainfall patterns are reducing the productivity of these feed resources (Bongo et al., 2018). The average duration of dry spells in Zimbabwe has increased over the past few decades, leading to a sharp decline in pasture growth during the dry season. This reduction in pasture availability forces farmers to rely on expensive supplementary feeds, which are often unaffordable for smallholder farmers (Mudiwa, 2021).

The rising temperatures in Zimbabwe also accelerate the degradation of grazing lands, making it difficult for pastures to regenerate and provide sufficient feed for dairy cattle. As a result, many farmers are experiencing feed shortages, which negatively affect milk production and herd health (Nyanga, 2021). The impact of climate change on natural pastures is particularly pronounced in regions like Seke District, where prolonged dry spells and water scarcity have become common occurrences (Bongo et al. 2018).

2.4.9 Declining Nutritional Value of Forage Crops

The quality of forage crops in Zimbabwe is also declining due to the combined effects of heat stress and erratic rainfall. Studies have shown that forage crops such as grasses and legumes exhibit reduced nutrient content when exposed to prolonged dry spells or waterlogged conditions (Mupangwa et al. 2021). This reduction in nutrient levels leads to nutritional imbalances in dairy cattle, which can cause lower milk yields, reproductive inefficiencies, and an increased susceptibility to diseases (Munyati, 2020).

The shortening of the growing season for key forage crops due to climate change further exacerbates the problem of declining forage quality. In Zimbabwe, farmers often have to harvest forage crops earlier than usual, resulting in immature forage with lower nutritional value (Chanza & Musakwa, 2021). The combination of reduced quantity and quality of forage crops is a major challenge for maintaining sustainable dairy production in Zimbabwe.

2.4.10 Adoption of Agro-Industrial By-Products

To cope with feed shortages, Zimbabwean dairy farmers are increasingly turning to agro-industrial by-products such as maize bran, cottonseed cake, and sunflower meal to supplement natural pastures (Magwaza, 2019). These by-products provide essential nutrients that help maintain milk production during periods of feed scarcity. However, the high cost and limited availability of these by-products present significant challenges for smallholder farmers, who often lack the financial resources to purchase sufficient quantities of supplementary feeds (Gusha, 2020). Climate change-induced crop failures, particularly in maize and cotton-producing regions, have further strained the availability of these by-products, making them more expensive and difficult to obtain (Chanza & Musakwa, 2021). As a result, many smallholder farmers in Zimbabwe are forced to reduce their herd sizes or sell cattle during periods of feed scarcity, leading to a decline in dairy production and household income.

2.4.11 Climate-Smart Agricultural Practices in Zimbabwe

In response to the growing challenges posed by climate change, Zimbabwean dairy farmers are increasingly adopting climate-smart agricultural practices aimed at improving feed resource management (Nyanga, 2021). These practices include the cultivation of drought-tolerant forage species such as Napier grass and lucerne, which are more resilient to erratic rainfall and high temperatures. In addition, water management practices such as rainwater harvesting and irrigation are being implemented to support forage growth and ensure a consistent supply of feed during the dry season (Chanza & Musakwa, 2021).

Feed preservation techniques such as silage making and haymaking are also being promoted to store forage during the wet season for use during the dry season (Gusha, 2020). These practices help mitigate the impact of feed shortages and ensure that dairy cattle receive adequate nutrition year-round. However, the adoption of climate-smart practices remains limited in Zimbabwe due to financial constraints, lack of access to extension services, and weak institutional support (Murendo et al. 2019).

In conclusion, climate change is having a profound impact on the quality and quantity of dairy feed resources globally, and this is particularly evident in vulnerable regions such as Africa and Zimbabwe. Rising temperatures and erratic rainfall patterns are reducing the productivity of natural pastures and forage crops, leading to feed shortages and declining nutritional value. In Zimbabwe, dairy farmers are increasingly relying on agro-industrial by-products and adopting climate-smart agricultural practices to mitigate the impact of climate variability on feed resources. However, financial constraints, limited access to technical knowledge, and institutional barriers continue to hinder the widespread adoption of these practices, highlighting the need for targeted interventions to support the resilience of the dairy sector in the face of climate change.

2.5 Adaptation strategies adopted by dairy farmers to mitigate the effects of climate change on feed resources

2.5.1 Diversification of Forage Species

Globally, dairy farmers are increasingly turning to the diversification of forage species as a key strategy to mitigate the impacts of climate change on feed resources. This involves the introduction of drought-tolerant forage crops such as *Cenchrus purpureus* (Napier grass),

Medicago sativa (Alfalfa / Lucerne), and fodder shrubs, which are better suited to withstand the extreme weather conditions brought about by climate variability. In regions such as South Asia and Latin America, Napier grass has become a popular choice for dairy farmers because of its high yield potential under both dry and wet conditions (Thornton et al. 2019). Alfalfa, a leguminous plant with deep roots, is another drought-tolerant species that is widely used in arid and semi-arid regions for its ability to improve soil fertility and provide high-protein feed for dairy cattle (FAO, 2020).

Agroforestry systems, which integrate trees and shrubs into farming systems, are also being promoted as an adaptive strategy to improve feed availability while conserving natural resources. In countries like Brazil and India, dairy farmers are planting fodder trees such as *Leucaena* and *Gliricidia* species to supplement traditional feed sources (FAO, 2018). These trees not only provide high-quality forage but also contribute to soil health and water conservation, making them an essential part of sustainable dairy farming systems.

Diversifying forage species has the dual benefit of improving feed availability during periods of climate-induced stress and enhancing the resilience of the overall farming system. The use of drought-tolerant species ensures that farmers can maintain a steady supply of feed even during prolonged dry spells or unpredictable rainfall patterns (Lipper et al. 2018). Furthermore, the integration of legumes and shrubs into grazing systems can improve soil fertility through nitrogen fixation, thus enhancing the long-term sustainability of the farming system.

2.5.2 Improved Water Management Practices

Water scarcity is one of the most significant challenges posed by climate change to dairy farming, especially in regions where natural pastures are rain-fed. Globally, dairy farmers are adopting improved water management practices to ensure the continuous growth of forage crops and maintain feed availability throughout the year. Water-efficient irrigation techniques such as drip irrigation and sprinkler systems are increasingly being used to optimize water usage and minimize wastage in fodder production (World Bank, 2020). In arid and semi-arid regions of the Middle East and North Africa, drip irrigation is helping dairy farmers sustain forage production despite limited water resources.

Rainwater harvesting is another critical strategy being employed by dairy farmers globally. This practice involves capturing and storing rainwater during the wet season for use during dry

periods. Rainwater harvesting systems can range from simple ponds and tanks to more advanced storage and irrigation systems, depending on the resources available to the farmers (Thornton et al. 2019). For example, in parts of India and Kenya, smallholder dairy farmers are using rooftop rainwater harvesting systems to collect water for their livestock and crops, thus ensuring a more stable water supply during the dry season.

Water management strategies are crucial for maintaining the productivity of dairy feed resources, particularly in regions experiencing prolonged droughts or erratic rainfall. Efficient use of water not only improves the resilience of forage crops but also reduces the pressure on scarce water resources, thereby contributing to the sustainability of the dairy farming system (FAO, 2018).

2.5.3 Feed Preservation Techniques

Feed preservation is another essential strategy that dairy farmers worldwide are adopting to cope with the impact of climate change on feed resources. The preservation of surplus forage during the wet season ensures that farmers have access to high-quality feed during periods of scarcity, such as the dry season or during prolonged droughts. Two widely adopted preservation techniques are silage making and haymaking. Silage involves fermenting green forage in anaerobic conditions to preserve its nutritional content for future use. It is especially useful for preserving high-moisture crops such as corn and grass, which can be harvested during the rainy season and stored for use during the dry season (FAO, 2020). In many countries, silage making is becoming an integral part of dairy feed management. For example, in Europe and North America, farmers commonly use corn silage as a staple in dairy cow diets, ensuring consistent feed quality year-round (Thornton et al. 2019).

Haymaking, on the other hand, involves drying and storing forage crops such as grasses and legumes to be used as feed during periods when fresh forage is unavailable. This method is particularly prevalent in regions where rainfall is seasonal, and fresh forage is only available for part of the year. In countries like Australia and parts of Africa, dairy farmers produce hay during the wet season and store it for use during the dry months (Lipper et al. 2018). In Zimbabwe most farmers cut their hay from January to June, but the quality becomes poor as the winter dry seasons approach. All grasses that are cut after complete seeding will have poor quality in terms of crude protein and energy levels.

Feed preservation techniques are vital for maintaining the nutritional quality of dairy feed and preventing feed shortages caused by climate-induced disruptions to natural pastures. By adopting these practices, dairy farmers can stabilize their feed supply and reduce the negative impacts of climate variability on milk production.

2.6 Challenges to the Adoption of Climate-Smart Agriculture Practices

While the adaptation and adoption of climate-smart agriculture practices and strategies discussed above offer significant benefits, their adoption remains limited in many parts of the world due to financial constraints, inadequate access to extension services, and limited availability of climate-related information. In low-income countries, smallholder dairy farmers often lack the capital needed to invest in technologies such as drip irrigation, rainwater harvesting, and silage-making equipment (FAO, 2018). Furthermore, the lack of extension services in rural areas means that many farmers are unaware of these practices or do not have the technical knowledge required to implement them effectively.

Additionally, climate-related information is often inaccessible to smallholder farmers, particularly in remote areas where communication networks are weak. Without accurate and timely information on weather patterns and climate risks, farmers are unable to make informed decisions about which adaptation strategies to adopt (World Bank, 2020). These barriers highlight the need for targeted interventions to improve access to financial resources, technical knowledge, and climate information for dairy farmers, particularly in developing countries.

2.7 Adaptation Strategies in Africa

2.7.1 Diversification of Drought-Tolerant Forage Species

In Africa, where dairy farming is a key livelihood activity for millions of people, climate change is posing serious challenges to the availability of feed resources. In response, African dairy farmers are increasingly adopting drought-tolerant forage species to ensure a stable supply of feed throughout the year. In East Africa, for instance, dairy farmers are planting Napier grass, a fast-growing and drought-tolerant grass that is highly nutritious for dairy cattle (Chikodzi, 2019). Similarly, in Southern Africa, leguminous forages such as lucerne (alfalfa) and fodder trees like *Leucaena* species are being introduced to improve feed availability during periods of drought (Mupangwa et al. 2021).

The introduction of legume-based pastures is particularly important in Africa because of their ability to fix nitrogen in the soil, thus improving soil fertility and supporting the growth of other crops (FAO, 2019). In regions like Ethiopia and Kenya, dairy farmers are integrating leguminous forages into their farming systems to enhance the nutritional content of the feed and improve milk yields (Chaudhary et al. 2019). These species are well-suited to the arid and semi-arid conditions found in many parts of Africa and help mitigate the impact of erratic rainfall and prolonged dry spells on feed resources.

2.7.2 Agroforestry Systems for Feed and Soil Conservation

Agroforestry systems are gaining traction in Africa as a sustainable approach to improving feed availability while conserving natural resources. Agroforestry involves the integration of trees and shrubs into agricultural systems, providing multiple benefits such as improved soil fertility, water retention, and biodiversity (FAO, 2020). In countries like Kenya and Rwanda, dairy farmers are planting fodder trees like *Calliandra* and *Leucaena* species to supplement their traditional feed resources and provide high-protein forage for dairy cattle (Chikodzi, 2019).

These fodder trees not only provide a reliable source of feed during the dry season but also contribute to soil conservation by preventing erosion and improving water retention. The deep-rooted nature of these trees allows them to access water and nutrients from deeper soil layers, making them more resilient to drought conditions (Chiduza, 2021). Agroforestry systems are also beneficial for the environment as they promote carbon sequestration and enhance biodiversity, thus contributing to climate change mitigation efforts.

2.7.3 Water Management Practices

Water scarcity is one of the most pressing challenges faced by dairy farmers in Africa, particularly in arid and semi-arid regions. To cope with this challenge, African dairy farmers are increasingly adopting improved water management practices to ensure the continuous growth of forage crops. Rainwater harvesting is a widely adopted practice in countries like Kenya, Ethiopia, and South Africa, where rainfall is seasonal, and water availability is limited during the dry season (Thornton et al. 2019). Farmers use rooftop rainwater harvesting systems and construct small ponds to capture and store rainwater for use during periods of water scarcity.

Drip irrigation is also being promoted in Africa as a water-efficient method for irrigating forage crops. In Tanzania and Zimbabwe, dairy farmers are using drip irrigation systems to optimize water usage and improve the productivity of their pastures (Chanza & Musakwa, 2021). These systems deliver water directly to the roots of the plants, minimizing evaporation and ensuring that crops receive the necessary moisture even in dry conditions. The use of drip irrigation not only improves feed availability but also reduces the pressure on scarce water resources, thus enhancing the sustainability of dairy farming in water-stressed regions.

2.7.4 Feed Preservation Techniques

Feed preservation techniques such as silage making and haymaking are critical for ensuring that dairy farmers in Africa have access to high-quality feed during periods of feed scarcity. Silage making is particularly popular in East Africa, where farmers are preserving surplus forage during the rainy season to use during the dry season (Chikodzi, 2019). In Kenya, for example, smallholder dairy farmers are using plastic bags and trenches to make silage from Napier grass and maize stalks, which can be stored for several months without losing its nutritional value (Mupangwa et al. 2021).

Haymaking is another widely adopted feed preservation technique in Africa. In countries like South Africa and Zimbabwe, dairy farmers are producing hay during the wet season and storing it for use during the dry months when fresh forage is unavailable (Chanza & Musakwa, 2021). These practices help farmers stabilize their feed supply and reduce the negative impacts of climate-induced feed shortages on milk production.

2.8 Challenges to Adoption in Africa

Despite the growing adoption of these climate-smart practices, many African dairy farmers face significant challenges in implementing them at full-scale. Financial constraints are one of the biggest barriers to the adoption of technologies such as drip irrigation, silage-making equipment, and rainwater harvesting systems (FAO, 2020). Many smallholder farmers in Africa lack the capital needed to invest in these technologies, limiting their ability to cope with the impacts of climate change on feed resources.

Additionally, the lack of access to extension services and technical knowledge further hinders the adoption of climate-smart practices in Africa. In rural areas, where communication

networks are weak, many farmers are unaware of these practices or do not have the necessary skills to implement them effectively (Murendo et al. 2019). This highlights the need for targeted interventions to improve access to financial resources, technical knowledge, and extension services for smallholder dairy farmers in Africa.

