

**Adoption of climate-smart agriculture practices by smallholder dairy
farmers in Chipinge and Mutasa Districts of the Manicaland Province,
Zimbabwe**

by

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Submitted in accordance with the requirements for the degree of

DOCTOR OF PHILOSOPHY

in Agriculture

at the

UNIVERSITY OF SOUTH AFRICA

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DEDICATION

This study is dedicated to my late father, Mr Tumirai Chavhunduka.

ACKNOWLEDGEMENTS

I give thanks to God for keeping me alive and well and for helping me complete this work. To my supervisor, Professor Khanyisile R. Mbatha, you deserve special mention for the diligence and leadership demonstrated throughout the study. Thank you for your patient guidance reading and correcting the chapters one by one. Special thanks go to the Zimbabwe Association of Dairy Farmers team, led by the executive director, Mrs Paidamoyo Patience Chadoka and Messrs. Gerald Chivete, Flaviano Chikonyora, Rishoni Chikuni and Sharp Mazivanhanga. They provided access to their database and continued to provide logistical support throughout the data collection process. The hard part of data collection was led and well done by the lead enumerators, Messrs. Caiphas Chihlayo and Gladman Tatenda Mulambo for Chipinge and Mutasa districts, respectively. Thank you very much, gentlemen, for your patience and good work. Last but not least, my family, to my wife Edigar, thank you for all the love and support you have put into our journey of life. Keep up the good work! You even went a step further by helping with editing and formatting the thesis. To my daughter, Chido, and my son, Komborero, you are the reason I do the things I do! Thank you for always checking on the progress of the thesis and, of course, for being the best children that you are.

ABSTRACT

Climate change poses significant constraints on smallholder dairy production systems in Zimbabwe, particularly in drought-prone regions such as Manicaland Province. This study analysed farmers' perceptions of climate change and their influence on the adoption of Climate-Smart Agriculture (CSA) practices among smallholder dairy farmers in Chipinge and Mutasa districts. It further quantified the extent of adoption of adaptation- and mitigation-based CSA practices and identified socio-economic and institutional determinants shaping adoption decisions.

Guided by the Climate-Smart Agriculture framework of the Food and Agriculture Organization, which integrates productivity, resilience, and greenhouse gas mitigation objectives, the study employed a cross-sectional survey design. Primary data were collected from 154 smallholder dairy households using structured questionnaires. Descriptive statistics indicated that feed shortages (59.6%) and water scarcity (55.0%) were the most severe climate-related constraints, while 84.7% of respondents reported high awareness of the impacts of climate change on dairy production.

Inferential analysis revealed a statistically significant association between climate change perception and CSA adoption (χ^2 , $p < 0.05$), indicating that perception significantly shapes adoption behaviour. Binary logistic regression results showed that CSA adoption was significantly influenced by household size, education level, herd size, farming experience, access to finance, and perception of climate variability ($p < 0.05$), confirming that both human capital and resource endowments are key adoption drivers. Further, multinomial logistic regression results demonstrated that district location significantly influenced farmers' choice among adaptation-only, mitigation-only, and integrated CSA strategies ($p < 0.05$), highlighting spatial heterogeneity in adoption behaviour. The model exhibited acceptable explanatory power, confirming robustness in predicting CSA adoption categories.

Despite high awareness levels (84.7%), CSA adoption remains constrained by structural socio-economic and institutional barriers. Adaptation practices are widely adopted but predominantly reactive and short-term coping strategies, while mitigation practices remain limited and are primarily motivated by productivity gains rather than by emission-reduction objectives. Agroforestry demonstrated moderate adoption (34%) and provided synergistic adaptation–mitigation benefits.

The study concludes that although smallholder dairy farmers exhibit adaptive capacity, their responses remain largely survivalist rather than transformative. Strengthening access to finance, enhancing extension services, and providing targeted incentives for mitigation-oriented technologies are critical to promoting integrated and sustainable climate-smart dairy systems in Zimbabwe.

Key words: Adaptation; climate change; climate-smart agriculture; constraints; mitigation; smallholder dairy farmers; sustainable milk production

ISIFINYEZO

Ukushintsha kwesimo sezulu kubeka ingcindezi enkulu izinhlelo zokukhiqiza ubisi kubalimi abasafufusa eZimbabwe, ikakhulukazi ezindaweni ezivame ukuhlaselwa yisomiso ezifana neSifundazwe sase Manicaland. Lolu cwaningo luhlaziye imibono yabalimi mayelana nokushintsha kwesimo sezulu kanye nomthelela wayo ekwamukelweni Ubuchule Bezolimo Obuhambisana Nesimo Sezulu (Climate-Smart Agriculture (CSA) phakathi kwabalimi abasafufusa abakhiqiza ubisi ezifundeni zaseChippinge naseMutasa. Luphinde lwalinganisa izinga lokwamukelwa kwezinqubo ze-CSA ezisekelwe ekuzijwayezeni nasekunciphiseni imithelela kanye nokuhlonza izici zenhlalo-mnotho kanye nezikhungo ezakha izinqumo zokwamukela.

Lolu cwaningo lulawulwa uhlaka loBuchule Bezolimo Obuhambisana Nesimo Sezulu mayelana neNhlangothi Ebhekelele Ukudla neZolimo, oluhlanganisa imikhiqizo, ukumelana nezimo, kanye nokunciphisa igesi ebamba ukushisa, ngokusebenzisa ucwaningo lwenhlolovo. Idatha esemqoka yaqoqwa emakhaya amancane ayi-154 akhiqiza ubisi ngokusebenzisa imibuzo ehlelekile. Izibalo ezichazayo zidalule ukuthi ukuntuleka kokudla (59.6%) nokuntuleka kwamanzi (55.0%) kwakuyizithiyo ezinamandla kakhulu ezihlobene nesimo sezulu, kanti ama-84.7% wabaphenduli babika ukuqonda okukhulu ngomthelela wokushintsha kwesimo sezulu ekukhiqizeni ubisi.

Uhlaziyo olujulile ludalule ubuhlobo obubalulekile ngokwezibalo phakathi kombono ngokushintsha kwesimo sezulu kanye nokwamukelwa kwe-CSA (χ^2 , $p < 0.05$), okukhombisa ukuthi indlela abantu ababona ngayo izinto ibumba kakhulu indlela abamukela ngayo i-CSA. Imiphumela ye-binary logistic regression ikhombise ukuthi ukwamukelwa kwe-CSA kunomthelela omkhulu kubungako bomndeni, izinga lemfundo, ubungako bomhlambi wemfuyo, ulwazi lokulima, ukufinyelela ezimalini, kanye nombono wokushintsha kwesimo sezulu ($p < 0.05$), kuqinisekisa ukuthi kokubili amandla abantu nokutholakala kwezinsiza yikona okukhuthaza ukwamukelwa. Ngaphezu kwalokho, imiphumela yocwaningo lwe-multinomial logistic regression ikhombisile ukuthi indawo yesifunda yaba nomthelela omkhulu ekukhetheni kwabalimi phakathi kwamaqhinga e-CSA agxile kuphela ekuzivumelaliseni nezimo kanye nasekunciphiseni imithelela kanye namaqhinga adidiyelwe ($p < 0.05$), agqamisa ukwahlukahlukana kwendawo endleleni yokwamukela. Imodeli ikhombise amandla amukelekayo okuchaza, okuqinisekisa ukuzinza ekuqaguleni izigaba zokwamukelwa kwe-CSA.

Naphezu kwamazinga aphezulu okuqwashisa angama- (84.7%), ukwamukelwa kwe-CSA kusavinjelwe yizingqinamba zesakhiwo senhlalo-mnotho kanye nezikhungo. Izingqubo zokuzivumelanisa nezimo zamukelwe kabanzi kodwa okusemqoka yizindlela zokuphendula ngokushesha kanye namaqhinga okukwazi ukumelana nezimo zesikhashana, kanti izingqubo zokunciphisa imithelela zihlala zincane futhi zigqugquzelwa ukuthola inzuzo yokukhiqiza kunokuba zibe yinhloso yokunciphisa ukukhishwa kwegesi. I-Agroforestry ikhombise ukwamukelwa okusesilinganisweni esingama (34%) yaphinde yahlinzeka ngemihlomulo ehlanganisiwe yokuzivumelanisa nezimo kanye nokunciphisa imithelela.

Ucwaningo luphetha ngokuthi nakuba abalimi abasafufusa abakhiqiza ubisi bekhombisa ikhono lokuzivumelanisa nezimo, izimpendulo zabo zisekelwe kakhulu ekusindeni kunokuguqula isimo. Ukuqinisa ukufinyelela kwezezimali, ukuthuthukisa izinsizakalo zokweluleka, kanye nokuhlinzekwa kwezikhuthazo eziqondile zobuchwepheshe obugxile ekunciphiseni imithelela kubalulekile ekukhuthazeni izinhlelo zokukhiqizwa kobisi ezididiyelwe nezisimeme ezibhekene nesimo sezulu eZimbabwe.

Amagama asemqoka: Ukuzivumelanisa; ukushintshashintsha kwesimo sezulu; ubuchule bezolimo obuhambisana nesimo sezulu; izingqinamba; ukulungisa; abalimi abasafufusa abakhiqiza ubisi; ukukhiqizwa kobisi okusimeme

TSHOSOBANYO

Phetogo ya tlelaemete e baka dikgoreletsi tse dikgolo mo ditsamaisong tsa tlhagiso ya maswi tsa balemirui ba bannye kwa Zimbabwe, segolobogolo mo dikgaolong tse di tlhaselwang ke komelelo jaaka Porofense ya Manicaland. Thutopatlisiso eno e sekasekile ditemogo tsa balemirui ka ga phetogo ya tlelaemete le tlhotlheletso ya tsone mo go amogeleng mekgwa ya Temothuo e e Botlhale mo Maamong a Phetogo ya Tlelaemete (Climate-Smart Agriculture [CSA]) gareng ga balemirui ba bannye ba maswi mo kgaolong tsa Chipinge le Mutasa. Gape e lekantse selekanyo sa go amogelwa ga mekgwa ya CSA e e ikaegileng ka go tlwaela maemo a a fetogang le go fokotsa mesi, mme ya supa mabaka a ikonomi ya loago le a ditheo a a bopang ditshwetso tsa go amogela mekgwa eno.

E kaelwa ke letlhomiso la Temothuo e e Botlhale mo Maamong a Phetogo ya Tlelaemete (Climate-Smart Agriculture framework) la Mokgatlo wa Dijo le Temothuo (Food and Agriculture Organization), le le kopanyang maikaelelo a tlhagiso, bokgoni jwa go itshokela maemo a a fetogang, le go fokotsa mesi ya digase tse di bakang go thuthafala ga lefatshe, thutopatlisiso eno e dirisitse thulaganyo ya patlisiso ya dikarolo tsotlhe ka nako e le nngwe. Tshedimosetso ya ntlha e ne ya kokoanngwa mo malapeng a le 154 a balemirui ba bannye ba maswi go dirisiwa dipotsolotso tse di rulagantsweng. Dipalopalo tse di tlhalosang di bontshitse gore tlhalelo ya dijo tsa leruo (59.6%) le tlhalelo ya metsi (55.0%) e ne e le dikgoreletsi tse di masisi thata tse di amanang le tlelaemete, fa 84.7% ya baarabi e begile temogo e e kwa godimo ya ditlamorago tsa phetogo ya tlelaemete mo tlhagisong ya maswi.

Tshekatsheko ya dipalopalo ya go dira ditshwetso go tswa mo tshedimosetsong ya sampole e senotse kamano e e botlhokwa go ya ka dipalopalo magareng ga temogo ya phetogo ya tlelaemete le go amogelwa ga CSA (χ^2 , $p < 0.05$), e bontsha gore temogo e tlhotlheletsa boitshwaro jwa go amogela mekgwa ka tsela e e botlhokwa. Dipholo tsa tshekatsheko ya go boelediwa jwa kgonagalo ya dipelo tse pedi di bontshitse gore go amogelwa ga CSA go ne go tlhotlhelediwa ka tsela e e botlhokwa ke bogolo jwa lelapa, maemo a thuto, bogolo jwa motlhape, maitemogelo a temothuo, phitlhelelo ya ditšhelete, le temogo ya go fetofetoga ga tlelaemete ($p < 0.05$), e netefatsa gore kitso le bokgoni jwa batho mmogo le didirisiwa le dithoto tse di leng teng ke mabaka a konokono a a tlhotlheletsang go amogelwa ga mekgwa. Mo godimo ga moo, dipholo tsa tshekatsheko ya go boelediwa jwa kgonagalo ya dikarolo tse dintsi di bontshitse gore lefelo la kgaolo le ne le tlhotlheletsa ka tsela e e botlhokwa boitlhophelo jwa balemirui magareng ga maano a a ikaegileng fela ka go tlwaela maemo a a fetogang, a a ikaegileng fela ka go fokotsa mesi, le maano a a kopantseng CSA ($p < 0.05$), e leng se se

totobatsang go farologana ga boitshwaro jwa go amogela mekgwa go ya ka mafelo. Sekaelo seno se bontshitse maatla a a amogelesegang a go tlhalosa dipholo, se netefatsa go tia ga sona mo go bonelapele dikarolo tsa go amogelwa ga CSA.

Le fa maemo a temogo a ne a le kwa godimo (84.7%), go amogelwa ga CSA go sa ntse go kgorelediwa ke dikgoreletsi tsa sebopego tse di amanang le ikonomi ya loago le ditheo. Mekgwa ya go tlwaela maemo a a fetogang e amogelwa thata mme segolobogolo ke maano a a tsibogelang mathata le a nakwana a go itshoka, fa mekgwa ya go fokotsa mesi e sa ntse e le kwa tlase mme segolobogolo e tlhotlhelediwa ke dipolelo tsa go oketsa tlhagiso go na le maikaelelo a go fokotsa mesi. Kopanyo ya ditlhare le ditiro tsa temothuo e bontshitse selekanyo se se magareng sa go amogelwa (34%) mme ya tlamela ka melemo e e nonotshanang ya go tlwaela maemo a a fetogang le go fokotsa mesi.

Thutopatlisiso eno e konela ka gore le fa balemirui ba bannye ba maswi ba bontsha bokgoni jwa go ikamaganya le maemo a a fetogang, ditsibogo tsa bone di sa ntse di ikaegile thata ka go falola le go itshoka go na le go tlisa diphetogo tse di tseneletseng. Go nonotsha phitlhelelo ya ditšhelete, go tokafatsa ditirelo tsa katoloso ya temothuo, le go tlamela ka dikgothatso tse di lebisitsweng mo dithekenolojing tse di ikaegileng ka go fokotsa mesi go botlhokwa thata mo go rotloetseng ditsamaiso tsa tlhagiso ya maswi tse di kopantseng le tse di tswelelang, e bile di le botlhale mo maamong a phetogo ya tlelaemete kwa Zimbabwe.

Mafoko a Botlhokwa: Go tlwaela maemo a a fetogang; phetogo ya tlelaemete; temothuo e e botlhale mo maamong a phetogo ya tlelaemete; dikgoreletsi; go fokotsa mesi; balemirui ba bannye ba maswi; tlhagiso ya maswi e e tswelelang

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LIST OF ABBREVIATIONS AND ACRONYMS

AfDB	African Development Bank
CH ₄	Methane
CO ₂	Carbon dioxide
CSA	Climate-smart agriculture
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GHG	Greenhouse gas
GoZ	Government of Zimbabwe
HLPE	High Level Panel of Experts on Food Security
IFAD	International Fund for Agricultural Development
IPCC	The Intergovernmental Panel on Climate Change
NAMA	Nationally Appropriate Mitigation Action
N ₂ O	Nitrous oxide
OECD	Organization for Economic Co-operation and Development
SSA	Sub-Saharan Africa
ZADF	Zimbabwe Association of Dairy Farmers

CHAPTER 1: INTRODUCTION

1.1 The importance of smallholder agriculture in Sub-Saharan Africa

Smallholder agriculture plays a central role in the economic and social development of Sub-Saharan Africa (SSA). Across the region, agriculture remains the backbone of rural livelihoods and a key driver of inclusive economic growth, employment creation, and structural transformation (Kamara et al., 2019; Nchanji & Lutomia, 2022). The integration of smallholder farmers into diversified rural economies and agri-food value chains strengthens local markets, enhances food security, and improves households' socio-economic status.

According to the World Bank (2018), approximately 60% of SSA's population resides in rural areas and depends predominantly on agriculture for their livelihoods. In this context, agricultural productivity is closely linked to food security, income generation, and broader human development outcomes, including health and well-being. Despite the sector's importance, rural populations continue to experience disproportionately high levels of poverty, hunger, and vulnerability to climatic and economic shocks, undermining both livelihood resilience and national development objectives (High Level Panel of Experts on Food Security (HLPE, 2017); The Food and Agriculture Organization of the United Nations (FAO and others, 2019). These vulnerabilities have been further exacerbated by recent geopolitical developments, including reductions in development assistance from the traditional donor countries, which have intensified livelihood insecurity among rural populations.