2.9 Adaptation Strategies in Zimbabwe's Dairy Systems

2.9.1 Diversification of Forage Species

In Zimbabwe, dairy farmers are increasingly adopting drought-tolerant forage species to mitigate the impact of climate change on feed resources. Napier grass and lucerne are two of the most popular forage species being introduced in the country due to their high yield potential and ability to withstand dry conditions (Mupangwa et al. 2021). These species are being integrated into traditional grazing systems to ensure a stable supply of feed throughout the year.

The introduction of fodder shrubs such as *Leucaena* and *Calliandra* species is also gaining traction in Zimbabwe. These shrubs provide high-protein forage for dairy cattle and improve soil fertility through nitrogen fixation (Chanza & Musakwa, 2021). In regions like Seke District, where water scarcity and poor pasture conditions are prevalent, the adoption of these drought-tolerant species is helping farmers maintain feed availability despite the challenges posed by climate change.

2.9.2 Water Management Practices

Water management practices such as rainwater harvesting and drip irrigation are being implemented by dairy farmers in Zimbabwe to cope with the increasing water scarcity caused by climate change (Nyanga, 2021). Rainwater harvesting systems are being used to capture and store rainwater during the wet season for use during the dry season, ensuring a continuous supply of water for forage crops.

Drip irrigation is also being promoted in Zimbabwe as a water-efficient method for irrigating pastures. By delivering water directly to the roots of the plants, drip irrigation reduces water wastage and ensures that crops receive the necessary moisture even in dry conditions (Chanza & Musakwa, 2021). These water management practices are crucial for sustaining forage production in Zimbabwe, where erratic rainfall and prolonged dry spells are becoming more frequent.

2.9.3 Feed Preservation Techniques

Feed preservation techniques such as silage making and haymaking are being adopted by dairy farmers in Zimbabwe to ensure that they have access to high-quality feed during the dry season (Gusha, 2020, Mudiwa, 2021). Silage making is particularly popular in regions where dairy farmers are producing surplus forage during the wet season and storing it for use during periods of feed scarcity. Haymaking is also widely practiced, especially in areas where rainfall is seasonal, and fresh forage is only available for part of the year.

These feed preservation techniques help dairy farmers in Zimbabwe stabilize their feed supply and maintain milk production levels despite the challenges posed by climate-induced feed shortages. By adopting these practices, farmers can reduce their reliance on expensive supplementary feeds and improve the resilience of their farming systems.

2.10 Challenges to Adoption in Zimbabwe

Despite the progress made in adopting climate-smart practices, there are still significant challenges to their widespread implementation in Zimbabwe. Financial constraints, limited access to extension services, and weak institutional support continue to hinder the ability of smallholder farmers to adopt these practices at scale (Murendo et al. 2019). Additionally, the lack of comprehensive research on the effectiveness of different adaptation strategies makes it difficult for farmers to make informed decisions about how to manage their feed resources in the face of climate change (Chanza & Musakwa, 2022).

Dairy farmers globally, in Africa, and in Zimbabwe are increasingly adopting various adaptation strategies to mitigate the impacts of climate change on feed resources. These strategies include the diversification of drought-tolerant forage species, the adoption of improved water management practices, and the use of feed preservation techniques such as silage making and haymaking. Despite the benefits of these practices, their adoption remains limited due to financial constraints, inadequate access to extension services, and poor availability of climate-related information. To improve the resilience of dairy farming systems in the face of climate change, targeted interventions are needed to support the widespread adoption of climate-smart practices, particularly in low-income countries and rural areas.

2.11 The challenges faced by dairy farmers in accessing and utilizing feed resources under the influence of climate change

2.11.1 Decline in Natural Pastures and Forage Availability

The global dairy sector is highly dependent on natural pastures and forage crops, particularly in countries where extensive livestock farming is the norm. However, climate change is exacerbating the decline in these vital feed resources due to erratic rainfall, rising temperatures, and the increased frequency of extreme weather events such as droughts and floods. In many parts of the world, prolonged dry spells have significantly reduced pasture growth and availability, directly impacting dairy production (Thornton et al. 2019). For instance, in parts of South Asia and Latin America, dairy farmers have reported that unpredictable weather patterns have shortened growing seasons, reduced pasture regeneration, and increased competition for limited grazing lands (FAO, 2018).

The loss of natural pastures is particularly problematic in regions where dairy production depends heavily on grazing. The degradation of rangelands, exacerbated by both climate change and unsustainable grazing practices, has led to widespread feed shortages, forcing farmers to turn to alternative feed sources that are often more expensive and less nutritious. In arid and semi-arid regions, such as parts of Australia and Africa, the combination of increased temperatures and declining rainfall has accelerated desertification, further reducing the availability of grazing lands for dairy cattle. The challenge also applies for Seke District in Zimbabwe.

2.11.2 Rising Costs of Supplementary Feeds

As natural pastures become less reliable due to climate variability, dairy farmers globally have been forced to rely more heavily on supplementary feeds such as maize bran, soybean meal, and cottonseed cake to sustain their herds. However, the rising costs of these agro-industrial by-products present a significant challenge, particularly for smallholder farmers in low- and middle-income countries (World Bank, 2020). The high cost of supplementary feeds is driven by multiple factors, including climate-induced crop failures that limit the supply of raw materials, increasing transportation costs, and growing demand for these feed products in both the livestock and biofuel industries (Thornton et al. 2019).

In many developing countries, dairy farmers often find it difficult to afford supplementary feeds, especially during the dry season when natural pastures are scarce and prices for feed products spike (FAO, 2018). In Zimbabwe, the cost of feeds was noted to account on average for 70-80% of cost of production for Zimbabwean dairy farmers (Chifamba, 2023). For instance, in parts of Asia and Africa, the cost of purchasing supplementary feeds can account for up to 70% of the total operating expenses for smallholder dairy farms (Lipper et al., 2018). As a result, many farmers are unable to maintain optimal herd productivity, leading to reduced milk yields and increased economic vulnerability.

2.11.3 Limited Access to Climate-Resilient Forage Crops

Globally, efforts are being made to promote the adoption of climate-resilient forage crops such as drought-tolerant grasses and leguminous forages. These crops have the potential to provide high-quality feed for dairy cattle even under adverse climatic conditions, but their uptake remains limited due to several challenges (FAO, 2020). One of the primary barriers is the lack of access to seeds for these forage species. In many parts of the world, particularly in rural areas, farmers struggle to obtain the necessary seeds to establish climate-resilient pastures (World Bank, 2020). Zimbabwe imports most of the fodder seed that most dairy farmers grow in Zimbabwe.

In Zimbabwe, the primary challenge faced by dairy farmers is the increasing scarcity of natural pastures and forage crops due to climate change. Prolonged dry spells, erratic rainfall, and rising temperatures have significantly reduced the availability of natural pastures in many parts of the country, including Seke District (Nyanga, 2021). Dairy farmers in these regions have reported that pasture growth has declined, leading to feed shortages and reduced milk yields (Bongo et al., 2018).

The degradation of grazing lands due to overgrazing and land mismanagement has further exacerbated the scarcity of natural pastures. In some cases, dairy farmers have been forced to migrate to new areas in search of better grazing conditions, while others have had to reduce their herd sizes to cope with the limited availability of feed resources (Mupangwa et al. 2021). The loss of natural pastures has a direct impact on dairy productivity, as cattle that do not receive adequate nutrition are less productive and more susceptible to diseases (Chanza & Musakwa, 2021).

Additionally, there is often a lack of technical knowledge regarding the cultivation and management of climate-resilient forage crops. Farmers who are unfamiliar with these species may be hesitant to invest in them, especially if they do not have access to extension services or other forms of support to guide them through the process (Thornton et al. 2019). Furthermore, climate-resilient forage crops often require upfront investments in terms of land preparation, water management, and fertilizers, which can be prohibitive for resource-constrained smallholder farmers (FAO, 2020).

2.11.4 Inadequate Institutional Support and Extension Services

In many parts of the world, including Zimbabwe, weak institutional support and inadequate extension services compound the challenges faced by dairy farmers in accessing and utilizing feed resources under the influence of climate change. Extension services play a crucial role in disseminating information about climate-smart agricultural practices, including feed management techniques, drought-tolerant forage species, and sustainable grazing practices (Murendo et al. 2019). However, in many low-income countries, these services are underfunded and understaffed, limiting their reach and effectiveness.

Without adequate extension services, farmers are often left to cope with the impacts of climate change on their own, without access to the latest research and technologies that could help them adapt. This lack of institutional support also extends to financial services, as many farmers are unable to access credit or insurance products that could help them invest in climate-resilient feed management practices (World Bank, 2020). The combination of inadequate technical support and limited financial resources makes it difficult for smallholder dairy farmers to adopt the strategies needed to mitigate the effects of climate change on feed resources.

2.11.5 Increased Competition for Grazing Land

In Africa, dairy farming is largely dependent on natural pastures, especially among smallholder farmers and pastoralists who rely on communal grazing lands. However, climate change has exacerbated the competition for these grazing lands due to the increasing scarcity of water and forage resources (Niang et al., 2014). In many parts of East and Southern Africa, prolonged droughts have led to the degradation of rangelands, reducing their capacity to support dairy cattle. This has intensified competition between livestock keepers, leading to overgrazing and further land degradation (FAO, 2020).

The downsizing of some dairy farms during the land reform led to grazing pressure on some grazing lands where dairy farming is practised. The increased competition for grazing land is particularly acute in the communal communities, where access to communal grazing areas is vital for maintaining herd productivity. In countries like Kenya, Tanzania, and Ethiopia, and Zimbabwe, dairy farmers are finding it increasingly difficult to access sufficient pasture for their cattle due to the encroachment of agricultural activities, land fragmentation, and the effects of climate change (Chikodzi, 2019). The scarcity of grazing land forces farmers to either reduce their herd sizes or migrate in search of better grazing conditions, both of which have significant economic and social consequences.

2.11.6 Declining Nutritional Value of Natural Pastures

The nutritional quality of natural pastures in Africa is declining due to the combined effects of climate change and land degradation. Rising temperatures and erratic rainfall patterns are reducing the growth and regeneration of key forage species, leading to a loss of biodiversity in rangelands (Thornton et al. 2019). In many parts of Africa, the grasses and shrubs that traditionally provided high-protein feed for dairy cattle are being replaced by less nutritious species, resulting in poor-quality feed that is inadequate to meet the nutritional needs of dairy cattle (FAO, 2020).

The decline in forage quality has serious implications for dairy productivity, as cattle that do not receive adequate nutrition produce less milk and are more susceptible to diseases (Muller, 2017). In regions like the Sahel and Horn of Africa, where dairy farming is a critical livelihood activity, the loss of high-quality pastures has contributed to reduced milk yields and increased vulnerability to food insecurity (Chaudhary et al. 2019). The decline in pasture quality also forces farmers to rely more heavily on supplementary feeds, which are often expensive and difficult to obtain in rural areas.

2.11.7 High Costs and Limited Availability of Cheap Good Quality Dairy Feeds

As natural pastures become less reliable due to climate variability, African dairy farmers are increasingly relying on supplementary feeds to maintain herd productivity. However, the high cost and limited availability of feeds present significant challenges for smallholder farmers. In many parts of Africa, the cost of supplementary feeds such as maize bran, wheat bran, and cottonseed cake has risen sharply due to climate-induced crop failures, increasing

transportation costs, and growing demand for feed products in the livestock sector (FAO, 2018).

The high cost of supplementary feeds is particularly problematic for smallholder dairy farmers, who often operate on thin margins and lack the financial resources to purchase these products in sufficient quantities. In countries like Zimbabwe, Kenya, and Tanzania, the cost of supplementary feeds can account for a significant portion of the total operating expenses of dairy farms, making it difficult for farmers to maintain profitability during periods of feed scarcity (Murendo et al. 2019). The limited availability of supplementary feeds in rural areas further exacerbates the problem, as farmers in remote locations often struggle to access these products due to poor infrastructure and weak market linkages (Thornton et al. 2019).

As natural pastures become less reliable, Zimbabwean dairy farmers are increasingly turning to supplementary feeds such as maize bran, cottonseed cake, and sunflower meal to sustain their herds. However, the high cost of these supplementary feeds presents a significant challenge for smallholder farmers, who often lack the financial resources to purchase them in sufficient quantities (Gusha, 2020). In many cases, the cost of supplementary feeds can account for a significant portion of a dairy farmer's operating expenses, making it difficult to maintain profitability during periods of feed scarcity (Murendo et al. 2019).

The rising cost of supplementary feeds is driven by several factors, including climate-induced crop failures that reduce the supply of raw materials, increasing transportation costs, and growing demand for feed products in both the livestock and biofuel industries (Chanza & Musakwa, 2021). In rural areas, the availability of supplementary feeds is further limited by poor infrastructure and weak market linkages, which make it difficult for farmers to access these products.

2.11.8 Lack of Access to Climate-Resilient Forage Crops

In many parts of Africa, efforts to promote the adoption of climate-resilient forage crops have been hindered by a lack of access to seeds and technical knowledge. While drought-tolerant forage species such as Napier grass and lucerne have the potential to improve feed availability during periods of drought, many farmers in Africa are unable to access the seeds needed to establish these pastures (FAO, 2020). In some cases, farmers may not be aware of these forage

species or may lack the technical knowledge required to cultivate and manage them effectively (Muller, 2017).

The lack of access to climate-resilient forage crops is particularly problematic in arid and semi-arid regions of Africa, where the impacts of climate change on natural pastures are most severe. In countries like Ethiopia, Kenya, and Zimbabwe, farmers have reported that they are interested in adopting drought-tolerant forage species but are unable to do so due to the high cost and limited availability of seeds (Chikodzi, 2019). Furthermore, even when farmers have access to seeds, they may not have the resources or knowledge required to manage these crops effectively, leading to suboptimal results and reduced adoption rates (FAO, 2020).

Efforts to promote the adoption of drought-tolerant forage crops in Zimbabwe have been hindered by a lack of access to seeds and technical knowledge. While forage species such as Napier grass and lucerne have the potential to improve feed availability during periods of drought, many farmers in Zimbabwe are unable to obtain the seeds needed to establish these pastures (Mupangwa, 2021). Additionally, even when farmers have access to seeds, they may lack the resources or knowledge required to manage these crops effectively, leading to suboptimal results and reduced adoption rates (Gusha, 2020).

The limited adoption of climate-resilient forage species is particularly problematic in regions like Seke District, where water scarcity and poor pasture conditions are prevalent (Nyanga, 2021). Without access to drought-tolerant forage crops, many farmers are forced to rely on natural pastures that are becoming increasingly scarce due to climate change.

2.11.9 Weak Institutional Support and Extension Services

The lack of institutional support and inadequate extension services is a significant barrier to the adoption of climate-smart feed practices in Africa. In many countries, extension services are underfunded and understaffed, limiting their ability to provide farmers with the information and support needed to implement adaptive strategies (Murendo et al. 2019). This is particularly problematic in rural areas, where access to extension services is often limited, and farmers rely on traditional knowledge to manage their feed resources.

Without adequate extension services, many African dairy farmers are unaware of the climate-smart practices that could help them mitigate the impacts of climate change on feed resources.

For instance, farmers may not be aware of drought-tolerant forage species, improved grazing management techniques, or feed preservation methods such as silage making (FAO, 2020). The lack of access to technical knowledge and support also limits farmers' ability to adopt water-efficient irrigation systems, rainwater harvesting, and other practices that could improve the resilience of their feed resources.

Furthermore, weak institutional support extends to the financial sector, where many farmers struggle to access credit and insurance products that could help them invest in climate-resilient feed management practices. Without access to these financial services, smallholder farmers are often unable to make the necessary investments to improve their feed resources, leaving them vulnerable to the impacts of climate variability (FAO, 2018).

The lack of extension services and institutional support is a significant barrier to the adoption of climate-smart feed practices in Zimbabwe. In many rural areas, farmers do not have access to the technical knowledge and support needed to implement adaptive strategies such as silage making, improved grazing management, and water-efficient irrigation systems (Murendo et al. 2019). This lack of support limits farmers' ability to cope with the impacts of climate change on feed resources and reduces the overall resilience of the dairy sector.

In addition to the lack of extension services, weak institutional support in Zimbabwe extends to the financial sector, where many smallholder farmers struggle to access credit and insurance products that could help them invest in climate-resilient feed management practices (Chanza & Musakwa, 2021). Without access to these financial services, farmers are often unable to make the necessary investments to improve their feed resources, leaving them vulnerable to the impacts of climate variability.

Dairy farmers globally, in Africa, and in Zimbabwe face significant challenges in accessing and utilizing feed resources under the influence of climate change. The increasing scarcity of natural pastures, rising costs of supplementary feeds, limited access to climate-resilient forage crops, and inadequate institutional support are some of the key challenges that farmers must contend with. To improve the resilience of the dairy sector, targeted interventions are needed to support the adoption of climate-smart feed management practices, improve access to financial resources, and strengthen extension services in rural areas.

2.12 Gap in the Literature

While the literature reviewed provides valuable insights into the impacts of climate change on dairy feed resources and the adaptation strategies employed by farmers, several gaps remain. First, most studies focus on the broader agricultural sector, with limited research specifically addressing the dairy industry in Zimbabwe, particularly in regions like Seke District. Additionally, there is a lack of comprehensive data on the effectiveness of specific adaptation strategies, such as the use of drought-tolerant forage crops and agroforestry practices, in enhancing feed availability and reducing vulnerability to climate change. This study seeks to fill these gaps by providing a detailed analysis of the impact of climate change on dairy feed resources in Seke District and identifying sustainable solutions to support the resilience of the dairy sector.

CHAPTER THREE: METHODOLOGY

3.1 Research Design

3.1.1 Subjects

The subjects for this research are all scales of dairy farmers, dairy extension staff officers, and pasture seed specialists in Seke District, Zimbabwe. The district was selected due to its significant dairy farming activities and the documented impacts of climate change on feed resources in the area. The research covered the whole of Seke district in Mashonaland East province of Zimbabwe. The sample size is fifty-four (54), which comprised a total of forty-eight (48) dairy farmers, four (4) dairy extension officers and two (2) pasture specialists from seed companies that supplied seed to the farmers in Seke district. The research included all scales of dairy farmers, eight (8) large scale, seven (7) medium scale and thirty-three (33) small-scale dairy farmers which were all conducted as a census. The study also assessed a wide range of feed resources utilized in the dairy industry, including natural pastures, cultivated forages, crop residues, agro-industrial by-products, and supplementary feedstuffs

3.1.2 Instruments

The primary data collection instruments for this study were structured questionnaires and interview guides. The questionnaires were used to collect quantitative data from the thirty-eight dairy farmers, four dairy extension officers and two pasture specialists. Interview guides were used to facilitate in-depth qualitative interviews with extension officers and pasture specialists who are the key stakeholders working with the dairy farmers.

Questionnaire

The questionnaire used to collect data consisted of closed-ended questions designed to gather information on the farmers' experiences with climate change, the availability of feed resources, and the adaptation strategies they employ. The questionnaire included sections on demographics, types of feed used, challenges faced in feed sourcing, and the impact of climate change on feed resources and dairy production. The questionnaire was used to measure the perceptions of farmers, extension officers and pasture seed specialists regarding the severity of climate change impacts and the effectiveness of different adaptation strategies.

Interview Guide

The interview guide used contained open-ended questions to explore the challenges faced by dairy farmers in more detail and to obtain insights into the broader institutional and policy context affecting feed availability and climate adaptation. The questions will focus on themes such as government support, access to extension services, and the effectiveness of climate-smart agricultural practices.

3.2 Data Collection Materials

Printed questionnaires and interview guides were used during interviews to ensure that all responses are captured accurately. The materials and instruments used in this study are standardized and readily available, ensuring that independent researchers can obtain similar materials and replicate the study. A table summarizing the materials and instruments is provided below for clarity.

Material/Instruments	Description	Purpose
Questionnaires	Structured, closed-ended questions	To collect quantitative data on climate impacts and feed resources
Interview Guides	Open-ended questions	To gather qualitative insights from stakeholders

Table 3.1: Materials and instruments used in data collection

3.2.1 Procedure

The research procedure followed a structured process, consisting of the following steps:

Pilot Testing

Before conducting the full study, a pilot test was carried out with a small group of five (5) farmers to assess the clarity and relevance of the questionnaire and interview guide. Feedback from the pilot test was used to refine the instruments.

Sampling

A census for all dairy farmers in Seke district was used for data collection was employed for all farmers who are actively engaged in dairy farming for at least two years was prioritized to ensure that they have sufficient experience with the challenges posed by climate change. Additionally, six key informants were selected based on their expertise in dairy farming and agricultural policy (the dairy extension officers and pasture seed specialists).

Questionnaire Distribution

Questionnaires were distributed to the selected farmers through dairy extension officers and through Marirangwe Milk Collection (MCC) centre administrator. The researcher also participated in data collection during his daily work as an Extension Officer working under the Zimbabwe Association of Dairy Farmers (ZADF). Farmers were given one month to complete the questionnaires, after which they were collected by the extension officers and returned to the researcher. The use of extension officers ensures that the questionnaires reach the farmers efficiently and that any queries they have during completion are addressed.

Interviews

In-depth interviews were conducted with the six key informants. The interviews were carried out in person, with each interview lasting approximately thirty minutes. The interview guide was followed closely to ensure consistency across all interviews.

Data Collection Timeline

Data collection took place over four weeks. The first two weeks was dedicated to the distribution and collection of questionnaires, while the remaining two weeks was allocated for interviews with key stakeholders.

The procedure described above is systematic and ensures that all data collection activities are conducted in a consistent manner. Independent researchers can replicate this process to obtain similar results.

3.3 Methods of Observation and Interpretation

The research relied on both direct observation through interviews and indirect observation through questionnaires. The following methods were used to observe and interpret the results:

Quantitative Observation (Questionnaires)

Responses from the questionnaires were recorded numerically. The data was interpreted through descriptive statistics, such as frequencies, percentages, and averages, to identify common trends and patterns among the responses. The primary variables observed include feed availability, challenges due to climate change, and the adoption of adaptation strategies.

Qualitative Observation (Interviews)

The interview data was transcribed, and thematic analysis was conducted to identify recurring themes and insights related to the challenges faced by dairy farmers. Key themes such as institutional support, climate resilience, and policy implications were highlighted through coding and categorization. Observations were made based on the frequency and intensity of responses related to these themes.

In this study, statistical techniques such as Chi-square tests were used to analyse the relationship between climate change impacts and feed availability, while correlation analysis were employed to explore the relationship between the adoption of adaptation strategies and dairy productivity. These statistical methods provided a clear interpretation of the results, ensuring that patterns and relationships are properly quantified.

3.4 Data Processing and Analysis

The data processing and analysis plan for this research was conducted in five key stages: data sorting, quality control, data processing, and data analysis. Each stage is essential to ensure the accuracy and reliability of the research findings.

3.4.1 Sorting the Data

After data collection, all questionnaires were checked for completeness. Incomplete questionnaires were discarded to ensure that only valid and usable responses are analysed. Any unclear or ambiguous responses were clarified with the interviewees if necessary.

3.4.2 Quality Control Checks

Questionnaire Data

The data entered from the questionnaires was cross-checked for accuracy. Double entry was used, where the same data is entered into the system twice by different individuals to ensure consistency. Any discrepancies were resolved by reviewing the original responses.

Interview Data

Transcriptions were cross-checked against the original recordings to ensure that no information has been misinterpreted or omitted. This ensures that the qualitative data is accurate and reflects the interviewees' intended meanings.

3.4.3 Data Processing

Categorization and Coding

Both quantitative and qualitative data were categorized according to the research objectives. Quantitative data was categorized into variables such as climate change impacts, feed resource availability, and adaptation strategies. Qualitative data was coded using thematic coding, where each response is assigned to a specific theme based on its content (Saldana, 2015). Common themes that emerge from the interviews, such as "climate resilience" and "institutional support," were grouped together for analysis.

Data Master

A master data sheet was created to consolidate all the quantitative responses. This master sheet will contain all the numerical data from the questionnaires, organized by respondent and variable. The qualitative data was organized into a digital database, with each interview transcript coded and linked to the relevant themes.

3.4.4 Data Analysis

Quantitative Data

Frequency counts, mean calculations, and standard deviations were used to summarize the data obtained from the questionnaires. The relationships between variables such as the impact of climate change on feed resources and the adoption of adaptation strategies were analyzed using correlation analysis and Chi-square tests. Correlation analysis will identify whether a statistically significant relationship exists between climate impacts and feed availability, while Chi-square tests were used to examine the association between categorical variables such as the type of feed used and farm size.

Qualitative Data

Thematic analysis was used to interpret the interview data. This involves identifying key themes and sub-themes based on the content of the interview transcripts. Each theme was analysed in terms of its frequency and importance, with direct quotes used to illustrate the points made by the interviewees. The results from the qualitative analysis will complement the quantitative findings, providing a richer understanding of the challenges and adaptation strategies employed by dairy farmers.

Comparisons of Variables

Comparative analysis was conducted to examine how different groups of farmers for example, smallholder versus commercial farmers experience climate change impacts and implement adaptation strategies. For example, the study will compare the availability of feed resources between smallholder, medium scale and large-scale commercial dairy farms and assess whether there are significant differences in the adoption of climate-smart practices. This analysis will help identify the key factors influencing feed availability and utilization under climate change.

By following this comprehensive data processing and analysis plan, the research ensured that the findings are robust, reliable, and also provided valuable insights into the challenges faced by dairy farmers in Seke District.

3.5 Chapter Summary

This chapter outlined the research design, materials, procedures, methods of observation, and data analysis techniques used in this study. The descriptive survey design, combined with a mixed-methods approach, ensures that the research captures both quantitative and qualitative data on the challenges and adaptation strategies of dairy farmers in Seke District. The detailed description of the materials, instruments, and procedures allows for the replication of the study, while the data processing and analysis plan ensures that the findings are accurate and meaningful. By applying both statistical analysis and thematic coding, the research will provide a comprehensive understanding of the impact of climate change on dairy feed resources and the adaptive measures employed by farmers.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results of the study conducted to assess the current status of dairy feed resource availability, analyze the impacts of climate change on the quality and quantity of feed resources, identify adaptation strategies employed by dairy farmers, and evaluate the challenges they face under changing climatic conditions in Seke District. The crafted research questions and objectives are answered in this chapter through a discussion of the findings. The findings are based on data collected from dairy farmers, dairy extension officers and pasture seed specialists in Seke district through surveys and interviews, focusing on their experiences, practices, and challenges related to feed resources. The chapter explores potential strategies to enhance the resilience and sustainability of the dairy sector in response to climate variability. The results are organized to provide a comprehensive understanding of the key issues impacting dairy farming in the region, with tables and figures used to illustrate the demographic characteristics of the participants, their adaptation strategies, and the effects of climate change on dairy feed resources. Data collected through the process outlined in chapter three is presented in this chapter.

4.2 Demography of participants

The demographic characteristics of participants are critical to understanding the context of dairy farming in Seke District. These characteristics provide insights into the backgrounds of the farmers, which include age, gender, farm size, and years of experience in dairy farming. These factors influence their capacity to adapt to climate change and access feed resources.