Food insecurity remains widespread across the region, with approximately one quarter of SSA's population undernourished. Rural smallholder households bear the greatest burden of this food insecurity (FAO, 2017; Gebre et al., 2024). The predominance of rain-fed production systems further heightens vulnerability to climate variability and extreme weather events. As rural livelihoods deteriorate, households may resort to unsustainable coping strategies, including deforestation, overharvesting of natural resources, and illegal hunting, thereby further degrading ecosystems and weakening their capacity to regenerate (UNEP, 2016).

The African Development Bank (2018) and Jayne et al. (2019) note that rapid population growth, estimated at approximately 2.5% per annum, continues to exert increasing pressure on land and water resources in SSA, amplifying risks related to soil fertility decline, land degradation, and food

insecurity. At the same time, there has been increased rural-to-urban migration driven by limited economic opportunities and climatic stressors in rural areas. This migration has placed additional strain on urban infrastructure and social services, exacerbating socio-economic challenges across both rural and urban spaces (Satterthwaite & Tacoli, 2014).

Agriculture employs approximately 65% of SSA's labour force and contributes nearly one-third of the region's combined gross domestic product (GDP), underscoring its critical role in economic transformation (Diao et al., 2023). Through the sector's strong backward and forward linkages with other sectors, agricultural development can stimulate industrial growth, generate foreign exchange earnings, and reduce poverty (Gassner et al., 2019). However, the sector's factor productivity remains relatively low due to persistent constraints, including limited access to quality inputs, lack of access to credit, challenges in accessing formal markets, weak and inappropriate extension services and lack of access to appropriate technologies.

Gassner et al. (2019) note that improving the efficiency and sustainability of smallholder agriculture is widely recognised as a central pathway to addressing food insecurity and poverty in SSA. Smallholder farms, typically less than two hectares in size, constitute the majority of agricultural holdings and play a crucial role in food production and employment generation (Jayne et al., 2016; Lowder et al., 2016; Gassner et al., 2019). The Organization for Economic Cooperation and Development/The Food and Agriculture Organization of the United Nations (OECD/FAO), (2020) posits that women represent a substantial proportion of the agricultural labour force, highlighting the gendered dimensions of agricultural development and the need for inclusive policy and technological interventions. This will help reduce inequalities between men and women, especially in resource allocation.

Despite its agricultural potential, SSA remains a net food importer, with food import bills projected to rise sharply if domestic production fails to keep pace with growing demand (Global Nutrition Report, 2017; Headey et al., 2023). As noted by the Alliance for a Green Revolution in Africa (2017), past attempts to replicate Green Revolution-style strategies have yielded limited success, largely due to weak institutional capacity, inadequate infrastructure, and inconsistent policy implementation. These challenges have been compounded by the growing impacts of climate change, which disproportionately affect smallholder farmers and further constrain productivity growth.

Within this broader agricultural landscape, smallholder dairy farming represents a significant yet underdeveloped subsector. Findings by Herrero et al. (2016) and Bosire et al. (2019) show that smallholder dairy systems are typically characterised by small herd sizes and low milk yields, reflecting resource constraints and limited access to technical support and markets. Nevertheless, dairy production plays an important role in rural livelihoods by contributing to household income, nutrition, and employment, particularly where functional value chains are in place (Herrero et al., 2016b).

Rising global demand for dairy products is creating opportunities for dairy farmers to increase incomes, strengthen livelihoods and contribute to food and nutrition security, although the nature and drivers of this demand differ across income groups and regions. In low- and middle-income countries, particularly in Africa and Asia, increasing population, urbanisation and rising incomes are expected to drive substantial growth in dairy consumption (OECD & FAO, 2025). In contrast, high-income countries generally have more mature dairy markets, where consumption patterns are increasingly oriented towards processed and value-added products, including cheese, butter, milk powders and other specialised dairy products. The distinction is important because international dairy trade occurs predominantly in processed dairy products, while processing and value addition provide opportunities for producers and value-chain actors to capture greater economic value beyond the farm gate (OECD & FAO, 2025).

The projected expansion of global dairy production, however, also raises concerns regarding resource use and environmental sustainability. Intensification can increase demand for feed, land and water and, where productivity gains are insufficient to offset these pressures, contribute to environmental degradation and greenhouse gas emissions. Global agricultural production is projected to increase substantially over the coming decade, with productivity growth expected to play an important role in meeting rising demand while reducing emission intensity; nevertheless, total direct agricultural greenhouse gas emissions are projected to increase (OECD & FAO, 2025). These challenges underscore the importance of climate-smart approaches across diverse dairy production systems, although the appropriate interventions may differ depending on production scale, resource availability, technology, and market orientation.

For smallholder dairy farmers in developing countries, particularly those operating under climate and resource constraints, the adoption of climate-smart agriculture (CSA) practices such as

improved pasture and forage management, drought-tolerant forage species, water-harvesting technologies, improved feeding regimes and heat-stress mitigation can contribute to both productivity and resilience. Such practices are consistent with the CSA approach, which seeks to sustainably increase productivity and resilience while, where possible, reducing or removing greenhouse gas emissions (FAO, 2013). However, achieving sustainable milk production requires more than increasing production in response to growing demand. It requires the simultaneous pursuit of productivity, climate resilience and environmental sustainability, supported by appropriate technologies, finance, extension services, processing infrastructure and access to remunerative markets. This integrated perspective is particularly relevant to smallholder dairy systems in Zimbabwe, where strengthening farm-level CSA adoption needs to be complemented by improvements in dairy value addition, processing capacity and participation in formal dairy value chains.

1.2 Climate change impacts on smallholder agriculture

Climate change is already exerting substantial pressure on crop and livestock production systems worldwide, increasing agricultural risk and uncertainty. Thornton et al. (2024) note that smallholder farmers in developing countries are among the most vulnerable to these impacts due to limited adaptive capacity, constrained access to resources, and heavy reliance on climate-sensitive livelihoods. In SSA, the dominance of rain-fed agriculture renders smallholder production systems particularly sensitive to climate variability and extreme weather events.

Climate change interacts with pre-existing socio-economic, institutional, and political inequalities, further undermining the productive capacity of smallholder farmers. According to Antwi-Agyei et al. (2018), structural constraints, including poverty, insecure land tenure, weak extension services, and limited access to finance, exacerbate vulnerability to climate shocks. In many parts of SSA, limited institutional capacity continues to constrain coordinated responses to climate risks, thereby increasing exposure and reducing adaptive potential. Increasing frequency and duration of dry spells during the rainy season have intensified heat and water stress in both crop and livestock systems, with adverse consequences for agro-ecosystem functioning and rural livelihoods (Climate Technology Centre and Network (CTCN), 2017; Dodman et al, 2022).

Climate projections indicate that global temperatures are likely to rise by 1-2°C above pre-industrial levels by 2050, with SSA expected to experience above-average warming (Masson-Delmotte et al., 2018). The Food Security Information Network (FSIN) (2018) and Zhao et al. (2017) project that for every 1°C increase in temperature, global cereal yields will decline by approximately 3-10%, with more severe impacts anticipated in tropical regions. An increase of 1.5°C in global mean temperature by 2030 is expected to have serious implications for food security, human health, and rural livelihoods in SSA, disproportionately affecting smallholder farmers (Masson-Delmotte et al., 2018; Ziervogel et al., 2022). Consequently, development strategies in the region must prioritise climate-resilient smallholder agriculture as a pathway to reducing poverty and food insecurity.

Southern Africa has been identified as one of the regions most vulnerable to climate change impacts, particularly recurrent droughts and rising average temperatures (Zougmore et al., 2018). These climate extremes, according to Shikuku et al. (2017), have resulted in repeated crop failures, declining pasture availability, increased livestock mortality, and reduced fisheries productivity, leading to widespread food insecurity and economic losses. Strengthening resilience among rural communities is therefore essential for enhancing their capacity to absorb shocks, adapt to climatic variability, and sustain agricultural production.

Climate change is also increasingly recognised as a major threat to dairy production systems in developing countries, particularly in southern Africa, where smallholder farmers depend heavily on rain-fed agriculture and natural grazing resources. Rising temperatures, recurrent droughts, erratic rainfall patterns, and increased incidence of extreme weather events negatively affect dairy productivity through reduced pasture availability, declining feed quality, water shortages, increased prevalence of livestock disease, and heat stress (Thornton et al., 2022a; IPCC, 2023). These impacts are particularly severe for smallholder dairy farmers because limited access to financial resources, irrigation infrastructure, and climate adaptation technologies constrains their ability to respond effectively to climate-related shocks. Consequently, climate change poses significant risks to milk production, household incomes, food security, and the sustainability of dairy value chains across developing countries (Mottet et al., 2017; IPCC, 2023).

In Zimbabwe, the dairy sector is an important contributor to agricultural livelihoods, employment, and nutrition, yet it remains highly vulnerable to climate variability and change. The country's

dairy industry has experienced substantial fluctuations in production due to recurrent droughts, feed shortages, high input costs, limited access to finance, and infrastructural constraints. National milk production has gradually recovered from approximately 37 million litres in 2009 to over 100 million litres in recent years, although domestic production still falls short of national demand (Ministry of Lands, Agriculture, Fisheries, Water and Rural Development (MLAFWRD), 2024). Climate-induced feed and water shortages continue to undermine dairy productivity, particularly among smallholder farmers in drought-prone regions such as Manicaland. However, growing demand for dairy products, increased investment in value chain development, and the promotion of CSA practices present important opportunities to improve resilience, productivity, and sustainability within Zimbabwe's dairy sector (FAO, 2023; MLAFWRD, 2024).

Climate change adaptation has become a central strategy for addressing food insecurity among smallholder farmers (Tanner et al., 2015). Ouédraogo et al. (2018) added that adaptive capacity is shaped by multiple interrelated factors, including farm productivity, livelihood diversification, soil quality, access to improved breeds, risk attitudes, investment capacity, and local knowledge systems. While smallholder farmers have traditionally relied on indigenous knowledge to guide production decisions, climate change is increasingly undermining the reliability of these systems, creating uncertainty in land-use planning and crop and livestock management. This context underscores the need for integrated, multidimensional adaptation strategies that address both direct and indirect impacts of climate change.

Cinner et al. (2018) highlight the importance of local institutions, social norms, and governance arrangements, and the critical role they play in shaping farmers' responses to climate risks. Access to resources and information, and the capacity to take collective action, are heavily dependent on the strength of local institutions. However, uncertainty remains regarding the effectiveness of existing local-level climate governance mechanisms in supporting smallholder adaptation. Adaptive capacity continues to depend largely on access to financial, natural, human, and social capital necessary for implementing farm-level changes (Cinner et al., 2018; Barrett et al., 2017). Totin et al. (2018), therefore, argue for continued research into policies and interventions, particularly climate-smart agriculture, that enable or constrain smallholder farmers' ability to adapt to climate change.

1.3 Climate-smart agriculture concept

Thornton et al. (2024) posit that climate change poses a significant threat to global agricultural systems and the livelihoods of approximately 2.5 billion people who depend on agriculture, in part or in full. In response to increasing climate variability, food insecurity, and environmental degradation, the FAO introduced the concept of CSA as an integrated approach to agricultural development under climate change (FAO, 2010; Torquebiau et al., 2018).

The FAO (2010) defines CSA as an approach that sustainably increases agricultural productivity and income, enhances resilience and adaptation to climate change, and where possible reduces or removes greenhouse gas emissions. These three interlinked pillars: productivity, adaptation, and mitigation position CSA as a comprehensive framework that directly supports food security, climate action, and sustainable development objectives (FAO, 2022). Rather than prescribing a single technology, CSA encompasses a portfolio of context-specific practices and institutional arrangements designed to address climate risks while improving agricultural performance.

Chandra et al. (2018) and Aziz et al. (2024) add that CSA seeks to transform and reorient agricultural production systems to better manage climate-related shocks and stresses, while safeguarding rural livelihoods. By integrating biophysical, technological, socio-economic, cultural, and institutional dimensions, CSA provides a systems-based perspective on agricultural development and farmer decision-making (Schut et al., 2016; Khatri-Chhetri et al., 2017). Strategies to promote the adoption of CSA practices, therefore, need to be comprehensive enough to include elements of all the dimensions mentioned above.

In smallholder dairy systems, CSA offers particular promise to transform the subsector already implicated in relatively higher levels of greenhouse gases (GHG) emissions (methane and nitrous oxide). Herrero et al. (2023) underscore the importance of milk as a critical source of high-quality protein and micronutrients, especially for children, and its significant contribution to household nutrition and health outcomes. More stable and productive dairy systems can therefore enhance food and nutrition security while providing regular income streams for rural households. At the community level, improved dairy productivity can also increase the local availability of milk through both informal and formal markets, with the potential to create local employment. Other benefits through multiplier effects may include the development of other non-farm businesses that support the dairy farming activities.

Empirical evidence shows that adopting CSA practices, such as improved forage production, efficient water use, heat stress management, and enhanced herd and manure management, can strengthen smallholder dairy farmers' adaptive capacity, improve productivity, and increase incomes (Arakelyan, 2017). In addition, FAO (2017) and Smith et al. (2019) posit that at broader scales, CSA contributes to environmental sustainability by reducing emissions intensity per unit of output, thereby supporting national and global mitigation objectives. Increased adoption of CSA practices also provides governments with opportunities to develop more robust, evidence based and implementable Nationally Determined Contributions (NDCs).

Overall, CSA provides a coherent conceptual and practical framework to address the interlinked challenges of climate change, food insecurity and environmental degradation in smallholder agriculture. Understanding the factors influencing the adoption of CSA practices, particularly within climate-vulnerable smallholder dairy systems such as those found in Chipinge and Mutasa Districts of Manicaland Province, Zimbabwe, is therefore essential for informing effective policy development and the design of appropriate interventions.

1.4 Problem statement

Climate change is increasingly recognised as a major threat to agricultural production, food security and rural livelihoods, particularly in countries where production systems depend heavily on climate-sensitive natural resources. Zimbabwe is already experiencing measurable changes in its climate rather than facing climate change solely as a future risk. National assessments indicate that temperatures increased by approximately 0.9°C between 1900 and 2018, with 1980 - 2018 identified as the warmest period in the country's instrumental record. The frequency of hotter days has increased, while rainfall patterns have become increasingly variable, including changes in the onset and cessation of the rainy season and the occurrence of dry spells (World Bank, 2019; Government of Zimbabwe (GoZ), 2021a). These changes, together with more frequent droughts, heatwaves and intense rainfall events, pose substantial risks to climate-dependent agricultural systems.

The implications are particularly important for livestock and dairy production because dairy cattle depend on adequate feed, water and suitable thermal conditions. Dairy cattle are susceptible to heat stress, which can reduce feed intake, milk yield and reproductive performance. At the same

time, drought and rainfall variability reduce pasture and forage availability and intensify seasonal shortages of feed and water. The World Bank (2020) identifies heat stress, reduced water availability and climate-related production shocks as important risks to Zimbabwe's livestock systems, while empirical evidence demonstrates that temperature-humidity indices can reduce milk yield and adversely affect dairy cattle performance (Kulaz & Ser, 2022). These risks are expected to intensify as Southern Africa continues to warm, with increasing heat extremes and agricultural drought risks projected under future climate scenarios (IPCC, 2022, 2023). Consequently, increasing milk production in Zimbabwe requires not only improvements in productivity but also production systems capable of withstanding increasing climatic stresses.

Zimbabwe's dairy sector continues to face structural challenges despite recent production recovery. National milk production reached approximately 260 million litres in 1991 but subsequently declined to about 37 million litres in 2009 (Chamboko & Mwakiwa, 2016). Although production has improved considerably, it remains below national requirements. Commercial raw milk production increased from 99.82 million litres in 2023 to 114.70 million litres in 2024, while the dairy herd increased from 60,398 to 65,659 animals (MLAFWRD, 2025). Production increased further to approximately 121.85 million litres in 2025 (MLAFWRD, 2026). Nevertheless, production remains below the estimated national requirement of approximately 130 million litres per year and substantially below the historical production peak. This persistent supply gap demonstrates that the dairy industry's recovery has not yet fully resolved Zimbabwe's structural milk-supply challenge.

The problem extends beyond milk production volumes to weaknesses in milk collection, quality management, market access and farmer incentives. The government's smallholder dairy development programme and Milk Collection Centres (MCCs) were established to integrate smallholder farmers into formal dairy markets by aggregating, testing, chilling and marketing milk. Although MCCs have provided an important institutional link between smallholder farmers and processors, their contribution to the formal milk market remains limited. Evidence indicates that smallholders contributed only about 5% of milk entering the national formal market despite the long-standing smallholder dairy development programme (Chamboko et al., 2017). Constraints affecting MCC performance include poor market access, inadequate technical and business management skills, weak governance and high operating costs associated with low milk volumes

(ZADF, 2019). Thus, the existence of collection infrastructure has not, by itself, resolved the underlying constraints to smallholder commercialisation.