4.2.1 Gender Distribution of Participants Interviewed

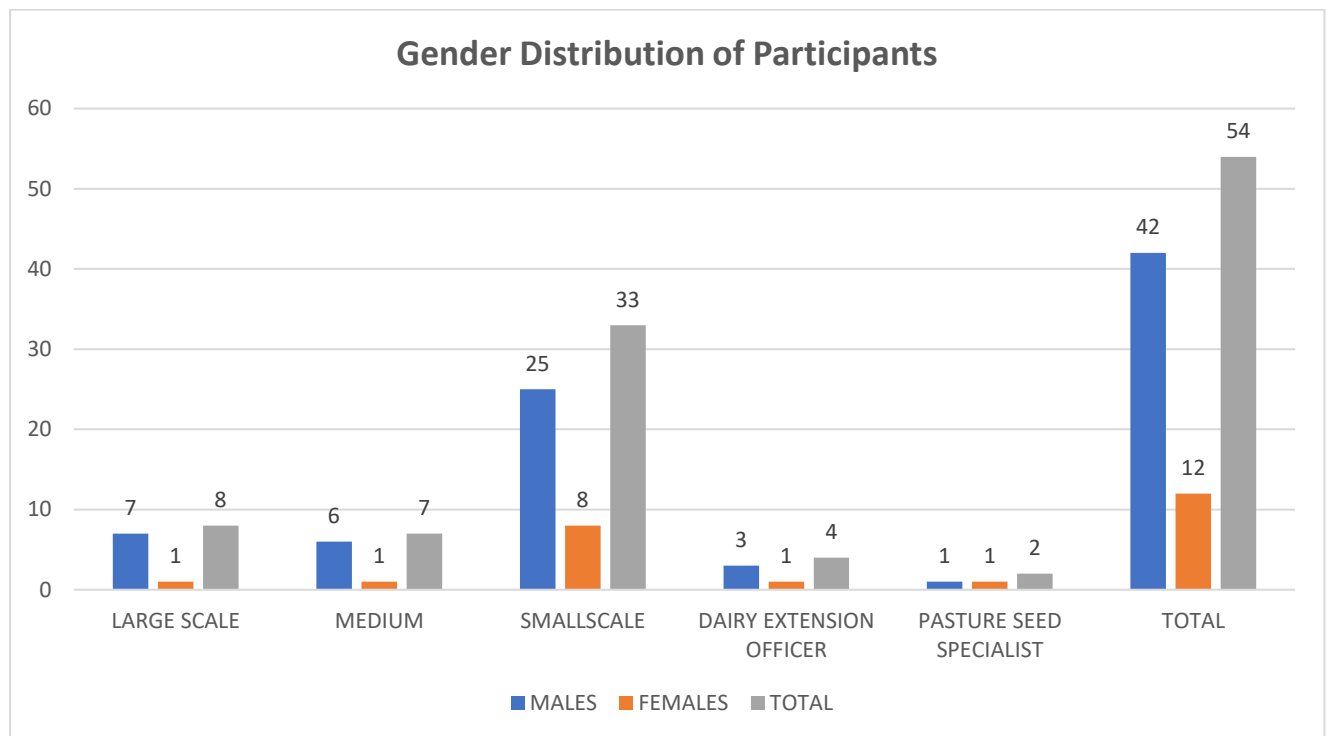


Figure 4.1: Gender distribution of dairy farmers, dairy extension officers and pasture seed specialist

Although both males and females are actively involved in dairy in Seke district, there is more dominance by males as farmers, extension officers and pasture specialists. The high proportion of male participants may reflect traditional gender roles in farming, but the significant presence of female farmers highlights the role women play in contributing to agricultural productivity, especially in the context of climate adaptation strategies.

4.2.2 Scales of dairy production in Seke District

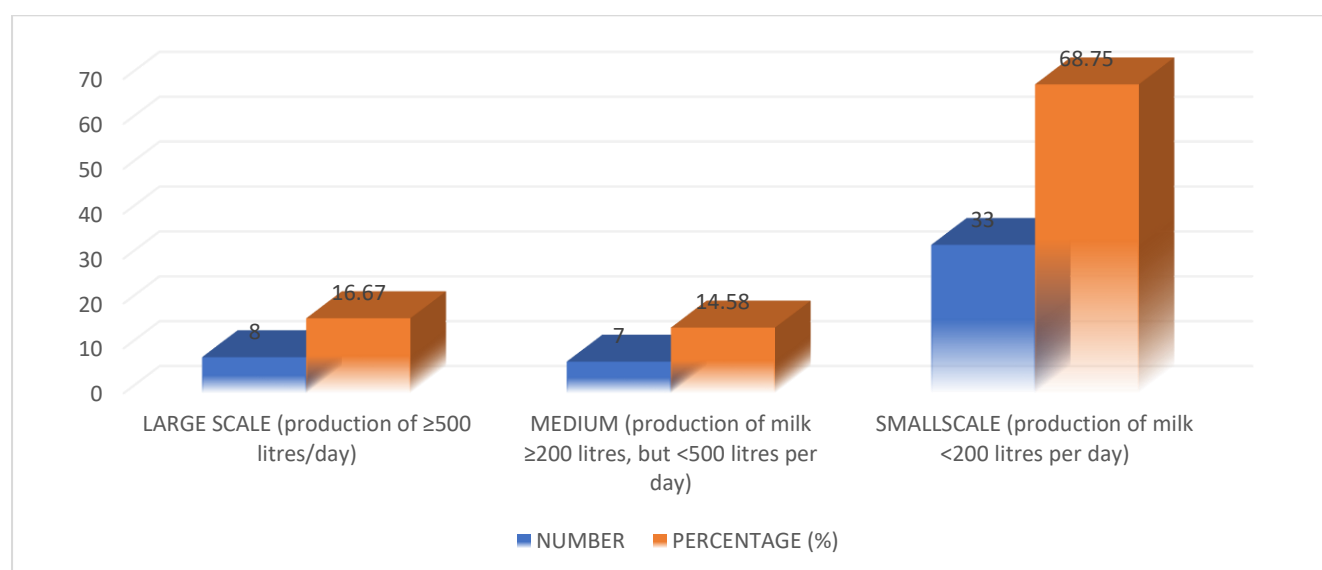


Figure 4.2: Number of dairy farmers in each category of dairy farmers in Seke District

The majority of the dairy farmers in the study operate as small-scale farmers. According to the Dairy Services Unit (DSU) dairy farmer categories, large scale farmers are those producing equal to or above 500 litres of milk per day, medium scale dairy farmers are those producing greater than or equal to 200 litres but less than 500 litres per day, and small-scale dairy farmers are those who produce anything less than 200 litres of milk per day (DSU -TranZDVC, 2020). The distribution suggests that most farmers in the district may face more challenges in accessing resources such as feed and water, which are exacerbated by climate change. Small-scale farmers are particularly vulnerable to climate variability, thus making them a key focus for adaptation strategies.

A significant portion of the farmers have been engaged in dairy farming for over ten years, indicating a wealth of experience within the community. This experience is crucial for understanding long-term changes in climate and feed resource availability, as well as for identifying effective adaptation strategies based on years of practical knowledge.

4.3 Current Status of Dairy Feed Resource Availability and Utilization

Aspect	Description
Primary feed resources	Natural pastures, improved pastures, crop residues, agro-industrial by-products (maize bran, wheat bran, cottonseed cake, sunflower seed cake, soya bean cake)
Seasonality	Highly seasonal, dependent on rain-fed agriculture, leading to feed shortages during dry periods
Reliability of natural pastures	Unreliable due to prolonged dry spells and erratic rainfall, affecting milk production
Use of supplementary feeds	Common but expensive; smallholder farmers struggle with accessibility
Nutritional Value	Decreased due to climate-induced changes, leading to higher costs for supplementary feeding
Adaptation strategies	Diversification of forage species (drought-tolerant varieties), agroforestry, water management, feed preservation practices

Table 4.1: Current status of dairy feed resource availability and utilization in Seke district

The data presented in the table 4.1 outlines the key components affecting dairy feed resource availability and utilization in Seke District. Natural pastures and improved pastures grown as fodder are the primary feed resources, have become increasingly unreliable due to climate change, leading farmers to rely on supplementary feeds that are often costly and not easily accessible for smallholders. Adaptation strategies such as the diversification of forage species and the use of agroforestry practices are being employed to address the challenges posed by climate variability, highlighting the need for sustainable approaches to ensure feed availability.

4.3.1 Primary Feed Resources

Dairy farming in Seke District is primarily sustained by natural pastures, improved pastures, crop residues, and agro-industrial by-products such as maize bran and cottonseed cake. Natural and improved pastures are the traditional mainstay of dairy cattle feeding especially among smallholder farmers. However, over-reliance on rain-fed natural grazing systems presents challenges as these pastures are highly vulnerable to the impacts of climate change. The improved pastures include *Brachiaria* species, star grass *panicum* species. Additionally, crop residues, such as maize and sorghum stover, provide an important supplement to pastures,

particularly during the dry season. Agro-industrial by-products like brewers grain (maseke), maize bran, wheat bran, sunflower cake, and cottonseed cake, are commonly used to supplement natural feeds, have increasingly become an essential part of dairy feeding in the district due to the diminishing availability of natural resources.

Studies confirm that in semi-arid regions like Seke district, livestock production is heavily dependent on these feed resources, which are sensitive to climatic variability. According to Amole et al., (2022), natural pastures remain the cornerstone of feed resources, yet they are becoming insufficient due to erratic rainfall and prolonged dry spells. The increasing reliance on agro-industrial by-products highlights the shift farmers must make to maintain productivity under these changing conditions. However, access to these supplements is limited by cost and availability, especially for smallholder farmers who may lack the financial resources to afford consistent supplemental feeding (Tui et al., 2022).

4.3.2 Seasonality

Feed availability in Seke District is highly seasonal, primarily dependent on rain-fed agriculture. During the rainy season, natural pastures and forage are plentiful, providing sufficient nutrition for dairy cattle. However, this abundance is short-lived, as the dry season brings about a sharp decline in the availability of pasture and forage resources. This seasonal variation results in feed shortages during the dry months, making it difficult for farmers to maintain adequate nutrition for their dairy herds throughout the year.

Mamphogoro et al.,(2024) highlights that the seasonality of feed resources is one of the major challenges facing livestock farmers in regions semi-arid regions, where climatic conditions dictate the productivity of natural pastures. The inability of rain-fed systems to provide consistent forage throughout the year means that farmers must find alternative strategies, such as supplementary feeding or forage preservation techniques like silage and hay making, to bridge the gap during feed-scarce periods. Assan, (2022) further emphasizes the need for climate-resilient practices to cope with this seasonality, noting that the fluctuations in feed availability directly affect milk production and farm profitability.

4.3.3 Reliability of Natural Pastures

The reliability of natural pastures in Seke District has drastically decreased due to prolonged dry spells and erratic rainfall patterns, which are key indicators of climate change. These

environmental changes have severely affected the growth and regeneration of natural grazing lands, and fodder fields, reducing their ability to provide consistent feed for dairy cattle. The unpredictability of rainfall not only shortens the growing season for natural and improved pastures but also reduces the quality of available forage, leading to lower nutritional intake for livestock and, consequently, reduced milk yields.

Mburu et al., (2024) noted that in many parts of sub-Saharan Africa, including Zimbabwe, the reliability of natural pastures is increasingly compromised by climate change. Prolonged dry periods, in particular, prevent the regrowth of pasture, resulting in overgrazed and degraded lands. In Seke District, farmers have reported a noticeable decline in pasture availability, which they attribute to these climatic changes. As natural pastures become less reliable, farmers are forced to rely more on expensive processed and conventional feeds, increasing the cost of production and affecting the sustainability of their operations.

4.3.4 Use of Supplementary Feeds

The use of supplementary feeds such as maize bran, cottonseed cake, sunflower cake, and other agro-industrial by-products like brewers' grain (masese) has become increasingly common among dairy farmers in Seke District. These feeds are critical for maintaining milk production, especially during periods when natural pastures are insufficient. However, the cost of purchasing raw materials for own farm feed formulations is a significant barrier for many smallholder farmers, who often operate on constrained budgets. As the availability of natural pastures declines, farmers are compelled to supplement their cattle's diets, but the high cost and limited access to these feeds pose substantial challenges.

Senda et al., (2020) highlights that the reliance on supplementary feeds has grown in regions where climate change has severely impacted natural pasture availability. In Seke district, the medium and small-scale dairy farmers are particularly vulnerable, as they often lack the financial resources to purchase dairy feeds consistently. The high cost of supplementary feeding adds to the already elevated costs of dairy production, pushing some farmers to reduce herd sizes or cut back on production. This financial strain is further exacerbated by fluctuating prices for agro-industrial by-products, which can increase during times of feed scarcity.

4.3.5 Nutritional Value

The nutritional value of dairy feed resources has also been significantly affected by climate-induced changes. Prolonged droughts and erratic rainfall have not only reduced the quantity of available pasture and fodder but have also degraded its quality. Drought conditions accelerate the degradation of plant matter, reducing the nutrient content of pastures and forage crops. Farmers are reporting that the pastures they rely on are less nutritious, leading to poor cattle health and lower milk yields. This reduction in feed quality forces farmers to rely more heavily on supplementary feeds, further increasing their production costs.

Tui et al., (2022) argue that climate change is causing widespread degradation of forage quality across many parts of the world, particularly in areas that rely on rain-fed agriculture. In Seke District, the impact of declining feed quality is evident in the reduced productivity of dairy cattle in terms of production per cow per day. Chari & Ngcamu, (2022b) points out that farmers are forced to use more expensive supplementary feeds, such as cottonseed cake and maize bran, to compensate for the lack of high-quality pasture. This reliance on supplemental feeding increases the cost burden on farmers, who must navigate the twin challenges of reduced pasture quality and rising input costs.

4.4 Impact of climate change on availability and quality of dairy feed resources

As rainfall diminishes in drought seasons, the ability of pastures to regenerate and sustain livestock productivity significantly declines, leading to reduced milk production and increased financial pressure on farmers. Lower pasture yields force farmers to rely on supplementary feeds, which are costly and less accessible for smallholder farmers. This reliance exacerbates financial strains and affects the long-term sustainability of dairy farming in the region. Furthermore, the declining pasture speaks to the decreased nutritional quality of available feed, a consequence that Battheu-Noirfalise, (2024) associate with climate-induced stress on forage crops. As pastures degrade under stressful climatic conditions, their nutrient content diminishes, leading to lower-quality feed that adversely impacts cattle health and milk yields. This, in turn, increases the need for costly supplements like maize bran and cottonseed cake, a trend observed not only in Seke but across similar drought-prone regions.

The relationship between climate variability and pasture degradation is further validated by studies in sub-Saharan Africa, where FAO (2019) reports that rising temperatures and erratic rainfall patterns are accelerating desertification and reducing the productivity of grazing lands.

As Erdaw, (2023) point out, farmers in Zimbabwe and other parts of Southern Africa have begun diversifying their forage sources by introducing drought-resistant species, such as Napier grass so as to improve feed availability despite reduced rainfall. In addition to crop diversification, water management techniques like rainwater harvesting and irrigation development are being adopted to optimize water use and maintain pasture productivity during dry spells. The declining trends in rainfall and pasture yield, consistent with regional and global studies, highlight the growing challenges faced by dairy farmers. As climatic conditions continue to worsen, the adoption of resilient farming practices and adaptation strategies will be crucial in ensuring the sustainability of dairy farming in the region.

Furthermore, argue that the reduction in pasture quality due to erratic weather patterns not only affects the quantity of feed available but also its nutritional value. Poor-quality pasture lacks the essential nutrients needed to sustain healthy milk production. As a result, dairy farmers in regions like Seke are forced to increase their reliance on expensive supplementary feeds, which is unsustainable for many smallholders. The increasing reliance on maize bran and cottonseed cake, as pointed out in the literature, exacerbates the cost burden on farmers who are already struggling with the economic impacts of reduced milk production.

To mitigate these impacts, Amole et al., (2022) emphasize the need for the adoption of climate-smart agriculture practices. Strategies such as the introduction of drought-tolerant forage species, improved water management through rainwater harvesting, and the use of silage and haymaking for feed preservation during the wet season are critical. These practices can help buffer the effects of dry spells, ensuring that dairy cattle receive adequate nutrition even when natural pastures fail due to insufficient rainfall.