Milk quality and supply reliability remain additional concerns. Poor milking hygiene, contaminated equipment and water, inadequate cooling, animal diseases and delays in transporting milk can contribute to quality deterioration and milk rejection. Research involving Zimbabwean dairy farmers identified transportation, inadequate storage and poor milking environments as important sources of milk-quality problems (Paraffin et al., 2018). Consequently, effective MCC systems require more than physical collection points; they also depend on reliable cooling and transport infrastructure, milk testing, farmer training, effective governance and transparent payment mechanisms. Where these complementary services are inadequate, farmers may continue to incur marketing losses and receive insufficient incentives to improve production and quality. The competitiveness of Zimbabwe's dairy sector is further constrained by high production costs, particularly feed costs. Feed has been identified as the dominant component of dairy production costs, accounting for more than 65% in some estimates and reaching as high as 85% on some farms (Commercial Farmers' Union of Zimbabwe (CFUZ), 2021).

Farmer incentives are further weakened by the high cost of producing milk in Zimbabwe. Feed is a major component of dairy production costs, and high feed, labour and electricity costs constrain the profitability and competitiveness of dairy farming. The International Finance Corporation (IFC, 2024) estimated Zimbabwe's dairy production cost at approximately US\$0.42 per litre, compared with an average producer price of approximately US\$0.43 per litre across the African countries included in its comparative assessment. The available official evidence from the Agricultural Marketing Authority (AMA) shows that milk producer prices in Zimbabwe ranged from US\$0.56 to US\$0.62 per litre in November 2024, depending on the processor (AMA, 2024). These relatively high farm-gate prices partly reflect the underlying cost pressures facing Zimbabwean dairy producers and have implications for the competitiveness and affordability of domestically produced dairy products. Farmers require remunerative milk prices to cover production costs and remain in production, while high domestic production costs can increase the prices of locally produced dairy products and weaken their competitiveness against imported products. This creates a difficult situation in which increasing milk production without improving

production efficiency and cost competitiveness may not provide a sustainable solution to the national milk deficit.

The challenges facing the dairy sector are particularly important for smallholder farmers, who contribute to household income, nutrition, asset accumulation and the supply of milk to formal and informal markets. However, smallholder dairy farmers operate under considerable resource and institutional constraints, including inadequate feed supplies, poor-quality feeds, high production costs, limited technical knowledge, inadequate veterinary services and weak institutional support (Ngongoni et al., 2006; Washaya & Chifamba, 2018; Mushunje, 2019). Climate change, therefore, acts as a risk multiplier by interacting with these existing constraints. Increasing temperatures, rainfall variability, drought and water scarcity can intensify feed shortages, reduce animal productivity and increase production risks for resource-constrained dairy households.

These circumstances create a strong justification for CSA in smallholder dairy production. CSA seeks to improve productivity and resilience while where possible, to reductions in greenhouse gas emissions. Relevant practices in dairy systems include improved pasture and forage management, fodder production, feed conservation, improved feeding regimes, water management technologies, heat-stress mitigation, improved animal health and breeding, agroforestry, renewable energy and improved manure management. Such practices can potentially address both immediate production constraints and longer-term climate risks. However, farmers' capacity to adopt them is likely to depend on access to finance, extension services, technical knowledge, productive resources and markets, as well as whether adoption generates sufficient economic returns. CSA adoption must therefore be understood within the wider socioeconomic, institutional and market environment in which smallholder farmers operate.

Despite growing recognition of CSA as a pathway for strengthening agricultural resilience, a critical empirical gap remains in Zimbabwe's smallholder dairy sector. Existing research has documented climate-related vulnerabilities and general constraints to dairy production, but there is limited empirical evidence on how smallholder dairy farmers perceive specific changes in temperature, rainfall and climate extremes; how these perceptions influence their adoption decisions; which adaptation and mitigation-based practices they employ; and which socioeconomic, institutional and farm-level factors determine adoption. There is also a limited distinction between short-term coping responses and longer-term CSA practices capable of

simultaneously improving productivity, resilience and environmental sustainability. This evidence gap limits the ability of policymakers, extension agencies, development organizations and dairy value-chain actors to design interventions that are technically appropriate, economically feasible and responsive to farmers' circumstances.

The problem is particularly relevant in Chipinge and Mutasa districts of Manicaland Province, where smallholder dairy farmers depend on climate-sensitive resources such as feed and water while operating under different socioeconomic, institutional and production conditions. Manicaland is an important contributor to Zimbabwe's commercial milk production, accounting for approximately 27% of the national total in 2024 (MLAFWRD, 2025). Differences in farmers' resources, dairy experience, access to finance and extension services, production systems and exposure to climatic stresses may therefore result in differences in climate-change perceptions and CSA adoption between the two districts. However, empirical evidence explaining these differences remains limited. Without such evidence, interventions intended to promote CSA adoption may fail to address the specific constraints preventing farmers from moving from short-term coping responses towards more sustainable adaptation and mitigation strategies.

Therefore, the central problem addressed by this study is the increasing exposure of smallholder dairy farmers to climate-related risks, including rising temperatures, rainfall variability, dry spells, drought and water scarcity within a dairy production system that remains below its historical production potential and national milk requirements. At the same time, there is insufficient empirical understanding of how farmers perceive these climate changes, how such perceptions translate into adaptation and mitigation decisions, and which socioeconomic, institutional and farm-level factors influence CSA adoption. This knowledge gap constrains the development of evidence-based strategies to build resilient, productive and environmentally sustainable smallholder dairy systems.

This study, therefore, examined the adoption of climate-smart agricultural practices among smallholder dairy farmers in the Chipinge and Mutasa districts of Manicaland Province, Zimbabwe. It assessed farmers' perceptions of climate change and their relationship to CSA adoption, identified adaptation and mitigation-based practices employed by farmers, and determined the socioeconomic, institutional and farm-level factors influencing adoption decisions. By linking climate risks with farmers' behavioural responses, production practices, and the broader

challenge of increasing milk supply, the study sought to generate empirical evidence to inform climate-smart dairy policies, extension programmes, financing mechanisms, and value-chain interventions aimed at strengthening the resilience, productivity, and sustainability of Zimbabwe's smallholder dairy sector.

1.5 Research aim and objectives

Research aim

To assess the adoption of CSA practices by smallholder dairy farmers in Chipinge and Mutasa Districts of Manicaland Province, Zimbabwe, with particular focus on farmers' perceptions of climate change, adaptation and mitigation practices, and the factors influencing CSA adoption.

Research objectives

The specific objectives were to:

1. Assess smallholder dairy farmers' perceptions of climate change in Zimbabwe.
2. Examine how climate change perceptions influence CSA adoption among smallholder dairy farmers.
3. Determine current adaptation and coping strategies employed by smallholder dairy farmers and the factors influencing their adoption.
4. Identify mitigation-based strategies adopted by smallholder dairy farmers and the factors influencing their adoption.
5. Analyse socio-economic, institutional, and farm-level factors influencing CSA adoption decisions.

1.6 Research questions

1. What is the smallholder dairy farmers' perception of climate change?
2. How do these perceptions influence the adoption of CSA practices?
3. What adaptation and coping strategies are employed by smallholder dairy farmers, and to what extent are they adopted?

4. What climate change mitigation-related strategies have smallholder dairy farmers adopted in Zimbabwe, and what factors influence their adoption?
5. Which socio-economic, institutional, and farm-level factors determine CSA adoption decisions?

1.7 Hypotheses

Main hypothesis

H₀: Smallholder dairy farmers in Chipinge and Mutasa Districts exhibit low adoption of CSA practices, and current farming systems contribute minimally to climate change adaptation, mitigation, and improvement of productivity and livelihoods.

Sub-hypotheses

1. Farmers are aware of climate change but hold heterogeneous perceptions regarding its impacts.
2. Farmers' perceptions of climate change significantly influence CSA adoption.
3. Adoption of adaptation-oriented CSA practices is low.
4. Adoption of mitigation-oriented CSA practices is low.
5. Multiple socio-economic, institutional, and farm-level factors influence CSA adoption decisions, with differential effects on uptake.

1.8 Justification of the study

Although interest in CSA has grown globally, empirical evidence on adoption in smallholder dairy systems in SSA remains limited. Despite the climate change challenges facing smallholder dairy farmers in southern Africa, research on their adoption of CSA practices remains very limited. The few existing studies in eastern and southern Africa have focused on a generalised approach to assessing the adoption of CSA practices, with no separation between adaptation- and mitigation-based practices (Arakelyan et al., 2017; Bosire et al., 2019; Odhiambo et al., 2019; Maindi et al., 2020). This study addresses this gap by examining adaptation- and mitigation-based CSA practices separately, advancing knowledge on how smallholder dairy farmers prioritise actions on climate

change adaptation and mitigation. The research hypothesised that adaptation-focused practices are more widely adopted than mitigation-based practices. The findings of the study will therefore inform evidence-based dairy sector strategies, climate-responsive Nationally Determined Contributions (NDCs), and Nationally Appropriate Mitigation Actions and policy interventions in Zimbabwe.

The study is particularly timely given ongoing dairy sector revitalisation efforts, including the European Union-funded Transforming Zimbabwe's Dairy Value Chain for the Future (TranZDVC) project. While such projects aim to increase milk production and efficiency of value chain efficiency, CSA integration remains limited, even as climate variability increasingly disrupts dairy farming systems.

In addition to providing a deeper understanding of the local-level smallholder dairy situation, the findings of the study contribute to the national, continental, and global body of knowledge on the impacts of climate change on smallholder farmers. In dealing with climate change, national governments have a responsibility to domesticate and implement the food systems transformation programme. This programme is driven by the Global Food Systems Transformation at the global level and by the Kampala Declaration 2026-2025 of the Comprehensive Africa Agriculture Development Programme (CAADP) at the continental level. The process of domesticating these higher programmes should cascade to the local level. It is at the local level that smallholder farmers carry out their dairy farming activities and experience the impacts of climate change. Study results will therefore contribute to food systems transformation by providing local-level evidence on the dairy situation. The national-level CSA programmes should target site-specific interventions that provide dairy farmers with immediate relief while gradually building their resilience. The findings of the baseline survey, which served as a diagnostic assessment of the current dairy situation in the study area, indicate strategic areas of intervention for adaptation and mitigation. Mitigation-based interventions in the dairy subsector have the potential to significantly contribute to GHG emissions reductions and can also assist governments and development partners to access climate finance.

Expected contributions:

- Practical value and potential to improve smallholder dairy farmers' productivity, incomes and overall sector development
- Provide evidence for dairy associations to influence policy, regulation and sector coordination
- Expand academic knowledge on CSA adoption, adaptation, and mitigation in dairy systems;
- Advanced knowledge, methodologies and future research directions in the smallholder dairy sector for academia and researchers
- Provide evidence for policy formulation and review by the GoZ and stakeholders;
- Inform climate-responsive dairy development strategies and NAMAs and NDCs;
- Guide donors and development partners in designing sustainable, context-specific interventions for smallholder dairy farmers.

1.9 Conceptual framework

The conceptual framework (Figure 1.1) positions smallholder dairy farmers at the centre of an interactive continuum of production, market, institutional, and knowledge-related processes shaping decision-making under climate variability.

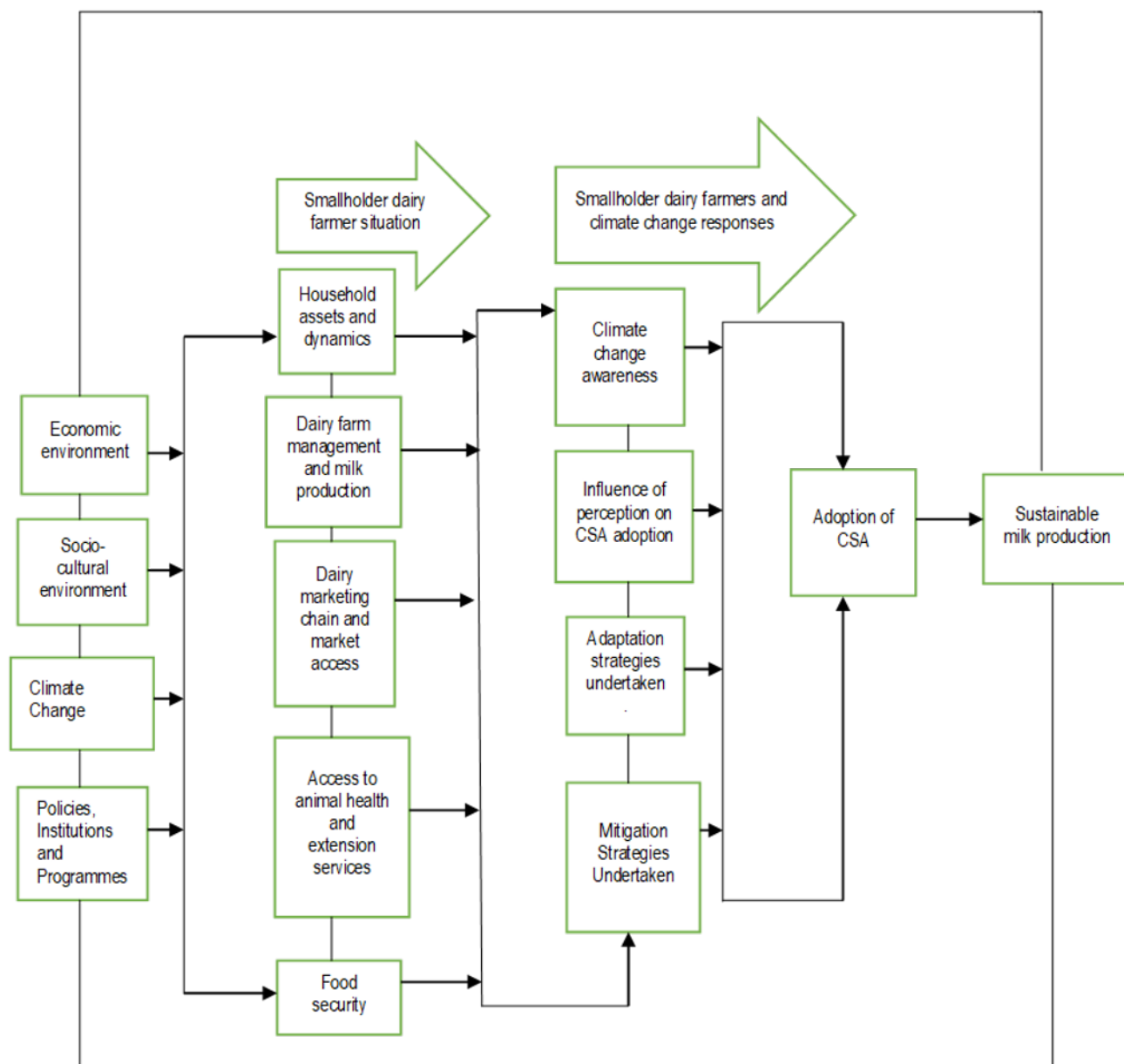


Figure 1.1: The interactive continuum of processes in which smallholder dairy farmers operate.

Source: Author's own framework

The dairy farmer situation and capacity to adopt CSA practices are determined by elements of the four main domains as follows:

- Socio-economic and institutional domain: Household characteristics, education, income, credit access, and exposure to policies and support programmes, shaping perceptions and adoption willingness.

- Production and resource domain: Herd size, feed availability, water access, landholding, and exposure to climate shocks, influencing the capacity to adopt adaptation and mitigation practice
- Market and value chain domain: Access to milk collection centres, market distance, price incentives, and value addition opportunities, affecting the economic feasibility of CSA adoption.
- Knowledge and innovation domain: Access to extension services, climate information, training, and improved technologies, determining CSA awareness and adoption intensity.

These domains are empirically operationalised in Chapter 4 through quantitative and qualitative indicators that link perceptions of climate change, adaptation and mitigation strategies, and adoption determinants. Chapter 5 synthesises these findings, highlighting interactions across domains and informing context-specific policy and development recommendations. The framework thus serves as both a theoretical guide and analytical tool, linking empirical observations to broader processes that influence sustainable smallholder dairy production.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Since the emergence of human civilisation, societies have continuously modified natural environments to improve livelihoods and living standards. While such transformations have supported socio-economic development, they have also accelerated the depletion of finite natural resources, contributing to widespread environmental degradation and intensifying climate change. Hence, climate change is now widely recognised as one of the most pressing global challenges, not least because of its profound and multidimensional implications for agriculture and natural resource-dependent livelihoods (Zwane, 2019; IPCC, 2023).

Globally, climate change has disrupted agricultural production systems through rising average temperatures, increased frequency and intensity of extreme weather events, and heightened variability and rainfall unpredictability. As noted by Pereira et al. (2020), these impacts are particularly acute in Africa, where agricultural systems remain predominantly rain-fed and therefore highly sensitive to climatic fluctuations. In SSA, climate vulnerability is further amplified by persistent structural constraints, including limited access to capital, weak physical and institutional infrastructure, constrained extension services, and inadequate access to climate and agricultural information. As a result, smallholder farmers, who constitute the majority of agricultural producers in the region, are disproportionately exposed to climate-related risks and shocks (Phiiri et al., 2016; Thornton et al., 2024).

The effects of climate change on agriculture operate through both direct and indirect economic and social pathways. At the farm level, climate-induced shocks reduce crop yields, livestock productivity, and farm income, thereby undermining household food security and resilience. The FAO (2022) adds that these impacts extend beyond the farm, reverberating across food value chains through market disruptions, price volatility, and reduced incentives for agricultural investment. Hence, agriculturally based economies must design transformative strategies responsive to current and anticipated climate change impacts. In response to declining incomes and heightened uncertainty, smallholder farmers often adopt short-term coping strategies, including the distress sale of productive assets such as livestock, land, and farm equipment. While such strategies may offer temporary relief, they frequently erode adaptive capacity and

compromise the long-term livelihood sustainability. The cumulative effects of these processes have far-reaching social consequences, limiting households' ability to invest in education, healthcare, and adequate nutrition (FAO, 2016).

Climate variability and long-term climate change pose significant threats to the sustainability of agriculture-based livelihoods, particularly in already vulnerable regions. Results from other studies show that erratic rainfall patterns, prolonged droughts, and rising temperatures are closely linked to heightened rural poverty, food insecurity, and environmentally induced migration (Falco et al., 2018; Thornton et al., 2018a). These challenges are unfolding against a backdrop of rapid population growth. Ababa (2023), as reported in the United Nations Department of Economic and Social Affairs (UN DESA) report, projects that the global population will exceed 9 billion by 2050. From these projections, the largest increases are expected in SSA and South Asia, regions that already face persistent food insecurity challenges. Fedoroff (2015) and Rockström et al. (2024) agree that meeting the food and nutritional needs of this expanding population will require transformative changes in agricultural production systems, underpinned by scientific, technological, and institutional innovations, and planetary boundary frameworks that maintain the stability of the earth system.

Agriculture occupies a dual position in relation to climate change; it is a significant contributor to GHG emissions and a sector highly vulnerable to climate impacts. The accumulation of GHGs in the atmosphere is largely driven by anthropogenic activities, including fossil fuel combustion, deforestation, and agricultural production. The Agriculture, Forestry, and Other Land Uses (AFOLU) systems account for a substantial share of global emissions, with livestock production being a major source of methane and nitrous oxide (IPCC, 2023). This dual role positions agriculture as a critical sector in the global climate change discourse, with potential for GHG emissions reduction. However, results from other studies show that mitigation measures in agricultural systems often entail trade-offs with food production in low-income rural livelihoods, particularly in smallholder-dominated contexts (Herrero et al., 2016; Searchinger et al., 2018). Balancing climate change adaptation, mitigation, and food security objectives, therefore, requires context-specific, socially inclusive approaches grounded in local realities. Totin et al. (2018) argue that, in addition to access to the knowledge, vulnerable groups such as smallholder farmers must also possess the capacity, resources, and incentives necessary to adopt new practices and adjust livelihood strategies. A nuanced understanding of local socio-economic, institutional, and

biophysical conditions is thus essential for the design and implementation of effective climate change response strategies in different farming systems.

The Sustainable Development Goals (SDGs) underscore the central role of agriculture in achieving global development objectives, particularly those related to poverty reduction, food security, good health and climate action (SDGs 1, 2, 3 and 13). Despite sustained efforts to transform agrifood systems globally, food insecurity remains pervasive. The FAO et al. (2024) estimate that more than 735 million people worldwide experience chronic hunger, the majority of whom reside in SSA and South Asia. Notably, a substantial proportion of food-insecure populations are smallholder farmers themselves, highlighting persistent structural inequities within global food systems (Niles & Salerno, 2018).

According to FAO (2013), global agricultural output is expected to increase by approximately 50% by 2050 to meet future food demand. In response, scholars and development practitioners have increasingly promoted sustainable intensification as a pathway for producing more food from existing agricultural land while minimising environmental harm (Zougmore et al., 2018; Rockström et al., 2024). This approach emphasises improving production efficiency by maximising output per unit of scarce resources while reducing environmental footprints. Pretty et al. (2018) differ and argue that conventional intensification pathways are associated with adverse environmental outcomes, including biodiversity loss, soil degradation, water pollution, and increased GHG emissions. These differences in opinion have intensified concerns about the feasibility of simultaneously ensuring food security and achieving rapid and substantial emission reductions under changing climatic conditions (Newell & Taylor, 2017).

Against this backdrop, CSA has emerged as an integrative approach that seeks to address food security, climate change adaptation, and mitigation objectives simultaneously. The increasing prominence of agriculture within global climate policy frameworks, particularly following the Conference of the Parties (COP22) in Marrakech, Morocco, in 2016, underpins the sector's strategic role in climate action (FAO, 2016). The CSA practices are now widely promoted as core components of sustainable agricultural development strategies, especially in climate-vulnerable regions such as SSA (Newell & Taylor, 2017). Understanding the determinants of CSA adoption among smallholder dairy farmers is therefore critical for enhancing climate resilience, reducing emissions, and improving livelihoods in contexts such as the Chipinge and Mutasa Districts of Zimbabwe.

2.2 The sustainable agriculture concept

Agriculture will continue to play a pivotal role in supplying food, fibre, and a range of ecosystem services to a rapidly growing global population (Velten et al., 2015; FAO, 2022). However, the intensification of agricultural production must increasingly occur in ways that minimise environmental degradation while remaining economically viable and socially acceptable. As a result, sustainability has become a central organising principle in contemporary debates on agricultural development.

Sustainable development was defined as development that meets present needs without compromising the ability of future generations to meet their own needs, while remaining environmentally sound, socially acceptable, and economically viable (WCED, 1987). This tripartite conceptualisation encompassing environmental, economic, and social dimensions has been widely adopted in the agricultural sustainability discourse (Latruffe et al., 2016; Czyżewski & Kryszak, 2022). Given agriculture's intensive reliance on land, water, biodiversity, and climatic stability, the environmental dimension of sustainability is particularly salient. Consequently, sustainable agriculture has emerged as a key pathway for enhancing productivity while safeguarding ecosystems and the natural resource base required for long-term food production (Rockström et al., 2017; Pretty et al., 2018).

Although definitions of sustainable agriculture vary across disciplines and contexts, they share several underlying principles. Reganold et al. (1990) defined sustainable agriculture as a farming system capable of producing sufficient quantities of high-quality food while conserving resources, remaining economically viable, and minimising environmental harm. Central to this definition is a reduced dependence on external inputs, such as synthetic fertilisers and pesticides, coupled with a greater reliance on on-farm renewable resources and ecological processes. Similarly, MacRae et al. (1989) conceptualised sustainable agriculture as the management of agroecosystems that integrate natural processes to conserve resources, minimise waste and environmental damage, enhance system resilience, and maintain stable food production to meet nutritional needs.

Building on these foundational perspectives, Khwidzhili and Worth (2016) articulated sustainable agriculture through five interrelated pillars: (i) sustaining and enhancing biological productivity; (ii) reducing production risks to improve food and livelihood security; (iii) protecting and preserving the quality of natural resources; (iv) ensuring the economic viability of agricultural

enterprises; and (v) promoting social acceptability and equity. These pillars form a continuum within which farmers, extension services, and supporting institutions interact to achieve sustainable agricultural outcomes, underscoring the multidimensional and systems-oriented nature of agricultural sustainability.

Across these conceptualisations, a unifying theme is the need to produce food and fibre in ways that minimise negative environmental impacts while maintaining resilience to shocks and stresses. This underscores the importance of working with, rather than against, natural processes in agricultural production systems. However, these imperatives raise critical questions regarding how agriculture can effectively respond to 21st-century challenges, including climate change, rapid population growth, biodiversity loss, soil degradation, and increasing water scarcity (the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), 2019; Singh & Singh, 2025).

Addressing these interconnected challenges necessitates a paradigm shift in agricultural development. Rockström et al. (2017) argue for a transformation of global food systems that simultaneously achieves two overarching objectives: meeting growing human food and nutrition requirements while operating within planetary boundaries to maintain a resilient and stable earth system. These objectives are often perceived as competing, as efforts to increase agricultural production may exacerbate environmental degradation, while strict environmental protection measures may constrain agricultural production growth. Nevertheless, the urgency of increasing food production remains evident, given that more than 800 million people worldwide continue to experience extreme poverty, hunger, and undernourishment (FAO et al., 2024).

Beyond food availability, sustainable agricultural development must also address nutrition security. In SSA, persistent hunger is frequently accompanied by widespread micronutrient deficiencies, contributing to malnutrition and an increasing burden of non-communicable diseases (Global Burden of Disease Study, 2017; Sathyamala, 2017). Despite producing the bulk of the region's food consumed, smallholder farmers remain disproportionately affected by poverty and food insecurity (Herrero et al., 2016a; Fanzo et al., 2017; Sibhatu & Qaim, 2017). This paradox underscores the importance of targeting smallholder agriculture as a strategic entry point for interventions to reduce hunger, improve nutrition outcomes, and enhance resilience under climate change.

Given this context, sustainable intensification has gained prominence as a dominant framework for addressing food security, poverty, and environmental sustainability simultaneously (Silva et al., 2021). Sustainable intensification is commonly defined as increasing agricultural output from existing land while reducing negative environmental impacts and enhancing ecosystem services (Pretty et al., 2012; Rockström et al., 2017). Central to this approach are efficient use of resources, reduced GHG emissions, and positive contributions to natural capital.

Sustainable intensification seeks to increase productivity while minimising or reversing ecological degradation, making it a critical component of sustainable agriculture development. Rockström et al. (2017) proposed several criteria and pathways for transitioning towards sustainable intensification, including diversification, improved soil and water management, enhanced nutrient cycling, and the integration of crop-livestock systems. These approaches align closely with the principles of climate-smart agriculture, particularly in enhancing resilience and adaptive capacity among smallholder farmers.

Empirical evidence suggests that sustainable intensification offers multiple options for improving farm performance and strengthening farmers' capacity to adapt to climate variability and change (Silva et al., 2021). Although some options may require substantial initial investment, integrated approaches often generate net benefits by offsetting climate-related productivity losses at relatively lower long-term costs (Rurinda, 2014; Masikati et al., 2015). Moreover, sustainable intensification has increasingly been linked to broader social sustainability outcomes, including gender equity and improved livelihoods for women in smallholder farming systems (Andersson Djurfeldt et al., 2019).

In SSA, smallholder-based intensification strategies have frequently drawn lessons from the Green Revolution experience in Asia, where productivity gains were achieved through technological innovation, price incentives, and strong state support (Andersson Djurfeldt et al., 2019). However, the direct transferability of this model to African contexts has been widely questioned due to concerns related to social inequality, environmental degradation, and institutional constraints (Petersen & Snapp, 2015; Silva et al., 2021). Consequently, productivity-oriented intensification strategies have not always explicitly incorporated environmental sustainability considerations. However, a distinction must be made between sustainable and conventional intensification. Sustainable intensification increases food production on the same land area while reducing environmental impacts and supporting biodiversity. On the other hand, conventional

intensification primarily targets yield maximization through high inputs such as synthetic fertilizers, pesticides and irrigation. The failures of the Asian Green Revolution can therefore be avoided by promoting sustainable intensification.

Despite the critiques, agriculture remains the largest human use of terrestrial land globally (Foley et al., 2011), and intensification continues to represent one of the most feasible pathways food production without further land expansion (Musumba et al., 2017). When pursued through a holistic and systems-oriented lens, agricultural intensification can improve the productivity of both crop and livestock systems while optimising the use of limited resources. Ultimately, however, the success of sustainable agricultural development depends not only on the design of policies and technologies but also on the extent to which proposed practices are adapted, adopted, and sustained by farmers. This means that the processes of implementing sustainable agriculture programmes must involve the farmers at the local level, particularly smallholder producers operating under diverse socio-economic and climatic conditions.

2.3 Why adaptation is necessary for sustainable agricultural development

Observed and projected changes in the global climate system provide compelling evidence that adaptation is indispensable for sustainable agricultural development. Climate records indicate a clear acceleration in global temperature increases over the past century, with warming rates intensifying since the late twentieth century. While global mean surface temperature increased at approximately 0.06°C per decade during the early twentieth century, the rate more than doubled after 1990, reflecting strengthened anthropogenic influences on the climate system (Dole et al., 2018; IPCC, 2023). The IPCC's assessments further indicate that most of the warmest years on record have occurred since 2000, underscoring the persistence and acceleration of global warming trends.

These climatic changes have already had measurable impacts on agricultural production systems worldwide. Empirical evidence shows that rising temperatures and altered precipitation patterns have contributed to yield declines in major staple crops such as maize and wheat across many low- and mid-latitude regions, while only limited productivity gains have been observed in some high-latitude areas (Thornton et al., 2018b; Ortiz-Bobea et al., 2021). Successive IPCC assessment reports have documented widespread physical impacts of climate change, including rising land

and ocean temperatures, increased frequency and intensity of extreme weather events, sea-level rise, and ocean acidification (FAO, 2016; IPCC, 2023). These changes are projected to intensify further, with significant implications for rainfall distribution, growing seasons, and agroecological suitability.

Agricultural systems, particularly those reliant on rain-fed production, are therefore highly vulnerable to climate variability and extremes. Rojas-Downing et al. (2017), supported by Thornton et al. (2018b), note that climate change affects both crop and livestock production through multiple interrelated pathways. These include heat stress, water scarcity, increased incidence of droughts and floods, shifts in pest and disease dynamics, and reduced availability of feed and fodder resources. Changes in rainfall timing, duration, and reliability further complicate farm-level decision-making and undermine production planning. The rainfall variability alongside other stressors necessitates deliberate context-specific adaptive responses to sustain productivity and livelihoods.

Africa is widely regarded as one of the region's most vulnerable to climate change impacts due to its geographic position within the tropics, high dependence on climate-sensitive agriculture, and generally limited adaptive capacity (Pereira et al., 2020; Niang et al., 2022). Weak human, institutional, social, and financial capacities in many African countries further constrain farmers' ability to cope with climatic shocks. As a result, climate change disproportionately affects rural livelihoods, food security, and nutrition across the continent.

The adverse impacts of climate change on crop and livestock systems directly translate into heightened risks for populations that are already food- and nutrition-insecure. Agriculture remains the primary livelihood source for a large proportion of the world's poor, particularly in rural areas. Despite progress in poverty reduction, hundreds of millions of people continue to live in extreme poverty, with the majority residing in rural and agriculture-dependent communities (United Nations, 2015; IFAD, 2021). The FAO (2022) notes that these climate-induced production losses exacerbate income instability, undermine food availability and access, and increase vulnerability to hunger and malnutrition for many people residing in rural communities.

Recognising these risks, the FAO (2016) identified key adaptation priorities for safeguarding food and nutrition security under climate change. These include: (i) raising awareness of climate change impacts on vulnerable populations and the urgency of action to protect progress towards hunger

eradication; (ii) improving understanding of the mechanisms through which climate change contributes to food insecurity across production, access, utilisation, and stability dimensions; and (iii) promoting the operationalisation of climate change adaptation within agriculture and food systems as a core development priority. Collectively, these priorities emphasise the need for coordinated and agile adaptation strategies that enhance resilience across agricultural value chains.

Climate change adaptation broadly refers to adjustments in natural and human systems in response to actual or expected climatic stimuli, intending to moderate harm or exploit beneficial opportunities (Aryal et al., 2019). Adaptation may occur autonomously or through planned interventions and can operate across multiple spatial and temporal scales.

The UNEP (2017) further conceptualised adaptation as processes through which societies adjust to climatic changes to minimise damages or leverage opportunities. Holzkämper (2017) distinguished between incremental (type A) adaptations, which are short-term, experience-based responses often undertaken at the farm level and transformative (type B) adaptations, which involve longer-term structural changes implemented through policies, institutions, and strategic planning.

In the agricultural sector, adaptation strategies encompass a wide range of actions operating at different levels. At the farm level, these include crop and livestock diversification, adjustments in planting and breeding calendars, improved water and soil management, and changes in herd composition (Aryal et al., 2019; Thornton et al., 2024). At the household level, income diversification, access to credit, and risk-sharing mechanisms enhance resilience to climate shocks. At broader scales, institutional and policy responses such as market reforms, extension services, subsidies, and investments in climate-resilient infrastructure play a critical role. Technological innovations, including climate-resilient crop varieties, improved livestock breeds, and water-saving technologies, further strengthen adaptive capacity. This multi-level framing is particularly relevant for smallholder systems, as it recognises the interconnected nature of adaptation across value chains.

Smallholder dairy farmers in southern Africa, including Zimbabwe, are particularly exposed to climate-induced stressors and therefore face an urgent need to adapt. SNV (2016) reported that recurrent droughts, rising temperatures, and declining pasture availability have intensified feed shortages and increased reliance on commercially available stock feed, which remains largely

unaffordable and inaccessible to many rural farmers. Communal grazing systems and shared water points further increase exposure to disease outbreaks, undermining herd productivity and survival. These challenges are closely linked to climate variability and change, reinforcing the necessity of targeted and context-specific adaptation interventions.