Mamphogoro et al., (2024) also suggest that improved access to extension services and technical training can enhance farmers' capacity to adopt these adaptive strategies. In areas like Seke District, where climate variability is expected to increase, the implementation of these measures is essential for sustaining milk production and protecting the livelihoods of dairy farmers.

From the data collected in Seke district, 78% of interviewed dairy farmers, extension staff and pasture seed specialists were aware of the impacts of climate change on agriculture and livestock production, 13% were somewhat aware and 9% were not aware on how it affects agriculture and livestock operations (figure 4.3). The large and medium scale understood well.

The fact that more farmers understood and were aware of the impacts of climate change means that there are tangible effects that they have seen in their farming communities.

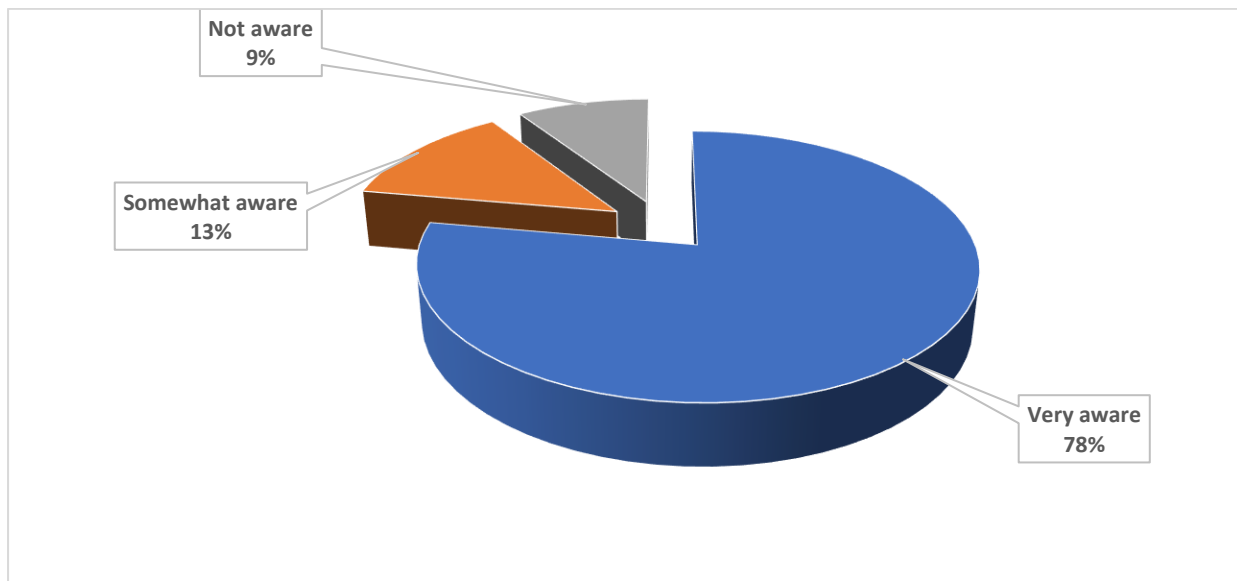


Figure 4.3. Statistical results on awareness to climate change impacts on agriculture

Ninety-three (93%) of interviewed participants also responded that climate change affects dairy feed availability, five percent (5%) were not sure how it affects and only two percent (2%) said that climate change does not affect dairy feed availability as they believed that they can buy the feed from other sources (figure 4.4)

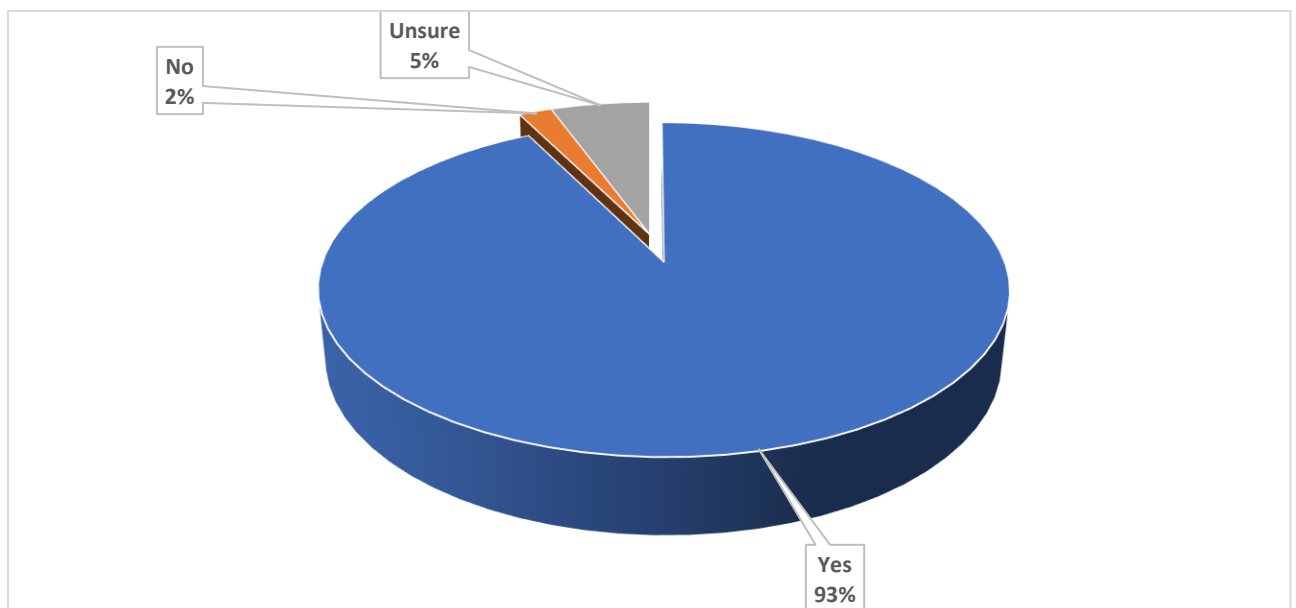


Figure 4.4: Climate change affects feed availability in the district

How farmers access or the source of their feed resources was determined where it was noted that most farmers (40%) were grazing their animals, thirty-nine percent (39%) relied on purchased feeds, twelve percent (12%) relied on crop residues nine percent (9%) relied on other sources livestock wastes like chicken litter, brewers' grain and orange peels as their feed resources (figure4.5)

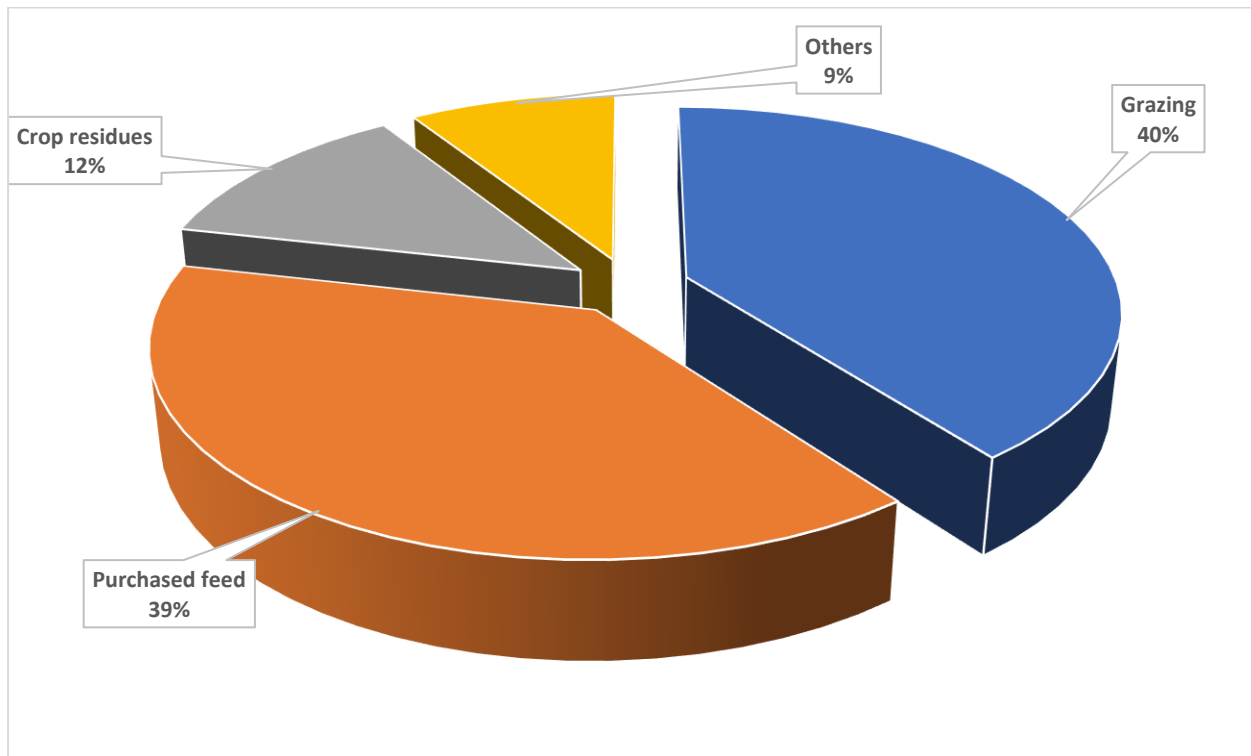


Figure4.5: Access or source of dairy feed resources on farm

Ninety-one percent (91%) of dairy farmers and extension specialists noted changes in dairy feed availability due to climate variability, and respectively, only five and four percent (5% and 4%) did not notice and were not sure of any changes in feed availability due to climate variability (figure 4.6)

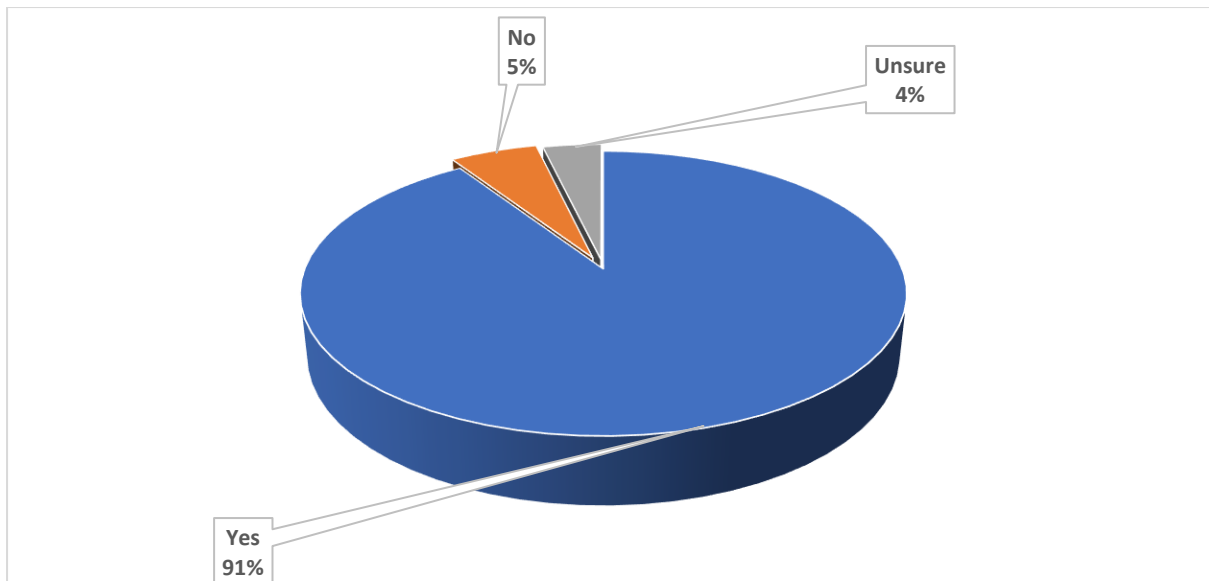


Figure 4.6: Observed changes in dairy feed availability over a decade due to climate variations.

The data collected and analysed also showed that availability of forage (pasture, hay, and silage) feed resources has changed due to irregular rainfall patterns caused by climate change. This was because fifty-nine percent (59%) agreed to the changes noted. Thirty-two percent (32%) strongly agreed to the noted changes in feed availability as a result in rainfall pattern changes, and seven and two percent (7% and 2%) disagreed and were neutral respectively (figure 4.7)

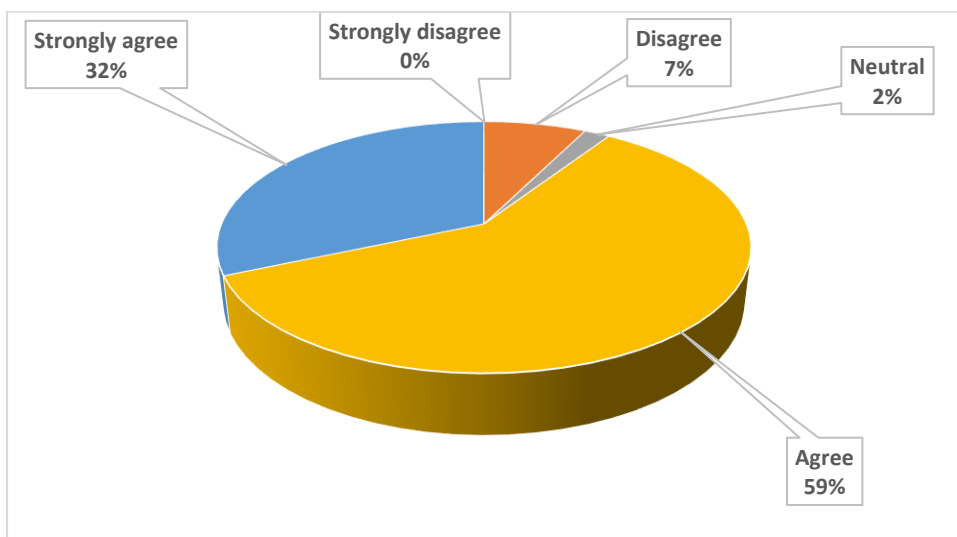


Figure 4.7: Confirmation to changes noted in dairy feed availability due to changed or irregular rainfalls

The main climate related challenges with an impact on dairy feed availability noted on various farms were erratic rainfalls (28%), increased temperatures (27%), droughts (25%), pests and

diseases (19%) and other challenges (1%) like long dry spells, and reduced night temperatures (figure 4.8) which affect fodder and pasture growth, as well as erratic power supplies due to poor water levels at Kariba power generation stations. Increased temperatures were noted to increase heat stress in dairy cows and led to low productivity. Prolonged droughts were said to reduce availability of feed resources for dairy animals.

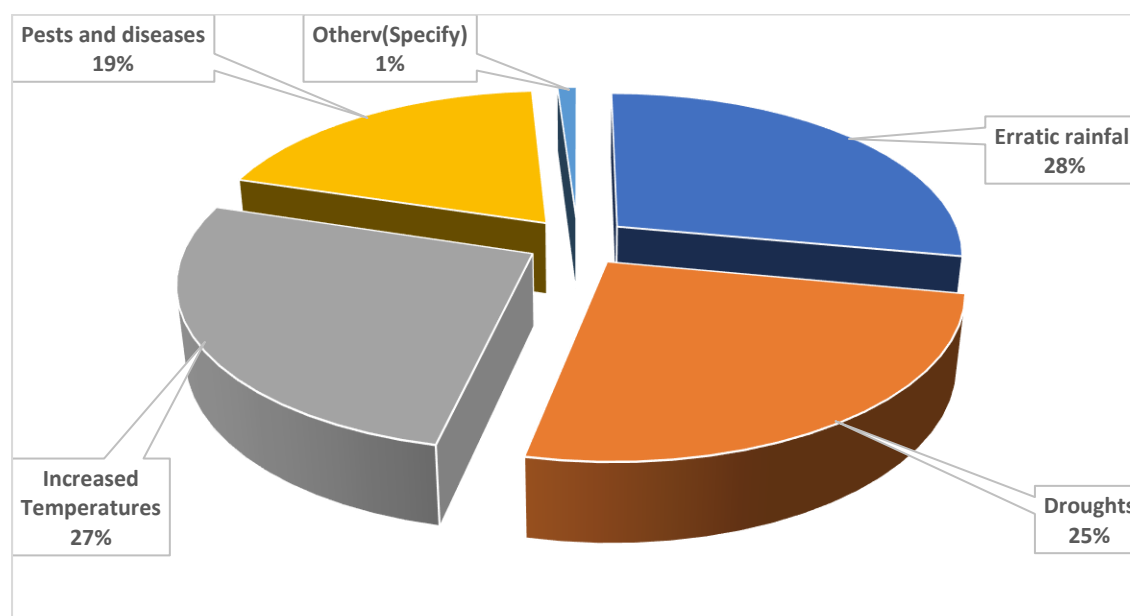


Figure 4.8: Climate related challenges with an impact on dairy feed availability

Mitigation strategies were identified that farmers, extension officers and seed specialist had implemented to mitigate the effects of climate change on dairy feed resources (figure 4.9). These were ranked in terms of frequencies they were reported by the interviewed participants. All interviewed participants had to implement improved storage and improved feed preservation techniques on their animal feeds (100%). Such techniques involve the making of silage from maize and sorghum crops so as to preserve the nutritive value of the crops. Preservation was also noted on the making of urea treated stover from poor quality roughages like maize stover and veldt grass. The technique improves the protein content and preserves the poor-quality roughages. Improved fodder production on farm, had a frequency of 85% respondents practising it as a measure to mitigate the effects of climate change on dairy feed resources. Farmers also diversified on feed sources (50% frequency). The other feed sources include bought in feeds like cotton seed cake, sunflower cake and soya bean meal cakes which were purchased from millers. Farmers also improved on water management techniques (26% frequency), where some farmers had to recycle water from dairy parlours for irrigation of

pastures. Nine percent frequency (9%) showed that there was altered feeding schedules as a strategy to mitigate the effects of climate change on dairy feed resources for dairy farmers in Seke district. Other strategies (6%) include the use of climate smart agriculture practices such as growing of short season varieties as silage crops as well as leguminous trees and crops to supplement protein sources (figure 4.9).

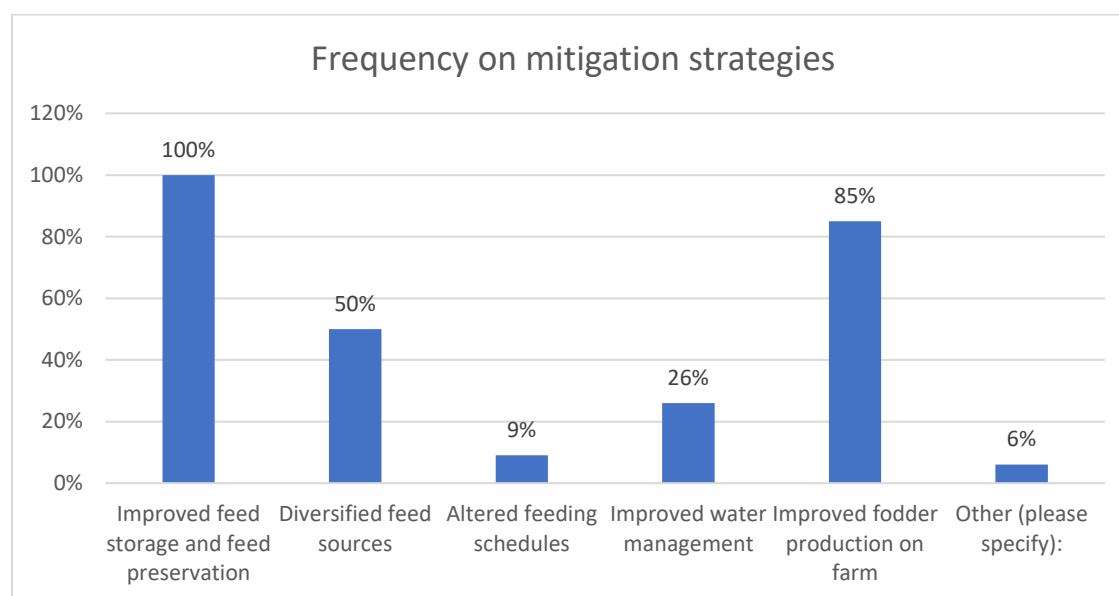


Figure 4.9: Frequencies of strategies implemented by farmers to mitigate effects of climate changes on dairy feed resources

There were challenges that were highlighted by respondents the listed strategies. The challenges noted were shortages of finance to improve feed storage and preservation, to diversify feed sources, to have improved water management systems as well to develop fodder production systems on farm. Farmers also lacked machinery to carry out various farm operation to compensate for climate change induced feed shortages. Machinery such as tractors, grass cutters and silage cutters were not affordable to all farmers for them to prepare their fodder banks and silage to be used during the long dry periods or during dry spells and drought conditions. Loan facilities were available but the conditions deterred the farmers from taking the loans as they were afraid to be fail in repayment periods that lenders required.

Ninety-four percent (94%) of farmers anticipated decreased availability of dairy feed resources in the next ten years as a result of climate change induced disasters like drought. Six percent of respondents anticipated no changes in feed resources for the same period and same factors due to climate change (figure 4.10).

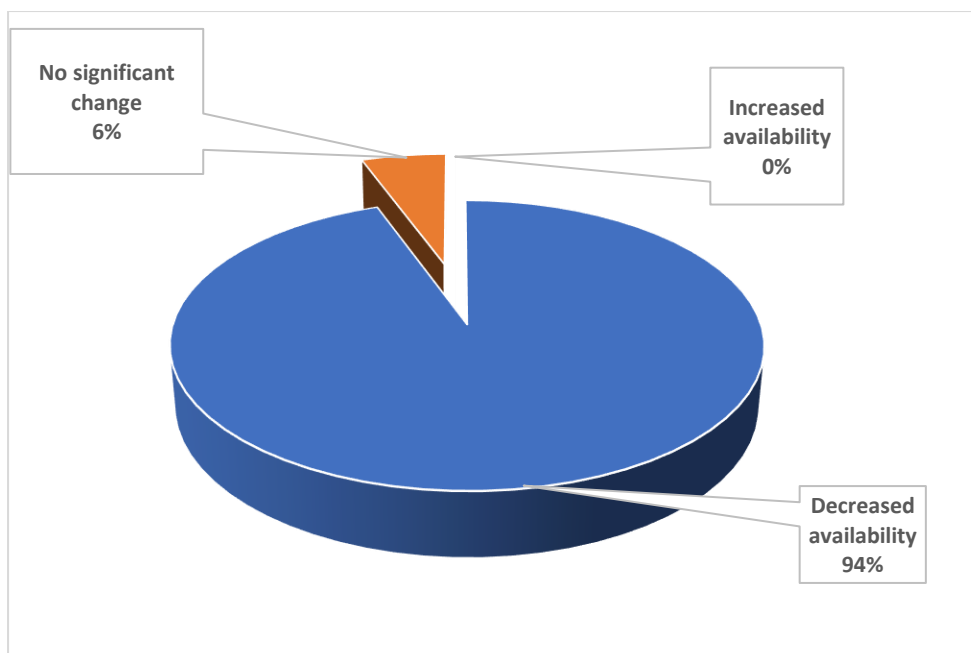


Figure 4.10: Anticipated availability of dairy feeds in the next decade

4.5 Practices and patterns of dairy feed resource utilization in the face of changing climatic conditions

Farmers, extension officers and pasture seed specialists considered feed composition and nutrient balance of dairy feeds that they used when formulating dairy rations. The bulk of the respondents consider (54%) and strongly consider (44%), the nutritive value of forages and feed that their dairy animals eat (figure 4.11). This helps in optimum productivity per cow per day in terms of milk yield.

The reasons why they consider the nutritive value composition are that they consider feeding a balanced ration, they need increased milk yields and production traits in their dairy animals. Good nutritious feeds help in good cow maintenance and good reproductive health for increased herd sizes which translate to increased volumes of milk per farm per day.

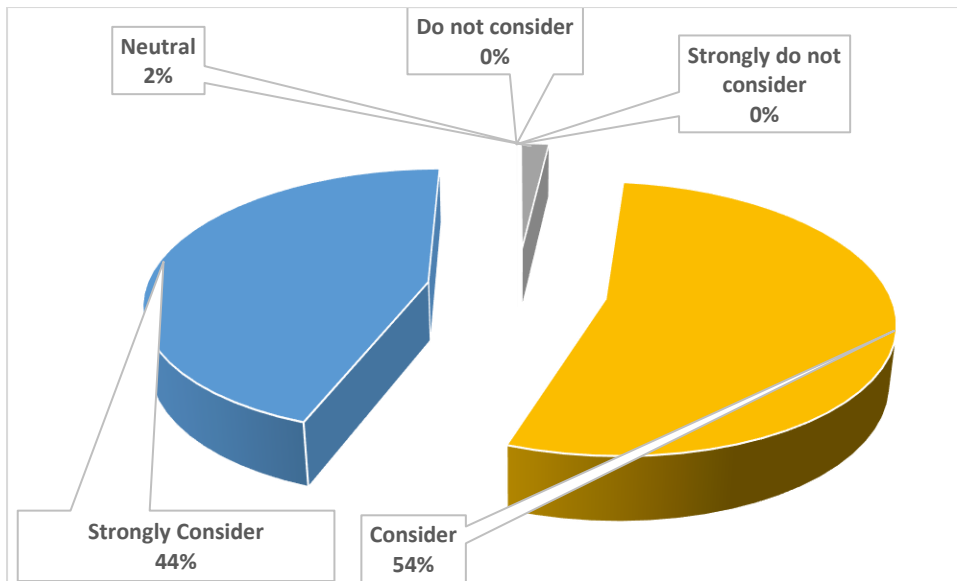


Figure 4.11: Consideration of nutritional content and balance of feed ingredients when formulating rations for dairy animals

Seventy-six percent (76%) of farmers actively plant climate-resilient forage crops so as to ensure dairy feed availability. Only twenty-four (24%) do not plant such forage crops (figure 4.12). This is because they rely on bought in feeds and they do not have water and land to grow the forage crops

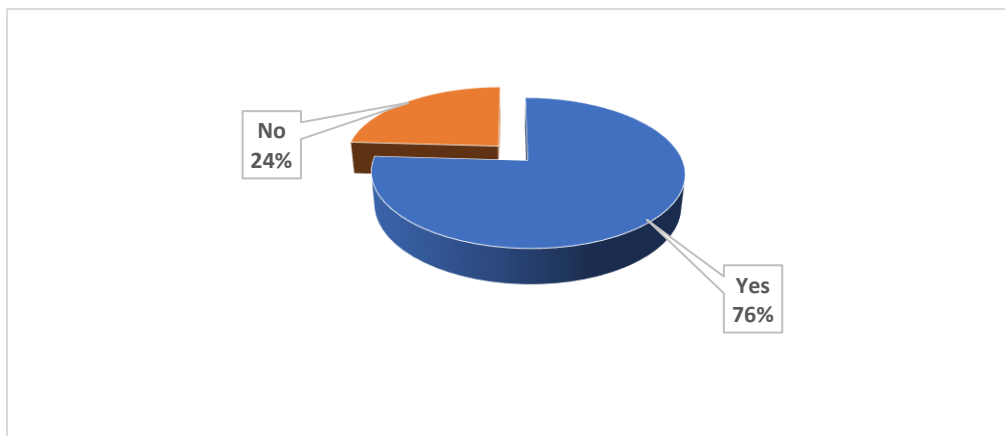


Figure 4.12: Frequency of farmers that consider growing climate-resilient fodder crops

The forage crops that were grown in Seke district are *Brachiaria* species for their high herbage, star grass for drought tolerance, velvet beans, lab-lab, Sunhemp, lucerne, rye grass, forage oats for their good protein sources, and sunflower for its drought resilience characteristics.

In terms of adequate water management practices such as irrigation and rainwater harvesting techniques, respondents strongly agree (55%) and agree (41%) that they contribute to pasture growth and availability (figure 4.13).