Given these challenges, climate-smart agriculture practices designed and implemented with a clear understanding of farmers' socio-economic and biophysical conditions offer viable pathways for the enhancement of resilience. Adaptation-focused CSA practices, such as improved fodder production, water harvesting, heat stress management, and integrated crop-livestock systems, can enable smallholder dairy enterprises to remain productive and viable under increasingly variable climatic conditions. Adaptation, therefore, is a critically important intervention which provides immediate relief to a dairy subsector already experiencing the severe impacts of climate change. It also contributes to both the sustainability of the subsector and ultimately to sustainable agricultural development.

2.4 Emerging climate change adaptation practices in agriculture

There is increasing global recognition of the need to address both the causes and consequences of climate change through decisive and coordinated action (Fankhauser, 2017; IPCC, 2023). This dual challenge requires substantial reductions in GHG emissions alongside scaled-up investments in climate resilience, particularly within climate-sensitive sectors such as agriculture. At the farm level, adaptation practices have therefore emerged as essential responses to increasing climatic variability and extremes, aimed at safeguarding agricultural productivity, sustaining livelihoods, and enhancing food security.

A wide range of agricultural adaptation practices has been documented across diverse agro-ecological contexts. Commonly adopted measures include multiple cropping, diversification of farming systems and products, the use of improved crop varieties and livestock breeds tolerant to climatic stresses, and flexible management strategies that enable farmers to respond to weather and price-related shocks (Rurinda et al., 2015; Arakelyane 2017). These practices enhance resilience by spreading risk, improving resource-use efficiency, and stabilising farm income under conditions of heightened uncertainty. Conceptually, adaptation responses are often categorised as incremental or transformational. Incremental adaptation involves adjustments to existing

technologies and management practices while largely maintaining current production systems. In contrast, transformational adaptation entails more fundamental shifts in production systems, management approaches, or livelihood strategies in response to severe or persistent climate stressors (Kates et al., 2012).

In southern Africa and many other regions, adaptation research and interventions have historically focused more heavily on crop production than on livestock systems, despite the latter's central role in rural livelihoods, income generation, and nutrition (Zougmore et al., 2018; Thornton et al., 2024). Livestock adaptation options are inherently context-specific, shaped by production systems, agro-ecological conditions, prevailing climatic hazards, and household socio-economic circumstances. Rojas-Downing et al. (2017) noted adaptive strategies for livestock producers, including adjustments in herd composition, improved feeding and watering practices, enhanced animal health management, adoption of climate-resilient breeds, and improved housing and shelter to reduce heat stress. As indicated, adoption of these strategies depends on available at the household-level resources and local institutional support systems.

Although mitigation and adaptation are conceptually distinct, many livestock management practices generate co-benefits by addressing both objectives simultaneously. Mitigation-oriented livestock practices typically involve technical and management interventions to reduce GHG emissions per unit of output, such as improved feeding regimes, balanced rations, enhanced feed quality, and efficient manure management (Gerber et al., 2013; Zougmore et al., 2018). When embedded within integrated farm management strategies, these practices can also enhance productivity and system resilience, thereby contributing to adaptation outcomes.

Integrated crop-livestock systems are widely regarded as one of the most promising adaptation pathways for smallholder farmers. Herrero et al. (2023) posit that such systems enhance resilience by creating functional synergies among enterprises, whereby outputs from one component serve as inputs for another. Crop residues and cultivated forages provide livestock feed, while animal manure contributes organic nutrients that improve soil fertility and water-holding capacity. In addition, the use of animal draught power can support land preparation, reducing reliance on external energy inputs. These interactions increase overall system efficiency, reduce waste, and strengthen adaptive capacity under variable climatic conditions.

Within smallholder dairy systems, climate change poses particularly acute challenges for commonly used dairy breeds, especially under conditions of rising temperatures and recurrent droughts (Tadesse & Dereje, 2018). Elevated ambient temperatures increase the incidence of heat stress, which adversely affects milk yield, reproductive performance, feed intake, and animal health in dairy cattle. At the same time, recurrent droughts contribute to feed and water shortages, land degradation, and declining pasture quality, thereby increasing livestock susceptibility to disease outbreaks and mortality. These climate-related challenges are particularly severe in smallholder dairy systems in developing countries, where farmers depend largely on rain-fed forage production and natural grazing resources (Polsky & von Keyserlingk, 2017; Nzeyimana et al., 2023). Consequently, smallholder dairy farmers have increasingly adopted a range of adaptation practices, including supplementary feeding, fodder conservation, drought-tolerant forage production, water harvesting, and improved livestock management, to enhance resilience and sustain dairy productivity under changing climatic conditions (Thornton et al., 2022b; Nzeyimana et al., 2023). In Zimbabwe, recurrent droughts associated with climate variability have resulted in severe feed and water shortages, reduced milk production, and increased pressure on smallholder dairy farming systems, necessitating the adoption of climate-smart adaptation strategies (GoZ, 2021a). According to Thornton et al. (2024), these strategies include improved pasture and rangeland management, integration of dairy and crop production, planting of forage trees and drought-tolerant fodder crops, adjustment of production calendars, and conservation of natural resources and ecosystems. These are wide-ranging, and their adoption shows that the need for climate change adaptation is very evident among dairy farming communities.

These adaptation practices typically require changes at both production and management levels and are often informed by farmers' experiential knowledge of local climatic conditions. However, their effectiveness and long-term sustainability depend heavily on enabling institutional environments. Governments and development partners play a critical role in identifying viable adaptation options, reducing barriers to adoption, and strengthening the drivers of voluntary adaptation among smallholder farmers (Aziz et al., 2024). Farmers are more likely to adopt practices that address immediate constraints while also delivering tangible short-term benefits alongside longer-term resilience gains. According to Onyango and Nzenya (2023), impact evaluations are necessary to assess the effects of climate adaptation strategies adopted by smallholder farmers. Accordingly, a thorough understanding of local socio-economic,

institutional, and biophysical contexts is essential for the design and implementation of effective climate change adaptation programmes in smallholder agricultural systems.

2.5 Farmers' perceptions of climate change

Farmers rely heavily on experiential knowledge derived from long-term observation of rainfall patterns, temperature trends, and other environmental signals to inform farm management decisions. Even where such changes are not explicitly framed as “climate change,” these observations shape how farmers interpret climate-related risks and develop coping and adaptation strategies. Effective climate risk management, therefore, requires not only biophysical assessments of climatic hazards but also a nuanced understanding of how risks are perceived, interpreted, and prioritised by those directly affected (Masson-Delmotte et al., 2018; Soubry et al., 2021).

Risk perception plays a central role in shaping both adaptation and mitigation responses. Masson-Delmotte et al. (2018) also noted that local and indigenous knowledge is a critical component of climate adaptation frameworks, interacting with scientific information to influence decision-making processes at the farm level. Farmers' experiential knowledge, while often informal and highly context-specific, provides valuable insights into local climatic trends, resource dynamics, and system vulnerabilities. Increasingly, such knowledge is acknowledged as an important input into regional and national adaptation planning, particularly in data-scarce environments common across SSA (Soubry, 2021).

Despite its value, farmers' knowledge has historically been marginalised and categorised as informal, resulting in its limited integration into the design of climate adaptation interventions. The disconnection between scientific knowledge systems and farmers' lived experiences can undermine the relevance, acceptability, and effectiveness of proposed adaptation strategies. As noted by FAO (2016), awareness of climate change does not automatically translate into adaptive action. Farmers may recognise climatic changes yet remain constrained by limited resources, institutional barriers, risk aversion, or competing livelihood priorities. Consequently, interventions aimed at promoting the adoption of climate-smart innovations must be grounded in an understanding of farmers' knowledge systems, capacities, and socio-economic realities (Soubry et al., 2020).

Farmers' perceptions of climate change and associated uncertainties are particularly significant for several reasons. Firstly, climate-related experiences are shared and reinforced through community networks and the formation of bodies of knowledge. This knowledge, though often undocumented, contributes to the improvement of community social capital. It helps community members to collectively identify emerging trends, for instance, under persistent water shortages, communities can develop socially embedded coping strategies (Ricart et al., 2019). Secondly, awareness of climate risks, perceived threats, and observed impacts on farming enterprises enhances farmers' motivation to engage in adaptation measures (Nyang'au et al., 2021). Farmers, therefore, constitute a key constituency for generating context-specific knowledge on climate impacts across agricultural and food systems and for co-designing effective adaptation and mitigation strategies. Hence, this study sought to gain a deeper understanding of Chipinge and Mutasa Districts' context-specific dairy farmers' knowledge of climate change and their perception of how it is affecting their farming operations.

Inclusive adaptation planning that actively involves farmers can strengthen institutional linkages between communities, extension services, and policy actors. Farmers operate within multi-actor networks that bridge formal and informal knowledge systems, positioning them as essential intermediaries in translating policy objectives into locally appropriate practices (Šūmane et al., 2018). Soubry et al. (2020) therefore argue that incorporating farmers' perceptions and experiential knowledge facilitates better alignment between top-down climate policies and bottom-up adaptive responses, thereby enhancing the legitimacy and effectiveness of interventions.

Farmers and farm workers are also among the first to experience climate-related shocks and stresses, making them particularly vulnerable to climate change impacts (Hallegatte, 2016; FAO, 2017). Thus, the farmers' embodied knowledge provides critical insights into local vulnerabilities, opportunities, and trade-offs that may not be readily apparent to higher-level institutions. For adaptation strategies to be effective and equitable, the livelihoods, losses, and priorities of primary food producers must be placed at the centre of climate action planning.

In SSA, persistent gaps in access to climate information and enduring knowledge asymmetries within rural farming communities remain major barriers to adaptation (Vaughan et al., 2019). Limited access to timely, credible, and locally relevant climate information can distort farmers' perceptions of climate risks and reduce the adoption of appropriate adaptive technologies (Arakelyan, 2017). A substantial body of empirical research across Africa has consistently

demonstrated that farmers' perceptions of climate change strongly influence their adaptation choices and strategies (Bryan et al., 2009; Osbahr et al., 2011; Rao et al., 2011; Silvestri et al., 2012; Zeleke et al., 2023).

Beyond awareness, farmers' self-identity, environmental values, and perceptions of risk play an important role in shaping responses to climate change. Empirical evidence shows that farmers who perceive greater climate risks and identify strongly with environmental stewardship are more likely to adopt sustainable practices (Yazdanpanah et al., 2014). These behavioural and socio-psychological dimensions underscore the importance of integrating perception-based variables into analyses of CSA adoption. This is particularly relevant in smallholder dairy systems where decisions are shaped by livelihood security concerns, cultural norms, and resource constraints.

2.6 Climate-smart agriculture and smallholder agriculture

Projections of global climate change indicate continued warming, with profound implications for agricultural productivity, particularly in climate-sensitive regions (Chandra et al., 2018; IPCC, 2023). In response to these challenges, CSA has emerged as an integrative approach that transforms agricultural systems to enhance food security while simultaneously addressing adaptation and mitigation objectives. Rather than prescribing a fixed set of technologies, CSA is conceptualised as a flexible framework that prioritises site-specific assessments of climate risks, local food security challenges, and contextually appropriate response strategies.

The CSA seeks to achieve three interrelated objectives: first, to sustainably increase agricultural productivity and farm incomes; second, to strengthen resilience and adaptive capacity to climate variability; and third, to reduce or remove GHG emissions where feasible (FAO, 2013; Torquebiau et al., 2018; Ariom et al., 2022). Given the diversity of agro-ecological, socio-economic, and institutional contexts in which smallholder farmers operate, CSA does not offer universal solutions. Instead, it emphasises locally tailored practices and governance arrangements that balance trade-offs and synergies among these three pillars.

Torquebiau et al. (2018) note that implementing CSA requires complex and potentially transformative changes in production practices, farm management, and institutional structures. Successful implementation depends on robust knowledge systems that can identify feasible CSA options, evaluate trade-offs, and support informed decision-making across multiple levels. Yet,

substantial knowledge gaps remain affecting the effectiveness, scalability, and long-term impacts of CSA interventions, particularly within smallholder systems (Rosenstock et al., 2016; Silva et al., 2021).

Despite its prominence in policy and development discourse, CSA has attracted critique. Some scholars argue that it functions more as a political framing tool, situating agriculture within international climate negotiations rather than providing a clearly defined scientific framework (Chandra et al., 2018). Others note that CSA's broad framing allows for multiple interpretations, supporting both agroecological and input-intensive pathways (Taylor, 2018). These critiques raise important questions about how CSA is operationalised in practice and whether it sufficiently reflects farmers' realities and priorities (Torquebiau et al., 2018; Ariom et al., 2022).

A gap in the literature is the limited attention to microeconomic and behavioural dimensions of adoption. Smallholder farmers are often treated as passive recipients of CSA interventions, yet evidence shows that adoption decisions are shaped by risk perceptions, resource access, labour constraints, institutional support, market opportunities, and immediate livelihood needs (Campbell et al., 2014; Aziz et al., 2024). Governance, financing, and information gaps further constrain CSA implementation. In addition, the lack of empirical evidence on real-world smallholder conditions reduces the reliability of decision-support tools, impeding scaling (Rosenstock et al., 2016). Africa should prioritise climate change in government agendas and implement adaptation strategies based on scientific research to increase acceptance of CSA (Ariom et al., 2022).

Importantly, many smallholder farmers are already engaging with CSA principles, sometimes implicitly, through practices such as farm diversification, soil and water conservation, and integrated crop-livestock systems. These existing practices highlight critical questions about the extent, determinants, and uneven adoption of CSA, which provide the foundation for this study focused on smallholder dairy farmers in Chipinge and Mutasa Districts of Zimbabwe.

2.7 Climate-smart agriculture in dairy production systems

Dairy products are central to global food and nutrition security due to their high nutrient density and contribution to balanced diets. Increasing demand for animal-source foods has positioned the dairy sector as a strategic driver of income generation and poverty reduction, particularly in developing regions (FAO, 2018; IPCC, 2023). Yet, climate change has heightened the vulnerability of dairy systems, exposing them to heat stress, droughts, and extreme weather events.

Heat stress and climatic extremes are among the most pressing challenges for dairy farmers in tropical and subtropical regions (Thornton & Herrero, 2015). These challenges are compounded by structural constraints, including low productivity, feed shortages, disease pressures, limited access to finance, and land degradation (Maindi et al., 2020; FAO, 2022). Building resilience in dairy systems, therefore, requires the targeted adoption of CSA practices appropriate to local conditions.

The CSA in dairy production is generally divided into adaptation and mitigation strategies. Adaptation measures aim to reduce vulnerability to climate variability, whereas mitigation focuses on lowering GHG emissions from dairy activities. Depending on their nature and goals, adaptation treatments can be carried out over short-, medium-, or long-term timeframes.

A widely implemented adaptation strategy in SSA is the promotion and conservation of indigenous livestock breeds, which are typically more resilient to heat stress and disease, and more tolerant of low-quality feed than exotic breeds (Mapiye et al., 2019; Ariom et al., 2022). These breeds, however, produce lower milk yields than most exotic breeds. Empirical evidence from other regions, such as India and Nepal, highlights that climate awareness, extension support, institutional backing, and collective action are critical enablers of effective adaptation (Kant et al., 2017). Mitigation strategies in dairy systems primarily target enteric fermentation, manure management, feed production, and energy use (FAO & GDP, 2018; Grossi et al., 2019). Enhancing feed quality, herd health, and manure management can substantially reduce per-unit milk emissions while simultaneously improving productivity (Hristov, 2024). However, adoption of mitigation CSA practices is often limited by financial, technical, and institutional barriers. For this study, adaptation and mitigation practices documented in the literature informed the selection of outcome variables used for analysing CSA adoption among smallholder dairy farmers in the study area.

This ensured conceptual alignment between the literature review and the empirical analysis presented in subsequent chapters.

2.8 Factors influencing the adoption of climate-smart agriculture practices by dairy farmers

Dairy farming operates within complex socio-economic, institutional, biophysical, and contextual environments, all of which shape farmers' behaviour, decision-making, and ability to adopt innovations. Adopting CSA practices is therefore not simply a technical choice. It reflects a dynamic interplay of factors that create both opportunities and constraints. Understanding these factors is essential for explaining observed adoption patterns and for designing effective policies and interventions.

Apata (2011a) categorised the determinants of climate change adaptation into four domains: socio-economic, natural, institutional, and physical factors. These remain relevant and continue to inform contemporary CSA adoption studies. Socio-economic factors include household demographics, assets, and livelihood strategies, which affect access to resources, risk tolerance, labour availability, and the capacity to absorb shocks. Studies focusing on dairy systems have consistently emphasised the importance of socio-demographic characteristics. For instance, Odhiambo et al. (2019) and Huyer et al. (2024) found that gender, age, education, household size, and dairy farming experience significantly influenced adaptation choices among Kenyan dairy farmers. Education and experience increase access to information and experiential knowledge, while gender affects access to resources, extension services, and decision-making power. Similar patterns are observed across SSA, with education, asset ownership, and labour availability consistently driving CSA adoption (Bryan et al., 2013; Owino et al., 2020a; FAO, 2022).