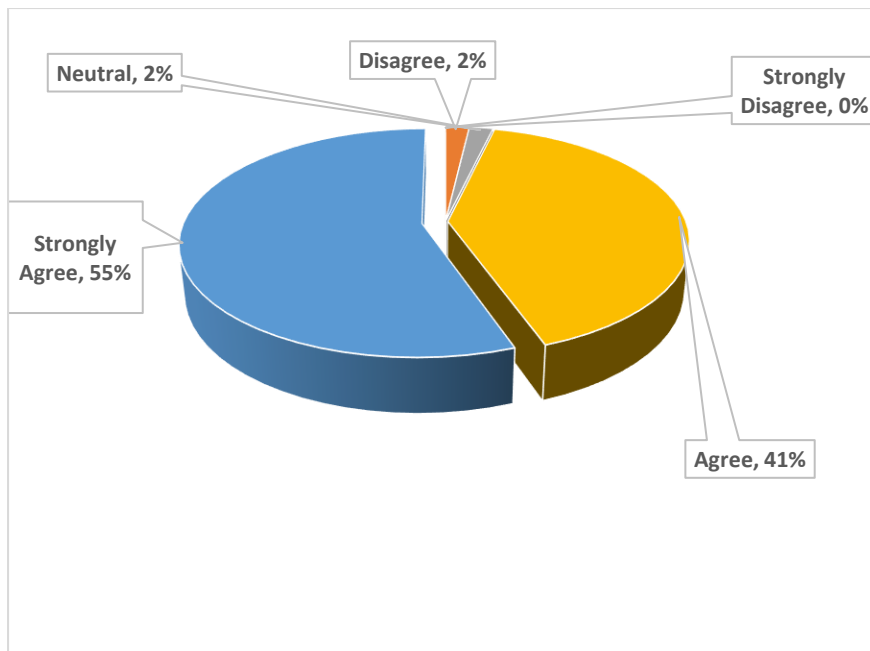


Figure 4.13: Adequate water supply and management contribute to pasture growth and availability

The interviewed participants (100%) showed that dairy farmers in Seke district adopt proper fodder storage and preservation techniques such as silage and hay making so as to maintain feed quality (figure 4.14)

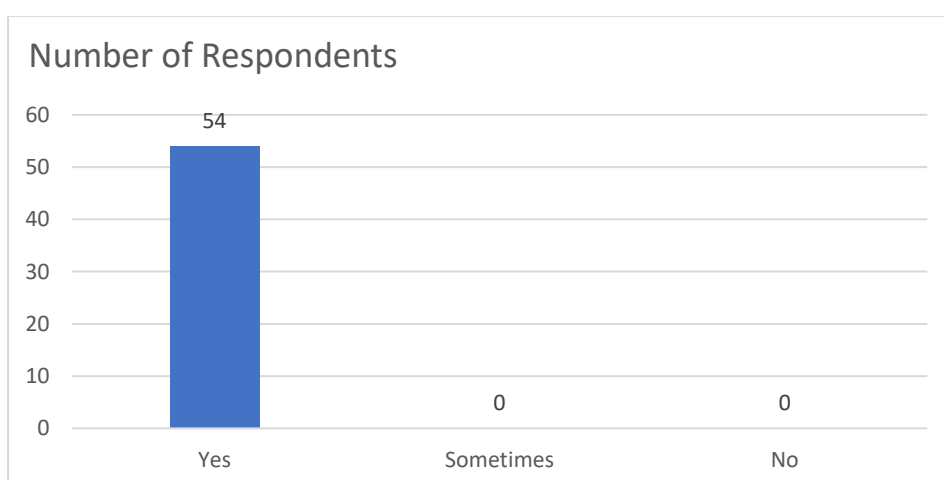


Figure 4.14: Adoption of proper fodder storage and preservation techniques

The main reasons captured why the farmers adopted these techniques were that the farmers wanted to sustain their dairy cattle during the dry and drought seasons. It was also a cost-

effective way to run dairy farming operations so as to cut on bought in feeds. Hay was also readily available in all farms and that was the only option to do so. Some farmers highlighted that this was the best way to preserve feed quality when properly done on the right time and right procedure.

Ninety-six percent (96%) of farmers interviewed collaborated with extension services through seeking guidance from agricultural experts and agricultural extension officers on climate-smart feed utilization practices, whilst only four percent (4%) did not seek the services of outside services.

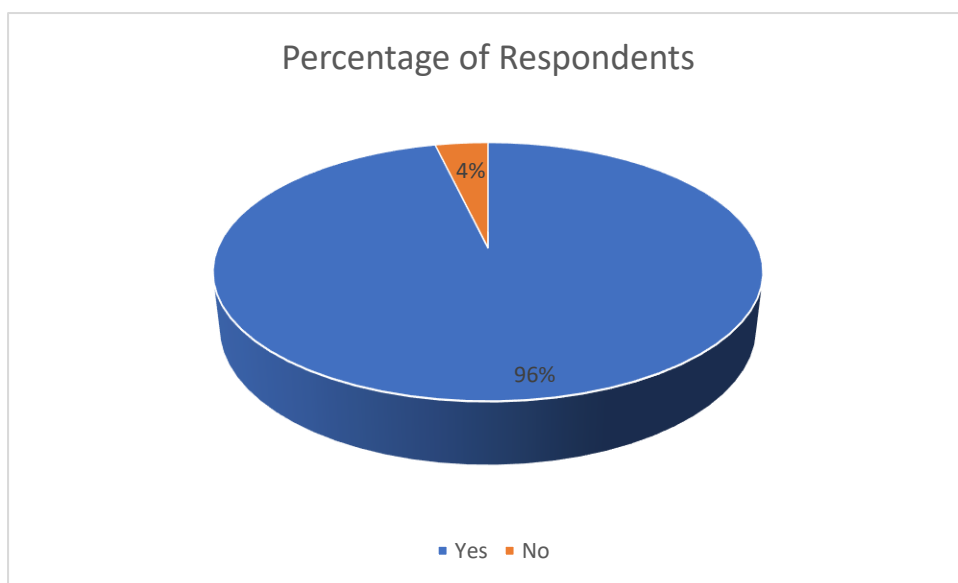


Figure 4.15: Frequency of farmer collaborations with outside extension services

The organizations that provided extension services in Seke district were Zimbabwe Association of Dairy Farmers (ZADF), ARDAS, Livestock Production and Development (LPD), Dairy Services Unit (DSU), Easi Seeds, Select Seeds, Redddane Agri Farming Solutions, University of Zimbabwe (UZ), Midland State University (MSU), Bindura University of Science Education (BUSE), African Breeders Society (ABS), Kushinga Phikhelela Agriculture College.

Those who did not seek advice from the extension organizations did not do as they cited that the services are not readily available and out of reach to them in terms of some costs involved.

4.6 Challenges faced by dairy farmers and stakeholders in accessing and utilization of feed resources under the influence of climate change

Fifty-nine (59%) strongly agree, and forty-one (41%) agree that access to sufficient and quality feed resources (pasture, silage, concentrates) has become more challenging due to climate-related factors (figure 4.16).

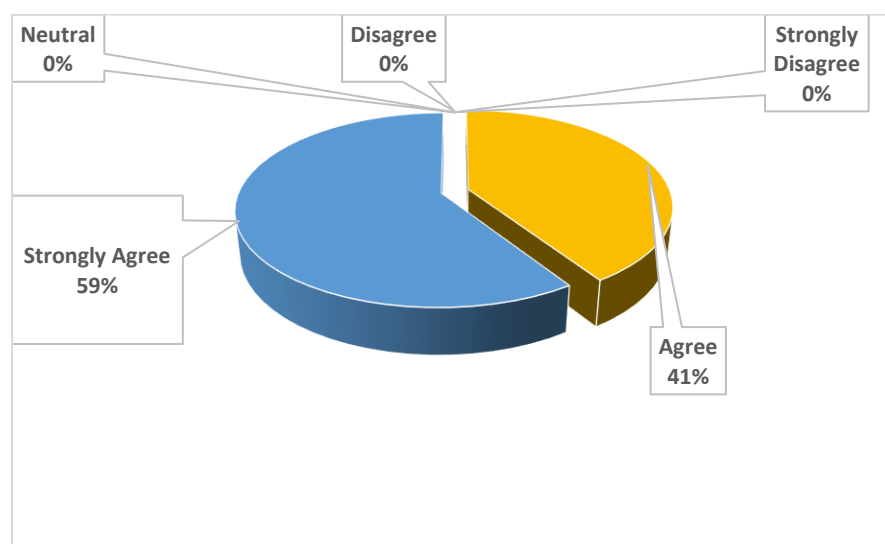


Figure 4.16: Percentage of respondents who believed that climate related factors bring challenges

The challenges were said to emanate from poor fodder and pasture yields, poor fodder and pasture seed banks, death of pastures due to dry spells, high seed costs, land disputes, overgrazing, bush encroachment, and invasive species growth.

Rising costs of feed inputs (such as grain, supplements) affect dairy farm profitability, and pose financial challenges for farmers. The interviewed participants highlighted some reasons how and why dairy farm profitability is affected. Unaffordability makes farmers to compromise, no feed options to use for the poor small-scale farmers, no inputs to plant pastures and fodder crops, no inputs needed to formulate rations.

Infrastructure limitations like inadequate storage facilities (for hay, silage, feeds) and transportation challenges hinder efficient feed utilization. Most large scale and medium scale dairy farmers have relevant facilities to store feeds, although some facilities may need renovations to avoid spoilage of feeds. Feed spoilage is mostly high in the small-scale dairy

farmers where poor or no facilities exist to store dairy animal feeds for preservation. Poor silage pits orientation and sitting affects quality of silage.

The study results also showed seventeen percent (17%) and seven percent (7%) respectively agree and strongly agree that there are knowledge gaps and extension services availability (figure 4.17). This has negatively impacted on lack of awareness on climate-change effects affect implementation of climate-smart agriculture practices and limited access to extension services affect fodder production, conservation, utilization and management.

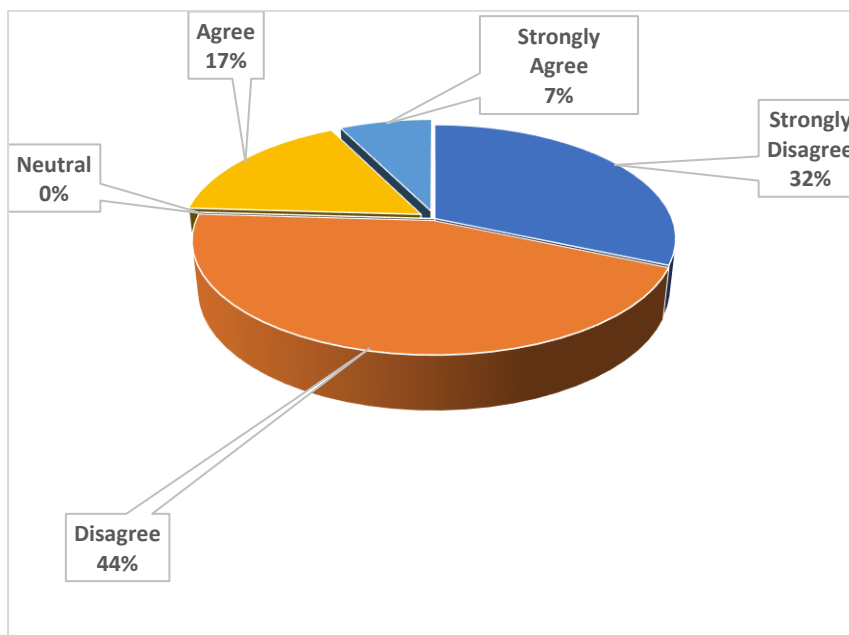


Figure 4.17: Lack of awareness and extension services availability responses.

The reasons cited by farmers for lack of extension services is limited extension worker mobility, and high ratio of farmers to extension workers. Most government extension workers need to be motorised to be able to cover all farmers in their working areas.

4.7 Dairy Feed Resources: Evaluation of challenges faced by dairy farmers in accessing and utilizing feed resources under changing climatic conditions.

Challenge	Mean (%)	Standard Deviation (%)	95% Confidence Interval Lower (%)	95% Confidence Interval Upper (%)
High Cost of Supplementary Feeds	45.0	10.5	37.22	52.78
Poor Access to Drought-Resistant Forage	32.5	10.6	24.65	40.35
Lack of Water for Irrigation	37.5	11.1	29.28	45.72
Limited Knowledge of Climate-Smart Practices	25.0	10.0	17.59	32.41
Inadequate Storage for Feed Preservation	20.0	9.6	12.89	27.11

Table 4.2: Key challenges faced by dairy farmers under changing climatic changes

The table presents the statistical analysis of key challenges faced by dairy farmers in accessing and utilizing feed resources under changing climatic conditions. The mean values represent the percentage of farmers reporting each challenge, while the standard deviation provides insight into the variability of these responses. The 95% confidence intervals indicate the range within which the true population mean likely falls, offering a robust understanding of the relative importance of each challenge.

4.7.1 High Cost of Supplementary Feeds

With a mean of 45.0% and a confidence interval ranging from 37.22% to 52.78%, this challenge is consistently the most significant problem for dairy farmers. The rising costs of supplementary feeds, as highlighted by Tui et al., (2022), directly stem from the growing reliance on these feeds due to climate-induced reductions in natural pasture availability. As more farmers are forced to purchase expensive feed alternatives, the economic burden continues to rise. FAO (2019) also emphasizes that rising input costs disproportionately affect smallholder farmers, who are already financially constrained, thus limiting their capacity to maintain productivity during feed-scarce periods.

4.7.2 Poor Access to Drought-Resistant Forage

This challenge has a mean of 32.5% and a confidence interval of 24.65% to 40.35%, showing that a significant proportion of farmers struggle to access resilient forage variety Battheu-Noirfalise,(2024), both point to the necessity of drought-resistant forages, such as Napier grass, for sustaining feed resources during periods of low rainfall. However, access to seeds, knowledge about these varieties, and the financial resources to cultivate them remain major barriers, especially for smallholder farmers. Without proper institutional support to facilitate access to such resources, farmers will continue to face difficulties adapting to increasingly erratic rainfall patterns.

4.7.3 Lack of Water for Irrigation

With a mean of 37.5% and confidence intervals ranging from 29.28% to 45.72%, water scarcity is another major concern for dairy farmers. As noted by Ogutu et al., (2024), the erratic and insufficient rainfall brought on by climate change significantly hinders forage production, leaving farmers unable to irrigate crops effectively. Amole et al., (2022) emphasize the importance of water management strategies, such as rainwater harvesting and irrigation infrastructure development, but the lack of infrastructure and resources to implement these techniques remains a persistent issue. This challenge directly impacts farmers' ability to sustain forage crops and maintain livestock health.

4.7.4 Limited Knowledge of Climate-Smart Practices

The mean of 25.0%, with confidence intervals between 17.59% and 32.41%, shows that knowledge gaps in climate-smart agricultural practices are a significant barrier. Erdaw, (2023) argue that access to education and technical training on climate resilience strategies, such as silage making and agroforestry, is crucial for enabling farmers to adapt to climate variability. However, smallholder farmers often have limited access to extension services, which leaves them less prepared to implement adaptive practices. Expanding educational outreach and providing technical assistance is critical to closing this gap.