Institutional factors such as access to extension services, credit, farmer organizations, climate and market information and the broader policy environment also play a critical role. Apata (2011b) and Kadzere (2018) agree on the importance of extension services as an instrument for disseminating knowledge, enhancing skills, and reducing uncertainties associated with new technologies. The extension services should, however, be appropriate and specific to the local context. Credit access facilitates investment in climate-resilient technologies, improved breeds, and infrastructure. Accordingly, farmers with stronger institutional support tend to adopt CSA practices more widely and intensively (Teklewold et al., 2013; Bell et al., 2018).

Natural and biophysical factors shape the adoption by influencing exposure to climate risks and the technical feasibility of interventions. Local climate conditions, rainfall variability, temperature extremes, and agro-ecological characteristics affect perceived vulnerability and urgency to adapt (Ericksen & Crane, 2018; Dodman et al., 2022). In dairy systems, stressors such as heat, drought-induced feed shortages, and water scarcity directly impact animal health and productivity. Farm-level characteristics, including land size, soil quality, and access to water, also determine the technical and economic viability of CSA practices (Obayelu et al., 2017; FAO, 2022).

Other studies highlight additional factors, including technology-specific attributes (complexity, compatibility, relative advantage), social capital, participation in farmer networks, cultural norms, and intra-household decision-making. Obayelu et al. (2017) and Ericksen and Crane (2018) classify adoption barriers into biophysical, informational, market-related, and organizational categories, illustrating the interrelated nature of factors influencing CSA uptake.

Drawing on these insights, this study adopted a multi-dimensional framework encompassing socio-economic, institutional, biophysical, and farm-specific factors to examine CSA adoption among the study group. This framework guided the selection of explanatory variables and hypotheses formulation for both adaptation- and mitigation-based CSA practices, ensuring coherence among the literature review, conceptual framework, and empirical analysis.

2.9 Agriculture and the dairy sector in Zimbabwe

Agriculture remains a cornerstone of Zimbabwe's economy and rural livelihoods, contributing significantly to national food security, employment creation, and household incomes. The sector supports most of the rural population, with smallholder farmers accounting for over 70% of agricultural producers. Within this broader agricultural landscape, livestock production plays a critical role, particularly in semi-arid and high-potential agro-ecological regions where mixed crop-livestock systems dominate. Among livestock subsectors, dairy production occupies a strategic position due to its contribution to nutrition, regular household income, and value chain development.

Zimbabwe's livestock subsector, which includes beef, dairy, small ruminants, pigs, poultry, apiculture, and aquaculture, contributes approximately 35% of agricultural GDP (GoZ, 2022). The national cattle herd of approximately 5.5 million head is predominantly in communal areas

characterised by semi-arid conditions, erratic rainfall, and declining grazing quality (World Bank, 2019b; Tui et al., 2022). Cattle provide milk, meat, hides, manure, draught power, and act as a store of wealth and a risk buffer (World Bank, 2019b; FAO, 2022). Despite their importance, livestock productivity remains low in communal areas, and herd sizes have declined due to droughts, disease outbreaks, and limited resources (ZimVAC, 2022; Svinurai et al., 2025). Constraints include poor husbandry practices, limited access to quality feed, high disease prevalence, weak extension support, inadequate breeding programmes, and low off-take rates (World Bank, 2019b; FAO, 2022; Svinurai et al., 2025). Nonetheless, evidence shows that productivity gains can improve household food security, income stability, and resilience to climate shocks.

Zimbabwe's dairy sector has undergone substantial structural changes over the past three decades. During the early 1990s, national milk production exceeded 250 million litres per annum, largely driven by large-scale commercial dairy farms. However, economic instability, land reform processes, recurrent droughts, and rising input costs led to a sharp decline in herd sizes and milk output during the late 1990s and early 2000s. Since the mid-2010s, the sector has shown a gradual recovery, supported by policy interventions, donor support, private-sector investment, and increasing participation by smallholder dairy farmers.

Recent national statistics indicate a steady improvement in both dairy herd size and milk production. The national dairy herd increased from approximately 60,398 cows in 2023 to about 65,659 in 2024, reflecting ongoing restocking efforts and improved access to dairy support programmes (ZimStat, 2025). Correspondingly, national milk production rose from about 100 million litres in 2023 to approximately 114.7 million litres in 2024, with commercial milk output exceeding 120 million litres in 2025. This increase represents the highest production level recorded over the past two decades (ZimStat, 2025). Despite this positive trend, current production remains well below historical peak levels, indicating persistent productivity constraints within the sector.

Evidence indicates that per capita milk consumption in Zimbabwe remains very low despite notable growth in national production. According to sector data, per capita milk consumption is reportedly under 10 litres per person per year. This figure is well below both historical regional benchmarks and the World Health Organization's recommended level of 45 litres annually for low- to middle-income countries (Zimbabwe Association of Dairy Farmers, as cited in Jeke, 2025). This low consumption reflects wide disparities in dietary uptake, with higher-income households

consuming substantially more dairy products than lower-income groups (Jeke, 2025). Over the past decade, raw milk production has risen from approximately 66 million litres in 2017 to nearly 115 million litres in 2024 (Zimbabwe Farmers Union, 2025). Nevertheless, even as domestic output increases, national demand (estimated at 131 million litres annually) continues to outpace supply, resulting in reliance on imports, elevated prices, and constrained household dairy budgets (Dairy Business Middle East & Africa, 2024). This structural gap between production and consumption underlines significant challenges in translating sector growth into widespread nutritional impact among the Zimbabwean population.

The structure of the dairy industry has also shifted markedly, with smallholder and medium-scale farmers now contributing an increasing share of national milk output. Smallholder dairy production is typically characterised by small herd sizes, limited access to improved breeds, dependence on rain-fed feed resources, and high vulnerability to climate variability. These characteristics make the sector particularly sensitive to climate change, feed availability, water scarcity, heat stress, and disease prevalence. Consequently, enhancing resilience through CSA practices has become increasingly important for sustaining dairy productivity and livelihoods.

At the sub-national level, Manicaland Province is recognised as one of Zimbabwe's key dairy-producing regions. The province accounted for approximately 27% of national milk output in 2024, reflecting its relatively favourable climatic conditions, availability of grazing land, and established dairy value chains (ZimStat, 2025). Dairy production in Manicaland is undertaken across a range of systems, including smallholder mixed-farming systems and commercial operations, with milk supplied to both formal processors and informal markets.

Chipinga and Mutasa Districts, which are part of Manicaland Province, are notable for their engagement in dairy farming, particularly among smallholder producers. Chipinga District benefits from comparatively high rainfall and diverse agro-ecological conditions, which support pasture production and mixed farming systems integrating dairy cattle with crop enterprises. Mutasa District similarly exhibits a mix of small-scale and commercial dairy activities, with production intensity varying across wards depending on access to land, water, veterinary services, and markets (Food and Nutrition Council, 2023). While national statistical reports do not routinely disaggregate milk production data at the district level, the presence of active dairy enterprises in both districts underscores their contribution to provincial milk output and rural livelihoods.

However, dairy production in Chipinge and Mutasa Districts faces multiple challenges, including climate variability, recurrent droughts, feed shortages during dry seasons, limited access to affordable inputs, and inadequate infrastructure for milk handling and marketing. These constraints disproportionately affect smallholder dairy farmers, whose adaptive capacity is often limited by financial, technical, and institutional factors. As climate change intensifies, these challenges are expected to become more pronounced, threatening the sustainability of dairy-based livelihoods unless appropriate adaptation and mitigation strategies are adopted.

The GoZ, in partnership with development organizations, has implemented initiatives to revitalise the dairy sector, especially for smallholder farmers. Interventions focus on capacity building, infrastructure, input access, and market linkages, including the (TranZDVC) project (see chapter 1). However, persistent climate variability, recurrent droughts, and systemic resource constraints continue to limit productivity gains. This context underscores the importance of CSA for enhancing resilience, sustainability, and productivity in Zimbabwe's smallholder dairy systems.

In light of this, CSA adoption and promotion in the dairy industry have emerged as a crucial policy and development goal. Enhancing forage production, conserving feed, gathering water, managing heat stress, and integrating crop-livestock systems are some practices that can boost productivity and increase resistance to climate shocks. Analysing smallholder farmers' perceptions of climate change and their adoption of CSA techniques requires an understanding of the current state of the dairy industry, especially at the national and district levels.

2.10 Synthesis of literature

Empirical studies conducted in SSA consistently show that smallholder farmers interpret climate change through observable changes such as declining rainfall reliability, increasing temperatures, delayed onset of rains, prolonged mid-season dry spells, and increased drought frequency (Bryan et al., 2009; McSweeney et al., 2010; Kalungu et al., 2013; Zwane, 2019). Across the literature, farmers' perceptions of climate change are widely reported to be shaped more by lived experiences than by scientific definitions of climate variability and long-term climate change. These perceptions are consistent with global scientific evidence that climate change is increasingly manifesting through intensified climate variability, extreme weather events, and rainfall unpredictability, particularly in climate-sensitive agricultural regions (IPCC, 2018, 2023).

While it is generally agreed that farmers perceive climate change as a major threat, the depth of farmers' understanding differs across contexts. Some studies argue that farmers demonstrate high awareness of climate change based on long-term observation and experiential learning (Kristjanson et al., 2012; Silvestri et al., 2012), while others are of the view that farmers often interpret climate change as temporary seasonal irregularities rather than a long-term structural shift (Osbahr et al., 2011; Ricart et al., 2023). This distinction is critical because farmers who perceive climatic variability as temporary may be less likely to invest in long-term adaptation strategies such as pasture rehabilitation, improved breeding systems, or water infrastructure, and may instead prioritize short-term coping responses (Rao et al., 2011; Morton et al., 2017).

Within livestock-based systems, perceptions of climate change impacts are often more immediate and pronounced than in crop-only systems. This is because dairy farming depends heavily on climate-sensitive resources such as water, forage, and the overall health status of the cows (Herrero et al., 2016a; FAO, 2018). Climate stress affects livestock production through heat stress, reduced feed intake, reduced fertility, and increased disease prevalence, which ultimately reduce milk productivity and profitability (Gerber et al., 2013; Knapp et al., 2014; FAO & GDP, 2018). Consequently, dairy farmers often associate climate change with declining pasture conditions, increased water shortages, and reduced livestock performance (Kadzere, 2018; Bosire et al., 2019; Maindi et al., 2020).

Despite relatively high levels of awareness of climate change among dairy farmers, their perception of climate change does not automatically translate into the adoption of CSA practices. Although farmers may recognize climate risks and the need to respond, their decisions to adapt are shaped by socio-economic and institutional conditions (Apata, 2011a; Obayelu et al., 2017; Ericksen & Crane, 2018). Studies consistently identify education, farming experience, and access to extension services as important determinants influencing both climate change perceptions and adoption behaviour (Bryan et al., 2009; Kalungu et al., 2013; Odhiambo et al., 2019). Farmers with higher education levels and stronger exposure to extension services are more likely to interpret climatic changes as part of broader climate change processes and are therefore more likely to adopt improved practices (Yazdanpanah et al., 2014). In contrast, limited access to extension and climate advisory services constrains understanding of climate dynamics and weakens farmers' capacity to plan proactively (McSweeney et al., 2010; FAO, 2016; Šūmane et al., 2018).

The age of farmers also influences both perception and adaptation to climate change. Younger farmers tend to rely more on external information sources, including extension services and weather advisories, while older farmers often rely on accumulated experiential knowledge (Odhiambo et al., 2019). However, the literature remains inconclusive on whether older farmers are more adaptive due to experience or less adaptive due to limited willingness and capacity to adopt innovations, highlighting the need for context-specific studies (Bryan et al., 2009; Kristjanson et al., 2012).

Evidence from adaptation studies indicates that smallholder dairy farmers employ a range of coping and adaptation strategies to respond to climate stress (FAO, 2016; Bosire et al., 2019; IPCC, 2023). Commonly reported responses include reducing herd sizes, purchasing supplementary feeds, shifting grazing patterns, adjusting breeding cycles, and implementing water-harvesting measures. These strategies are, however, often reactive rather than transformative. Similar findings have been reported across SSA, where drought-induced feed shortages and water scarcity often force farmers to destock herds and increase feed purchasing (Hallegatte, 2016; Herrero et al., 2016a; Thornton et al., 2018a). These types of coping mechanisms may stabilize livelihoods in the short term but undermine herd growth and productivity in the long term.

The determinants of adaptation in dairy systems are largely linked to household income, availability of inputs, institutional support and market integration infrastructure (Apata, 2011a; Odhiambo et al., 2019; Musafiri et al., 2022). Farmers with access to credit and market opportunities are more likely to adopt improved feeding systems, pasture development, improved breeds, and animal housing. However, limited income and weak rural financial systems often lead farmers to adopt low-cost coping mechanisms. These mechanisms, which may include herd reduction or reduced veterinary care, eventually worsen productivity decline and vulnerability over time (FAO, 2016; Hallegatte, 2016). This implies that adaptation is shaped not only by perception but also by broader structural limitations, including poverty, limited infrastructure, and weak institutional support (World Bank, 2019).

Although adaptation strategies are widely documented, fewer studies systematically assess their effectiveness and the sustainability of these strategies in improving resilience and productivity in smallholder dairy systems. Much of the literature focuses on describing farmers' responses without evaluating whether these practices lead to sustained improvements in milk yield, herd productivity, or long-term livelihood outcomes (Campbell et al., 2016; Rosenstock et al., 2016). This gap is

particularly significant for dairy systems because adaptation practices such as improved breeds, water infrastructure, and feed technologies often require substantial capital investment and long-term institutional support (FAO & GDP, 2018; Kadzere, 2018).

The literature on mitigation-oriented CSA practices within smallholder dairy systems remains comparatively less developed than adaptation-focused research. This is against the backdrop of evidence that livestock systems contribute significantly to agricultural greenhouse gas emissions. Livestock emissions are mainly associated with enteric methane, manure management, and land-use changes linked to feed production (Gerber et al., 2013; Knapp et al., 2014; FAO & GDP, 2018). Studies identify improved feeding regimes, manure management systems, pasture improvement, sustainable energy use, and integrated crop-livestock systems as mitigation pathways that can also improve productivity and reduce emissions intensity (Descheemaeker et al., 2016; Herrero et al., 2016b; FAO, 2018). However, adoption of mitigation practices remains limited among smallholder farmers due to high costs of implementation, weak technical support systems, and limited awareness of long-term environmental benefits (Rosenstock et al., 2016; Ericksen & Crane, 2018).

Furthermore, evidence suggests that smallholder farmers tend to prioritize CSA practices that provide immediate livelihood benefits, rather than those framed mainly as environmental interventions (Sibhatu & Qaim, 2017; Fanzo, 2018). Adoption is strongly influenced by perceived profitability, risk reduction, and household welfare gains. Therefore, CSA interventions framed primarily around climate mitigation objectives may have low uptake. Farmers adopt practices directly linked to tangible benefits such as improved milk yield, improved feed efficiency, reduced disease incidence, and lower production costs (Newell & Taylor, 2017; FAO & GDP, 2018). This highlights the importance of aligning CSA implementation strategies with the livelihood realities of rural dairy farmers.

Overall, the reviewed literature demonstrates that the adoption of CSA practices among smallholder dairy farmers is driven by an interaction of perceptions, capacities, and institutional opportunities. Awareness of climate change is necessary but not sufficient to ensure adoption. Instead, access to extension services, climate information, credit, markets, and collective action platforms such as cooperatives consistently emerges as a decisive driver of CSA uptake (Apata, 2011a; Ericksen & Crane, 2018; Odhiambo et al., 2019; Musafiri et al., 2022). Adoption is also highly context-specific, shaped by agro-ecological conditions, farming systems, and institutional

arrangements, implying that CSA interventions cannot be uniformly applied across different locations (Campbell et al., 2016; Rosenstock et al., 2016; Torquebiau et al., 2016).

Despite the growing body of CSA literature, several key gaps remain. First, most CSA adoption research in Africa focuses on crop production systems, with limited empirical evidence on livestock-based enterprises such as dairy farming. Second, studies addressing livestock often focus on broad national or regional scales, with insufficient district-level evidence explaining how adoption drivers differ across specific socio-economic and agro-ecological environments. Third, within Zimbabwe, there is limited empirical work that integrates farmers' perceptions of climate change, their adaptation and mitigation practices, and the determinants of CSA adoption within a single analytical framework, particularly for smallholder dairy systems. Fourth, limited comparative evidence exists examining differences in CSA adoption patterns between districts such as Chipinge and Mutasa, which may differ in climate exposure, market access, and institutional support structures (GoZ, 2018; World Bank, 2019).

These gaps provided a strong basis for this study, which sought to generate district-specific empirical evidence on CSA adoption among smallholder dairy farmers in Chipinge and Mutasa Districts of Manicaland Province. By integrating farmers' perceptions, adaptation and mitigation responses, and socio-economic and institutional determinants of CSA uptake, this study will strengthen the evidence base needed for designing targeted CSA interventions in Zimbabwe's dairy sector. The findings of the study also advance broader debates on sustainable livestock development in sub-Saharan Africa under climate change.

In conclusion, the adoption of CSA practices among smallholder dairy farmers is best understood as an outcome of interactions among the production constraints, socio-economic conditions, institutional support systems, and market incentives. While many studies identify determinants of adaptation and mitigation in isolation, fewer integrate these dimensions into a unified analytical approach. Therefore, this study adopts a conceptual framework that positions dairy farmers at the centre of a continuum of interacting domains, namely: socio-economic and institutional, production and resource, market and value chain, and knowledge and innovation. This provides an opportunity to have a deeper understanding of how these combined factors shape perceptions of climate change and the adoption of CSA practices in Chipinge and Mutasa districts.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Study area

Zimbabwe has four seasons in a calendar year, cool to cold temperatures are experienced from mid-May to the end of August, warm to hot temperatures from the beginning of September to mid-November, a main rainy season from mid-November to mid-March and lastly a mid-March to mid-May post-rainy season (MoEWC, 2016; Manatsa et al., 2020). Zimbabwe is divided into five agroecological regions, with regions I, II and III favouring commercial crop production due to better rainfall patterns, while livestock production and irrigated agriculture are more suitable production systems for regions IV and V (World Bank, 2019). The annual rainfall ranges from above 1050 mm to below 650 mm in regions I to III, while regions IV and V receive below 650 mm (GoZ, 2018; Manatsa et al., 2020). It has been observed that during the rainfall seasons, the onset, duration, frequency of dry spells and rainfall intensity have worsened.

While Zimbabwe has ten Provinces, Manicaland Province was chosen as the focal area of the study. The province was selected as the study area because it is one of Zimbabwe's major dairy-producing regions and plays an important role in the country's smallholder dairy sector. The province possesses favourable agroecological conditions, including relatively high rainfall and moderate temperatures, which support pasture production, fodder cultivation, and dairy farming. Districts such as Mutasa and Chipinge have well-established smallholder dairy schemes and have benefited from dairy development initiatives, making them appropriate locations for examining climate-smart agriculture (CSA) adoption among dairy farmers (Mhlanga et al., 2018; Gondo, 2026).

The province is also highly suitable for climate change research because it experiences increasing climate variability, including recurrent droughts, erratic rainfall, and rising temperatures, which affect feed availability, water resources, and livestock productivity. These climatic challenges have heightened the need for adaptation strategies among dairy farmers, making Manicaland an ideal setting for assessing the adoption of CSA practices and the factors influencing their uptake (Rusinga et al., 2014; Tirivanhu et al., 2023).

Manicaland province covers an area of 36,459 km² and has seven Districts, namely Buhera, Chimanimani, Chipinge, Makoni, Mutare, Mutasa, and Nyanga (Chingarande, 2020). This

province is located in eastern Zimbabwe, bordering Mozambique. The total human population in the province was 2,037,703 according to the 2022 census, accounting for almost 14% of the national population (ZimStat, 2022). Due to high rainfall in some parts of the province, perennial rivers, such as the Odzi River, run through three Districts (Nyanga, Mutasa and Mutare) before draining into the Save River (Chingarande et al., 2020). Other perennial rivers in Mutasa District include Pungwe, Honde, Muroti, and Mpudzi, which provide opportunities for farmers to practice irrigated agriculture. The Save River functions as the geographical boundary between Manicaland and Masvingo provinces. Furthermore, Zimbabwe's fourth-largest inland dam, Osborne, is in Mutasa District. This dam and others, together with the network of perennial rivers, provide substantial potential for agriculture-driven economic development in the province (Chingarande et al., 2020). The province features a barrier mountain belt (popularly known as the Eastern Border Highlands), which influences weather patterns, producing high-rainfall microclimates in some parts of the province.

The province spans all of Zimbabwe's natural regions, presenting opportunities for a wide range of farming activities. It stretches from the high-precipitation Region 1 areas of the Vumba Highlands to the dry Region V, with hot areas in the Middle Save (Chingarande et al., 2020). The agricultural production activities are both subsistence and commercial, with dairy farming, tea, coffee, timber, horticulture, seeds and potatoes contributing most of the province's agricultural output. Drought-tolerant crops such as cotton and sorghum are produced in the drier parts of the province. The mountainous landscape in the province, particularly in Nyanga, Vumba and Chimanimani, offers beautiful scenery that attracts tourists from all over the world. Most tourists visit Mount Nyangani, which stands at 2,592 m and is regarded as the highest point in Zimbabwe. Despite this beauty and scenery, poverty is prevalent in some densely populated rural areas of Buhera and Chimanimani Districts (Chimonyo et al., 2012).

Chipinge District has both highlands and lowlands and lies within the agroecological regions 1, 4 and 5 (Mavhura et al., 2017). These highlands make up the agroecological region 1 and are characterised by cool temperatures and high rainfall. The lowlands constitute agroecological regions 4 and 5, which experience low precipitation and high temperatures. The mid-season dry spells and droughts characterise the lowlands of the district. The district's annual rainfall is 520 mm, and its aridity index is between 0.2 and 0.5. The district's average monthly temperature is 23.5°C, with September and October the hottest months, recording temperatures above 34°C. The

lowest mean temperature, 5° C is recorded in July. The greater part of southern Chipinge comprises sandy soil that is unsuitable for agricultural activities. According to Mavhura et al. (2017), drought-tolerant Mopani trees are commonly found in the district's low-lying areas. In 2022, Chipinge District had a total population of 375,259 (ZimStat, 2022). Smallholder farming is the most common economic activity practised in the district, and the prevalence of poverty was about 79.8% in 2021 (ZimStat, 2021). The majority of smallholder farmers (72%) practise mixed farming as a strategy to address climate-change-induced challenges (Mavhura et al., 2017).

Mutasa District is located in a semi-arid valley and is home to approximately 1,177 households forming five villages (ZimStat, 2022). Pockets of agroecological zones 1 – 4 are found in the district. The average annual rainfall ranges from 850 to 1000 mm and is normally received from October to April (Ndlovu, 2011). Even though the district has poor soils and very uneven terrain, most households engage in agriculture as an economic activity. The topography of this district allows most of the farmers to use gravity to irrigate their crops. Cash crops such as tea, coffee and bananas are grown in the district, along with other crops that include maize, legumes and tubers (Mushunje, 2005). The average annual temperature is around 26°C. Mutasa District had a population of 197,808 in 2022 (ZimStat, 2022).

Chipingge and Mutasa Districts are among the leading smallholder dairy-producing areas in Manicaland Province, Zimbabwe. Dairy farming in these districts is predominantly undertaken by smallholder farmers operating within organized dairy schemes and milk collection centre networks that facilitate access to markets and extension services. In Chipingge, dairy production is concentrated in schemes such as Rusitu Valley and Mayfield, which were established to improve rural livelihoods and enhance household income through market-oriented milk production (Hahlani & Garwi, 2014). Mutasa District also has a well-established dairy sector supported by favourable agroecological conditions, relatively high rainfall, and development initiatives that promote small-scale commercial dairy farming. Despite their dairy production potential, farmers in both districts face challenges, including feed shortages, high production costs, disease outbreaks, limited access to inputs, and increasing climate variability, which threaten dairy productivity and sustainability (Ngongoni et al., 2006; Hahlani & Garwi, 2015). These characteristics make Chipingge and Mutasa suitable locations for studying the adoption of climate-smart agriculture practices among smallholder dairy farmers. The maps show the location of the study area (Figure 3.1).

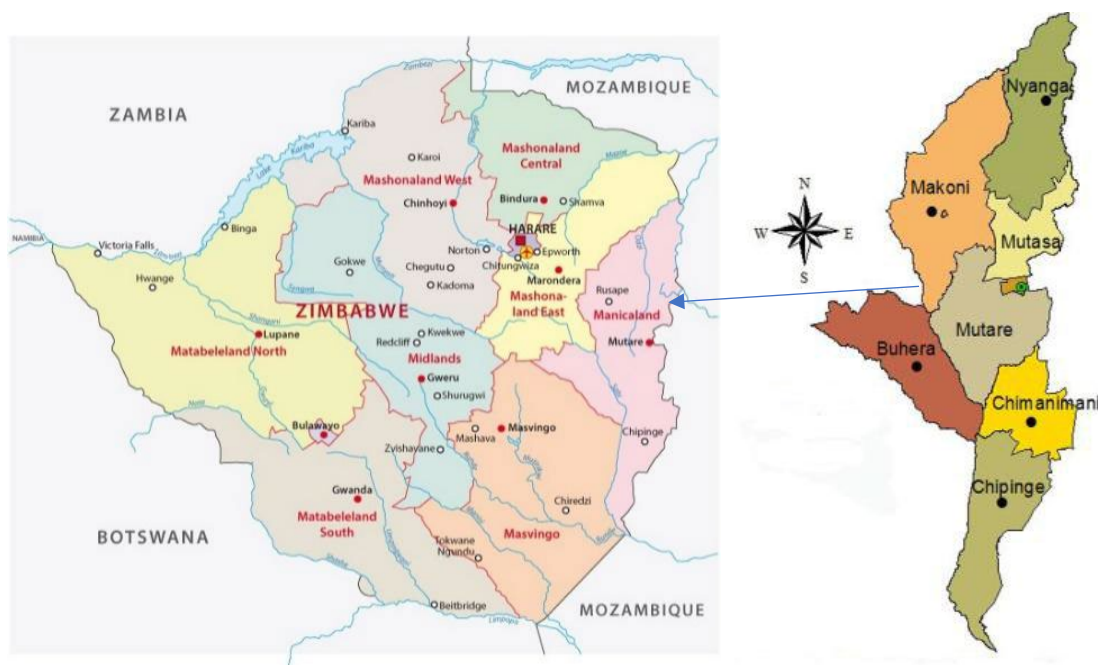


Figure 3.1: Zimbabwe map (arrow showing the study area - Manicaland Province)

Source: Google Maps and Environmental Management Agency (EMA) (2021)

3.2 Research design

Studies done in other countries of SSA (see Maindi et al., 2020; Kurgat et al., 2020, Owino et al., 2020a) suggested that a cross-sectional household survey approach was a more appropriate design to achieve the objectives of the study. An iterative process of refining the questionnaire was used to ensure that all necessary data were collected during the survey. The demand for detailed, up-to-date socio-economic data on households and individuals has been rising in developing countries over time (Arakelyan, 2017). The role of such data in economic and social policy analysis and development planning cannot be overemphasised. Household surveys have become an important tool for gathering data that are not only central and strategic, but critical for the development of national policies in developing countries. Both open-ended and closed-ended questions were used in the survey.

The questionnaire for the survey had sections based on five main elements: 1) Basic household information; 2) Smallholder dairy farmers' perception of climate change; 3) Milk production, dairy farm management and the environment; 4) Dairy farm support systems, and 5) Value chain linkages. Under these five main elements, there are other subdivisions that make the questionnaire comprehensive, capture data that ensures all the objectives of the study are achieved, and avoid collecting data that would not be used in the research. Prior to this study, no comprehensive household survey of smallholder dairy farmers had been conducted in Zimbabwe, especially one that focused on the main elements outlined above. Given the importance of the dairy sector in Zimbabwe, such surveys are critical for promoting evidence-based smallholder dairy farmer capacity-building programmes in the future.

One of the important roles in this study linking the researcher with the smallholder dairy farmers is played by the Zimbabwe Association of Dairy Farmers (ZADF). This is a national association of dairy farmers, with an efficient extension services division that works with farmers in the districts where dairy farming is practised. Chipinge and Mutasa Districts were chosen because of their relatively high concentration of smallholder dairy farmers according to ZADF records. Collaboration with the ZADF aimed to connect the researcher to other stakeholders, such as government, development agencies and donors working directly or indirectly with local smallholder dairy farmers in the study areas.

A fully developed questionnaire was used as the basis for training workshops for the four enumerators who assisted with data collection in the two districts. The workshops were held in both Chipinge and Mutasa Districts. The study leader was responsible for supervising the entire data collection, including facilitation during the training workshop. After the training, the questionnaire was piloted with a few smallholder farmers. Based on the test results, necessary adjustments were made, and the team was then deployed to collect data under the researcher's close supervision. No focused group discussions could be held during the data collection process due to COVID-19 restrictions; however, interviews with key informants (Government and ZADF extension officers) were conducted.

3.3 Population of the study

According to the ZADF records, the total number of smallholder dairy farmers affiliated with the association in Manicaland province was 1,114, with the majority in four districts, including Chipinge and Mutasa.

3.4 Sample size and sampling procedure

There is neither enough time nor sufficient resources for researchers to analyse the entire population; therefore, sampling techniques are needed to obtain a smaller number of cases (Taherdoost, 2016). Taking samples, which are subsets of the entire population, can be used to draw conclusions about the population. Multi-stage sampling was considered appropriate because the study population was geographically dispersed and organized under the Zimbabwe Association of Dairy Farmers (ZADF) membership structure. The sampling process was conducted in three main stages, as described below.

Stage 1: The first stage involved purposive selection of Chipinge and Mutasa Districts

These districts were selected because they are among the key dairy production areas in Manicaland Province and have an established population of smallholder dairy farmers registered under ZADF. In addition, the two districts are characterized by mixed farming systems and varying climatic conditions, making them suitable for investigating the adoption of climate-smart agriculture CSA practices among smallholder dairy farmers. The total number of ZADF members in the two selected districts was 657 in January 2026 (ZADF, 2026). This shows more than double increase in membership in these districts from the 256 obtained in January 2021. The sample size for the study was calculated using the January 2021 total membership figure (256). The sample size was deemed sufficient to meet the study's objectives despite the increase in membership as of January 2026. It is also important to note that there are more members categorised as non-active than active. The increase in membership includes the establishment of new MCCs (Paidamoyo and Charurwa in Charurwa) as shown in Table 3.1.

Table 3.1: Numbers and distribution of smallholder dairy farmers in Chipinge and Mutasa Districts

District	MCC Name	Number of active members	Number of non-active members	Total number of members	Total per district
Chipinge	Rusitu Mayfield/Upperand/Goshen	144	99	243	373
	Rusitu United/Mafumise	52	78	130	
Charurwa	Paidamoyo	45	65	110	165
	Charurwa	10	45	55	
	Tsonzo	30	12	42	
Mutasa	Cynara	38	24	62	119
	Honde valley	12	3	15	
Total					657

Source: ZADF database (2026)

Stage 2: Determination of sample size and proportional allocation (stratified sampling)

The sample size was determined using Cochran's (1977) formula for estimating sample sizes for proportions:

$$n_0 = \frac{Z^2 pq}{e^2} \dots \dots \dots \text{equation 1}$$

where:

- n_0 = initial sample size;
- Z = standard normal deviate corresponding to the desired confidence level (1.96 for 95% confidence);
- p = estimated proportion of the population possessing the characteristic of interest (0.5);
- $q = 1 - p = 0.5$;
- e = desired margin of error (0.05).

Substituting the values:

$$n_0 = \frac{(1.96)^2 (0.5)(0.5)}{(0.05)^2}$$

$$n_0 = \frac{3.8416 \times 0.25}{0.0025}$$

$$n_0 = \frac{0.9604}{0.0025}$$

$$n_0 = 384.16$$

Therefore, the initial sample size was approximately 384 respondents.

Since the target population of smallholder dairy farmers was finite ($N = 256$), the finite population correction (FPC) was applied:

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}} \dots \dots \dots \text{equation 2}$$

Substituting the values:

$$n = \frac{384.16}{1 + \frac{384.16 - 1}{256}}$$

$$n = \frac{384.16}{1 + \frac{383.16}{256}}$$

$$n = \frac{384.16}{1 + 1.4967}$$

$$n = \frac{384.16}{2.4967}$$

$$n = 153.87$$

$$n \approx 154$$

Thus, the final adjusted sample size for the study was 154 respondents.

Proportional Allocation to Strata

The total population comprised 181 farmers in Chipinge District and 75 farmers in Mutasa District ($N = 256$). Proportional allocation was used to determine the sample size for each district:

$$n_h = \frac{N_h}{N} \times n \dots \dots \dots \text{equation 3}$$

Chipinge District

$$n_h = \frac{181}{256} \times 154$$

67

$$n_h = 108.9 \approx 109$$

Mutasa District

$$n_h = \frac{75}{256} \times 154$$

$$n_h = 45.1 \approx 45$$

Therefore, the final sample allocation was 109 respondents from Chipinge District and 45 from Mutasa District, for a total of 154 respondents. This allocation ensured that each district was represented in proportion to its share of the total population.

Stage 3: Selection of respondents (systematic random sampling)

The third stage involved selecting the required number of respondents from each district using systematic random sampling. Systematic sampling was adopted because the study population was organized in membership registers, allowing for efficient selection of respondents while maintaining randomness.