4.7.5 Inadequate Storage for Feed Preservation

This issue, with a mean of 20.0% and confidence intervals of 12.89% to 27.11%, reflects the challenge of feed preservation, particularly during periods of surplus. As Magwegwe et al.,

(2024) emphasize, farmers often lack proper infrastructure to store preserved feeds like silage and hay, leading to feed shortages during the dry season. Inadequate storage exacerbates reliance on expensive supplementary feeds, particularly when natural pastures are scarce. Increasing investments in storage infrastructure and promoting feed preservation techniques could mitigate this problem and improve farmers' resilience to climatic changes.

The results highlight the high cost of supplementary feeds as the dominant challenge, suggesting that financial constraints are a key limitation for smallholder dairy farmers. The consistent rise in the cost of feeds correlates with reduced pasture availability, as noted by FAO (2019), and emphasizes the importance of economic interventions to reduce the burden on farmers.

The relatively high prevalence of challenges related to water scarcity and poor access to drought-resistant forage demonstrates the need for broader support in terms of infrastructure and resource allocation. Without access to resilient forage species and water management systems, farmers will continue to face difficulties sustaining livestock, leading to decreased milk yields and potential reductions in herd sizes.

The knowledge gap surrounding climate-smart agricultural practices also points to the need for enhanced extension services and educational outreach programs. As Mamphogoro et al., (2024) argue, building farmer capacity through training and the dissemination of climate-smart techniques is vital for improving their ability to adapt to changing climatic conditions.

Finally, the challenge of inadequate storage reflects a significant opportunity for improvement. By investing in storage facilities and promoting feed preservation techniques, farmers could better manage feed resources, reducing their dependency on external markets and lowering costs.

The challenges highlighted by the data reflect both economic and resource-based constraints that are exacerbated by climate change. The high cost of supplementary feeds and the lack of access to critical resources, such as water and drought-resistant forage, are the most pressing concerns. Addressing these challenges will require comprehensive solutions, including financial support for farmers, improved access to climate-smart technologies, and enhanced extension services to provide knowledge and resources. By tackling these barriers, dairy farmers in regions like Seke District can become more resilient to the impacts of climate variability and ensure sustainable production in the long term.

4.8 Chapter Summary

The chapter presented the results of the study evaluating the current challenges and adaptation strategies employed by dairy farmers in Seke District in response to climate change. Key findings highlight that the changing climatic conditions, particularly erratic rainfall and prolonged dry spells, have had a significant impact on the availability and utilization of feed resources for dairy farming. Farmers are increasingly relying on supplementary feeds due to the declining availability of natural pastures. This has led to a substantial rise in the cost of feed, which was identified as the most significant challenge faced by dairy farmers.

The analysis of adaptation strategies shows a steady increase in the adoption of drought-resistant forage species, water-saving techniques such as rainwater harvesting, and feed preservation practices like silage and haymaking. Despite this progress, many farmers continue to face barriers such as poor access to these resources, inadequate knowledge of climate-smart agricultural practices, and insufficient infrastructure for feed storage.

The statistical analysis further revealed that the high cost of supplementary feeds, poor access to drought-tolerant forages, and water scarcity are the most prevalent challenges. The study emphasizes the need for integrated support mechanisms, including financial assistance, improved infrastructure, and access to technical knowledge, to enhance the resilience and sustainability of dairy farming in the district.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a conclusion drawn from the findings, and recommendations for practice and further study. The chapter revisits the study objectives and provides an evaluation of whether these objectives were met. It then synthesizes the key insights gained from the study and outlines practical actions that can be taken by dairy farmers and other stakeholders to address the challenges identified to be associated with climate changes in dairy farming. Lastly, the chapter suggests areas for future research that could further build on the results of the current study.

5.2 Statement of Objectives

The primary objectives of this study were to assess the current status of dairy feed resource availability and utilization in Seke District, analyze the impact of climate change on the quality and quantity of these resources, identify adaptation strategies employed by dairy farmers to mitigate the effects of climate change, evaluate the challenges farmers face in accessing and utilizing feed resources, and suggest strategies to enhance the resilience and sustainability of the dairy sector in response to climate variability. Based on the research conducted and the data analyzed, all of the study's objectives were largely achieved. The objectives related to adaptation strategies and challenges were particularly well-addressed, with detailed findings on the strategies farmers are using and the specific barriers they encounter. However, challenges related to the financial and institutional support systems that farmers need for successful adaptation were found to be more complex and could not be fully explored within the scope of this study. Future research is recommended to focus on these gaps.

5.3 Summary of Major Findings

The study revealed several important findings regarding the impacts of climate change on dairy farming in Seke District. It was found that the availability of natural pastures has significantly declined due to erratic rainfall patterns and prolonged droughts, forcing farmers to increasingly rely on supplementary feeds. This has led to a substantial rise in the cost of dairy farming, with many smallholder farmers struggling to afford the necessary feed resources. Adaptation strategies, including the adoption of drought-resistant forage species, water-saving techniques like rainwater harvesting, and feed preservation practices such as silage and haymaking, have

been increasingly implemented by farmers. Despite this, the high cost of supplementary feeds, limited access to drought-tolerant forage varieties, and water scarcity remain significant barriers. The study also identified knowledge gaps in climate-smart agricultural practices and insufficient infrastructure for feed storage as key challenges facing farmers in their efforts to adapt to changing climatic conditions.

5.4 Conclusions

From the findings, several conclusions can be drawn. First, dairy farmers in Seke District are increasingly vulnerable to the impacts of climate change, particularly with respect to feed resource availability. As climate variability continues to disrupt rainfall patterns, the traditional reliance on rain-fed natural pastures is no longer sufficient to meet the nutritional needs of livestock. Farmers have recognized this vulnerability and are actively seeking adaptation strategies, yet financial and institutional support remains inadequate. The growing adoption of drought-resistant forage species and water-saving techniques shows that farmers are willing to adapt, but poor access to necessary resources, such as seeds and water infrastructure, limits their ability to fully implement these strategies. The study also concludes that there is an urgent need for capacity-building initiatives to address the knowledge gaps in climate-smart agricultural practices. Additionally, the high cost of supplementary feeds continues to be the most pressing challenge for farmers, suggesting a need for more affordable and sustainable alternatives. Overall, while farmers are making progress in adapting to climate change, more robust support systems are needed to ensure the long-term resilience and sustainability of the dairy sector in Seke District.

5.5 Recommendations

Based on the findings and conclusions, several recommendations can be made. First, there is a need for financial support mechanisms, such as subsidies for supplementary feeds and drought-resistant forage seeds, to help farmers cope with the rising costs of feed. The government and agricultural organizations should collaborate to provide these resources at affordable rates. Second, efforts should be made to improve access to water-saving technologies, such as rainwater harvesting and efficient irrigation systems, which are essential for maintaining fodder production during periods of low rainfall. Third, capacity-building programs should be implemented to provide farmers with training in climate-smart agricultural practices. These programs should focus on techniques such as silage making, water conservation, and the cultivation of drought-tolerant crops. Additionally, the government should invest in feed

storage infrastructure to help farmers preserve excess feed produced during the wet season for use during drought periods. Lastly, it is recommended that the government and development organizations expand extension services to reach more farmers, providing them with the technical knowledge and resources needed to adapt to climate change.

5.6 Areas for Further Study

While this study provided valuable insights into the challenges faced by dairy farmers in adapting to climate change, there are several areas that require further research. First, a deeper investigation into the financial barriers to adaptation, particularly the role of credit and insurance systems, would provide a clearer understanding of how farmers can be better supported. Second, a study focusing on institutional frameworks and how they can be strengthened to facilitate access to resources, such as seeds and water infrastructure, would be beneficial. Third, further research on climate-smart technology adoption and how it can be scaled up, particularly among smallholder farmers, is needed. Finally, a longitudinal study examining the long-term effects of climate adaptation strategies on dairy farming sustainability would provide valuable insights into the effectiveness of these practices over time.

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APPENDICES

Appendix 1: Questionnaire

Dear sir/madam

This questionnaire is based on the research topic titled “An Investigation into the Influence of Climate Change on Dairy Feed Resources Availability and Utilization: Case study of Seke District, Zimbabwe”. May I kindly request your assistance in responding to the questions in this questionnaire? The data to be collected is going to be used solely for academic purposes with a high level of confidentiality.

Researcher’s Name: Flaviano Chikonyora

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Email: flaviangc@gmail.com

Institution: Bindura University of Science Education (BUSE)

Master of Science Degree Disaster Risk Management (MSc DRM)

Instructions

Tick where applicable in the box(es) provided for each question, for example ☒

Kindly respond to all questions.

Do not write your name, phone number, or address on the questionnaire - confidentiality.

Location (Province / District) -----

1. Which class of dairy farmer or dairy value chain do you belong to? (Single response)

- ☐ Large Scale (production of +500 litres of milk per day)
- ☐ Medium Scale (production of 200 -500 litres of milk per day)
- ☐ Small Scale (production of less than 200 litres of milk per day)
- ☐ Dairy Extension Officer
- ☐ Pasture Seed Specialist

SECTION A:

How is climate change impacting the availability and quality of dairy feed resources in Seke District?

2. How aware are you of climate change and its impact on agriculture and livestock production? (Single response)

- ☐ Very aware
- ☐ Somewhat aware
- ☐ Not aware

If aware, how does it affect agriculture and livestock production?

3. Do you believe that climate change affects dairy feed availability in the district? (Single response)

- ☐ Yes
- ☐ No
- ☐ Unsure

If yes, how?

4. How do you access / source dairy feed resources (e.g., grazing, purchased feed, crop residues)? (Multiple responses)

- ☐ Grazing
- ☐ Purchased feed

- ☐ Crop residues
- ☐ Other (please specify): -----

5. Have you observed any changes in dairy feed availability over the past decade due to climate variations? (Single response)

- ☐ Yes
- ☐ No
- ☐ Not sure

If yes, what are the changes that you have noted?

6. The availability of forage (pasture, hay, and silage) has changed due to irregular rainfall patterns caused by climate change. (Single response)

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

7. What climate-related challenges impact dairy feed availability on your farm? (Multiple response)

- ☐ Erratic rainfall
- ☐ Droughts
- ☐ Increased Temperatures
- ☐ Pests and diseases
- ☐ Other (please specify)

8. Increased temperatures lead to heat stress in dairy cattle, affecting milk production and overall productivity. (Single response)

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

9. Prolonged droughts reduce the availability of feed resources for dairy animals. (Single response)

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

How?

10. What strategies have you implemented to mitigate the effects of climate change on dairy feed resources? (Multiple response)

- ☐ Improved feed storage and feed preservation
- ☐ Diversified feed sources
- ☐ Altered feeding schedules
- ☐ Improved water management
- ☐ Improved fodder production on farm

☐ Other (please specify):

Are there any challenges in adopting these strategies?

11. What changes do you anticipate in dairy feed availability in the next decade due to climate change? (Single response)

- ☐ Decreased availability
- ☐ No significant change
- ☐ Increased availability

How can policymakers and researchers support dairy farmers in adapting to climate change?

SECTION B

How are the current practices and patterns of dairy feed resource utilization changing in the face of ever-changing climatic conditions?

12. Feed Composition and Nutrient Balance: Do you consider the nutritional content and balance of feed ingredients when formulating rations for dairy animals? (Single response)

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree

☐ Strongly Agree

Why?

13. Climate-Resilient Forage Crops: Do you actively cultivate climate-resilient forage crops (e.g., drought-tolerant grasses, legumes) to ensure consistent feed availability? (Single response)

☐ Yes

☐ No

Which forage crops do you actively cultivate and why?

14. Water Management for Pasture Growth: Adequate water management practices (irrigation, rainwater harvesting) contribute to pasture growth and availability. (Single response)

☐ Strongly Disagree

☐ Disagree

☐ Neutral

☐ Agree

☐ Strongly Agree

15. Feed Storage and Preservation: Do you and other farmers adopt proper fodder storage and preservation techniques (silage, haymaking) to maintain feed quality. (Single response)

☐ Yes

☐ No

Why?

16. Collaboration with Extension Services: Do you seek guidance from agricultural experts and agricultural extension officers on climate-smart feed utilization practices? (Single response)

☐ Yes

☐ No

If yes, which organizations do you normally consult or get your guidance on climate-smart feed utilization practices?

If no, why?

SECTION C:

How do dairy farmers and stakeholders face challenges in accessing and utilizing feed resources under the influence of climate change?

17. Feed Availability and Scarcity: Access to sufficient and quality feed resources (pasture, silage, concentrates) has become more challenging due to climate-related factors. (Single response)

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

How?

18. Erratic Rainfall Patterns: Unpredictable rainfall affects forage growth and availability, impacting feed supply. (Single response)

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

How and why?

19. Droughts and Water Scarcity: Prolonged droughts reduce water availability for irrigation and livestock, affecting fodder crops. (Single response)

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

20. High Feed Costs: Rising costs of feed inputs (e.g., grain, supplements) affects dairy farm profitability, and pose financial challenges for farmers. (Single response)

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

How does high cost of feed inputs affect profitability on a dairy farm?

21. Infrastructure Limitations: Inadequate storage facilities (for hay, silage) and transportation hinder efficient feed utilization. (Single response)

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral

- ☐ Agree
- ☐ Strongly Agree

How does that hinder efficient feed utilization?

22. Knowledge Gaps and Extension Services: Lack of awareness about climate-smart practices and limited access to extension services affect fodder production, conservation, utilization and management. (Single response)

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

How does it affect fodder production, conservation and utilization?

Appendix 2: Letter of authorization to conduct research

Bindura University
of Science Education



DISASTER RISK REDUCTION DEPARTMENT

Private Bag 1020,

Bindura, Zimbabwe

Tel 263 – 66210-7531-6, 7621-4

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BINDURA UNIVERSITY OF SCIENCE EDUCATION

5 June 2024

To Whom It May Concern:

ASSISTANCE TO THE STUDENT WHO IS SEEKING INFORMATION FOR HIS RESEARCH PROJECT

This is to confirm that Flaviano Chikonyora, Registration Number B231527B is a student doing a Master of Science Degree in Disaster Risk Management in the Disaster Risk Reduction Department at Bindura University of Science Education and is required to do a Research Project as part of his degree programme. The student is expected to gather data for his project from various sources including your institution.

This letter therefore serves to kindly ask you to assist the above-mentioned student with information relating to his project entitled:

AN INVESTIGATION INTO THE INFLUENCE OF CLIMATE CHANGE ON DAIRY FEED RESOURCE AVAILABILITY AND UTILIZATION: CASE STUDY FOR SEKE DISTRICT, ZIMBABWE

Thank you.

EMMANUEL MAVHURA (PhD)
CHAIRMAN