A complete list of registered dairy farmers in each district was obtained from ZADF. Farmers were then assigned unique identification numbers to form the sampling frame. The sampling interval (k) was calculated separately for each district using the formula:

$$k = \frac{N}{n} \dots \dots \dots \text{equation 4}$$

Where:

- k = sampling interval
- N = population size
- n = required sample size

Chipinge District

$$k = \frac{181}{109} = 1.66 \approx 2$$

Thus, in Chipinge District, every 2nd farmer was selected after determining a random starting point.

Mutasa District

$$k = \frac{75}{45} = 1.67 \approx 2$$

Similarly, in Mutasa district, every second farmer was selected after a random starting point was determined.

To ensure randomness, the first respondent in each district was selected using a random-start method (for example, by selecting a number between 1 and k from and k using a random number table or lottery method. Thereafter, every k th farmer on the list was selected until the required sample size was reached. Where a selected respondent was unavailable or unwilling to participate, the next farmer on the list was selected to maintain the sample size.

Treatment of active and inactive ZADF members

As indicated in Table 3.1, ZADF members are classified into active and non-active categories. Although this classification was not treated as a separate stratum during sampling, each respondent was coded by membership status (active or non-active) during data entry and analysis. This enabled the study to examine whether membership status influenced the adoption of CSA practices without altering the proportional representation of the district strata.

Summary of the sampling procedure

In summary, the study used a multi-stage sampling design: purposive selection of districts (Stage 1), sample size determination and proportional stratification by district (Stage 2), and systematic random sampling of respondents from district registers (Stage 3). This approach ensured that the final sample was representative of the ZADF dairy farmer population in both Chipinge and Mutasa Districts.

3.5 Data collection

The researcher visited the study area for two weeks in March 2022. The visit had several objectives, as follows: to request permission from the relevant authorities to conduct the study; to conduct a training workshop for the enumerators; to test the research instrument; and to visit some

farmers and MCCs. All these activities were conducted successfully. The trained enumerators were responsible for data collection under the researcher's supervision, who continued to ensure the process remained consistent and smooth. Data collection and verification took three to five months in Mutasa and Chipinge Districts, respectively. Data entry was carried out immediately after the survey, followed by the necessary data cleaning to ensure that the data were ready for analysis.

The study employed data triangulation approach, whereby information obtained from smallholder dairy farmers was complemented with insights from key informants and secondary sources to enhance the credibility, consistency, and comprehensiveness of the findings. Triangulation enabled the verification of information from multiple sources and reduced the risk of bias associated with reliance on a single data source. The questionnaire and interview guides were pre-tested with a small group of dairy farmers with characteristics similar to those of the study population but located outside the selected study sample. The pre-test was conducted to assess the clarity, relevance, sequencing, and comprehensibility of the questions, as well as the time required to complete the questionnaire. Feedback obtained during the pre-testing process was used to revise ambiguous questions, improve wording, and ensure that the instruments effectively captured the intended variables. This process enhanced the reliability and validity of the data-collection tools and contributed to the overall quality and robustness of the study findings.

3.6 Data analysis

Data were coded and analysed using IBM SPSS Statistics Version 29.0. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarise respondents' socio-economic characteristics, farm characteristics, and climate change perceptions.

Different analytical techniques were employed to address the study objectives. For Objective 1, which sought to assess smallholder dairy farmers' perceptions of climate change in Zimbabwe, descriptive statistics and Chi-square tests were used to summarise and examine variations in perceptions among respondents.

For Objective 2, which examined how perceptions of climate change influence the adoption of CSA practices, a binary logistic regression model was used to estimate the effect of farmers' perceptions on the likelihood of adopting CSA practices.

For Objective 3, which aimed to determine the adaptation and coping strategies employed by smallholder dairy farmers and the factors influencing their adoption, descriptive statistics were used to identify the various strategies adopted, while multinomial logistic regression analysis was employed to determine factors influencing farmers' choice of adaptation strategies.

For Objective 4, which sought to identify mitigation-based strategies adopted by smallholder dairy farmers and the factors influencing their adoption, descriptive statistics were used to establish the prevalence of mitigation practices, and multinomial logistic regression was applied to analyse factors influencing the choice of mitigation strategies.

For Objective 5, which analysed socio-economic, institutional, and farm-level factors influencing CSA adoption decisions, binary logistic regression was used to identify factors associated with the likelihood of CSA adoption. Chi-square tests were also conducted to examine associations between selected categorical variables and adoption status.

Statistical significance for all inferential analyses was assessed at the 5% level ($p < 0.05$), corresponding to a 95% confidence interval.

3.6.1 Research objective 1 – dairy farmers' perception of climate change

This part of the study focused on understanding dairy farmers' perceptions of climate change and how their perceptions influence the adoption of CSA practices. Data were collected on climate conditions, including weather and climate variability, as well as dairy farmers' perceptions of how these changes affect their farms. The questions aimed to gather information about what the farmers had observed in the previous five years to the time of data collection. This study adopted a five-year reference period to examine dairy farmers' perceptions of climate variability and change because farmers' understanding of climate risks is largely shaped by recent experiences rather than distant historical trends. In smallholder farming systems, perceptions of climate change tend to be grounded in what farmers have personally observed and responded to in their day-to-day farming activities in recent years.

Evidence from other studies shows that farmers typically base adaptation decisions on climatic events experienced within a short- to medium-term timeframe, often between three and ten years, as these events are easier to recall and are perceived as more relevant to current livelihood risks (Jha et al., 2021; Niles et al., 2025). A five-year period is therefore long enough to capture meaningful patterns in climate variability such as repeated droughts, irregular rainfall, or increased

disease incidence while remaining short enough to minimise recall bias and inaccuracies in respondents' responses (Tesfaye et al., 2021; van Valkengoed et al., 2022).

In addition, evidence from climate adaptation and CSA adoption studies suggests that farmers are more likely to adjust management practices in response to climate shocks that have occurred in the recent past, as these experiences are viewed as immediate and directly relevant to farm performance (Abid et al., 2020; Nyang'au et al., 2021). Kikstra et al. (2022) similarly emphasize that recent climate variability plays a critical role in shaping behavioural responses, particularly in climate-sensitive agricultural systems in Sub-Saharan Africa.

Overall, the use of a five-year reference period in this study provides a practical and contextually appropriate balance between capturing meaningful climate experiences and ensuring reliable recall, making it suitable for analysing farmers' perceptions and their influence on the adoption of climate-smart agriculture practices. The climatic events the farmers were asked about included rainfall patterns, flooding and drought frequency, prevalence of animal diseases and how these were affecting trends in milk yields.

A binary logit model was used to estimate the factors influencing dairy farmers' perceptions of changes in weather variability, which they link to climate change. Adapted after Bryan et al. (2013), the binary logit model can be expressed as follows:

$$R_i^* = X_i\alpha + \epsilon_i \dots \dots \dots \text{equation 5}$$

R^* is the latent variable, X denotes the set of explanatory variables or factors that influence farmers' perceptions of weather variability, and i is the individual observation (respondent). The α measures the effect/impact of each independent variable in X_i on the dependent variable and ϵ_i is the error term. The binary outcome is equal to 1 ($P_i=1$) if the farmer perceives a change in, for instance, the amount of rainfall received in the past 5 years and 0 otherwise ($P_i=0$).

However, the farmers' observations of the impacts of climate change on farm activities fall into several categories, and a multinomial logit (MNL) model was therefore used to analyse the factors affecting these perceptions. The farmers' perceptions of climate change were grouped into the following categories: increased frequency of droughts, increased frequency of flooding, erratic rainfall patterns, increased temperature, and no change. Open-ended questions were asked to allow farmers to express themselves fully on matters regarding the groups mentioned above. Using a

single group, the factor analysis method takes the total variance and calculates the linear combination of variables that maximises. This procedure produced the first factor. The same procedure is repeated for the second factor maximising the remaining variance with the condition that the two factors are not correlated. This iterative process is continued until the factors reach the number of variables in the set.

The MNL model has been widely used as an analytical framework for climate change adaptation in studies involving multiple options considered by smallholder farmers in Africa (Hassan & Nhemachena, 2008; Deressa et al., 2009; Tazeze, 2012; Arakelyan, 2017). The MNL model has the advantage of computational simplicity, with choice probabilities that can be expressed analytically. The model provides a convenient closed-form expression for the underlying choice probabilities without requiring multivariate integration. This brings another advantage of simplifying the computation in a choice situation characterised by many options.

The main limitation of the MNL model is the Independence of Irrelevant Alternatives (IIA) property, which states that the ratio of the probabilities of choosing any two alternatives is independent of the attributes of any other alternative in the choice set (Tazeze, 2012). The Hausman's test was used to test the validity of the IIA assumptions. The test should accept the null hypothesis of independence of the climate change adaptation options for the model to be appropriate for this study. The MNL regression analysis was estimated to identify the factors influencing a dairy farmer's choice of adaptation strategy to reduce climate change impacts. The model's estimation was based on normalising one category, which is usually referred to as the "base category". The "no adaptation" option was used as the base category. The main hypothesis tested in the model was that the dairy farmers' socio-economic situation and institutional support systems, coupled with their perceptions of weather variability, affect their perceptions of climate change impacts on their farming activities.

Prior to running the MNL model, all 16 explanatory variables were checked for multicollinearity using the Variance Inflation Factor (VIF). This study considered VIF less than 10 for all explanatory variables as an indication that multicollinearity is not a major problem in model estimation. All independent variables with a VIF greater than 10 were excluded from the model estimation. The explanatory variables, their expected signs and hypotheses are presented in Table 3.2.

Table 3.2: Explanatory variables expected sign and hypotheses, dairy farmers' perception of climate change and its perceived impacts on farming activities

Model 1. Factors influencing farmers' knowledge and perceptions of climate change			
Variable	Description of variable	Expected sign	Hypothesis
X ₁	Gender of household head (1 – female; 0 – male)	–	Female dairy farmers are less likely to perceive weather variability as a sign of climate change due to gender-linked disparities, including education levels and information asymmetry.
X ₂	Age of household head (years) (Continuous)	+	Senior farmers are more likely to have accumulated knowledge of the impacts of climate change.
X ₃	Level of education (measured as years of schooling) (Continuous)	+	Dairy farmers with more years of schooling are more likely to associate weather variability to climate change.
X ₄	Access to extension services (1 – yes; 0 – otherwise)	+	Dairy farmers with frequent access to extension services are more likely to be aware of climate change and its impacts.
X ₅	District of respondent (1 – Chipinge; 0 – Mutasa)	+	Respondents from Chipinge district are more likely to be aware of climate change and its impacts due to their exposure to extreme weather patterns (e.g. flooding).

Model 2. Factors influencing perceived impacts of climate change on dairy farming activities

X ₁	Gender of household head (1 – female; 0 – male)	–	Female dairy farmers are less likely to link changes to weather variability to the impacts on dairy farming activities due to limited knowledge.
X ₂	Age of household head (Years) (Continuous)	+	Senior farmers are more likely to notice and report impacts.
X ₃	Size of household (Continuous)	+	Bigger families are more likely to report impacts of climate change.
X ₄	Land size in hectares (Continuous)	+	Dairy farmers with larger landholdings are more likely to report impacts.
X ₅	Level of education (denoted as years of schooling) (Continuous)	+	Dairy farmers with more years of schooling are more likely to report impacts.
X ₆	Access to extension services (1 – yes; 0 – otherwise)	–	Dairy farmers with access to extension services are less likely to report impacts.
X ₇	Farm income in USD (Continuous)	+	Farmers with higher incomes are more likely to adapt to and report impacts of climate change.
X ₈	Non-farm income in USD (Continuous)	+	Farmers with other sources of income are more likely to report the impacts of climate change.
X ₉	Access to finance (1- yes; 0 – otherwise)	–	Farmers with access to finance are less likely to report impacts.
X ₁₀	Dairy farming experience (years)	+	More experienced dairy farmers are more likely to report impacts.

X ₁₁	Access to weather and climate change information (1 – yes; 0 – otherwise)	+	Dairy farmers with access to weather and climate change information are more likely to report impacts.
X ₁₂	Increase in drought frequency (1 – yes; 0 – otherwise)	+	Dairy farmers in Mutasa district are more likely to report the impacts of droughts on their farming activities.
X ₁₃	Increase in flooding frequency (1 – yes; 0 – otherwise)		Dairy farmers in Chipinge district are more likely to report flooding frequency.
X ₁₄	Erratic rainfall patterns (1 – yes; 0 – otherwise)	+	Dairy farmers are more likely to report impacts linked to rainfall patterns.
X ₁₅	Increase in temperature (1 – yes; 0 – otherwise)	+	Dairy farmers are more likely to report high temperature-related impacts on their activities.
X ₁₆	Food security (1 – food secure; 0 – otherwise)	–	Food-secure dairy farmers are less likely to report impacts of climate change on their farming activities.

3.6.2 Research objective 2 – influence of dairy farmers’ perception of climate change on climate-smart agriculture adoption

The hypothesis tested in this part of the study was that perceptions of climate change influence smallholder dairy farmers’ adoption of CSA. To achieve this, chi-square tests were used to examine how the smallholder dairy farmers’ perceptions of climate change influence their choice of adaptation/coping strategies. A pairwise correlation analysis was done to assess the relationship between perceptions of climate change and adoption of CSA practices.

3.6.3 Research objective 3 – climate change adaptation practices adopted by dairy farmers

To determine the factors influencing the adoption of climate change adaptation practices among smallholder dairy farmers, a binary logistic regression model was estimated. The dependent variable was adaptation uptake, coded as 1 for adopters and 0 for non-adopters. Farmers were classified as adopters if they had implemented at least one adaptation practice, such as supplementary feeding, fodder production, forage conservation, water harvesting, improved herd health management, or improved housing. The binary nature of the dependent variable justified using logistic regression to estimate the likelihood of adopting adaptation practices.

The explanatory variables comprised socio-economic, demographic, institutional, and farm-level characteristics that may influence adoption decisions. These included age, gender, education level, household size, dairy farming experience, herd size, and landholding size. Institutional variables included access to extension services, credit, dairy cooperatives or farmer groups, and climate information. Farm management variables, such as improved herd health management and proximity to markets or milk collection centres, were also included. These variables were selected based on their potential influence on farmers' access to resources, information, and capacity to adopt climate-smart adaptation practices.

Based on literature review on adaptation strategies in dairy farming (Kant et al., 2017; Acharya et al., 2025), the study considered the following four practices suggested to be climate change adaptation strategies: 1) Use of improved breeds (livestock diversification), 2) water harvesting and storage, 3) Feed conservation and storage, 4) use of shades to avert heat stress. These practices allow dairy farmers to reduce their vulnerability to climate change, as using any one of them or a combination of them increases the resilience of the dairy farming system. The identified adaptation strategies were incorporated into the analysis by first collecting data on whether each respondent had adopted the four practices. Each practice was coded as a binary variable, with 1 indicating adoption and 0 indicating non-adoption. These individual adaptation variables were then combined to generate an overall adaptation uptake variable. Farmers who had adopted at least one of the four adaptation practices were classified as adopters (1), while those who had not adopted any of the practices were classified as non-adopters (0). This composite binary variable served as the dependent variable in the logistic regression model, enabling analysis of socio-economic, demographic, institutional, and farm-level factors influencing the likelihood of adopting adaptation among smallholder dairy farmers.

3.6.3.1 Model Specification

Two categories of dairy farmers are defined: adopters and non-adopters of the practices given above. Cross-tabulation was conducted to compare adopters and non-adopters with respect to a given characteristic. At the farm level, adoption was calculated using a binary variable, for example, adoption of breeding to enhance herd quality = 1, non-adoption = 0. To assess the relationship between the adoption of the practices and socio-economic characteristics, chi-square tests were done. A standard logistic regression model was used to model a binary choice (adoption or non-adoption of the practice). This model empirically estimated how changes in exogenous and socio-economic variables influence the probability of adoption of adaptation strategies and assessed the effectiveness of technology adoption (Nkonya et al., 1997).

To derive coefficients for explanatory variables likely to influence dairy farmers' adoption of CSA practices, a logistic regression model was used to estimate odds ratios. For this study, the level of adaptation strategy adoption is the dependent variable, and ten selected socio-economic factors were the independent variables. Adoption level is a dichotomous variable (adopter = 1; non-adopter = 0), and all independent variables are categorical. Correlation analysis between the independent variables was conducted to assess whether multicollinearity exists in their interrelationships. Respondents were assigned 1 if they used adaptation; otherwise, 0. The binary logistic model used in the study is specified as follows (adapted after Quddus, 2012):

$$P = P(Y = 1/X) = \frac{e^{\beta_0 + \sum_{i=1}^{10} \beta_i X_i}}{1 + e^{\beta_0 + \sum_{i=1}^{10} \beta_i X_i}} \dots \dots \dots \text{equation 6}$$

And,

$$1 - P = p(Y = 0/X) = \frac{1}{1 + e^{\beta_0 + \sum_{i=1}^{10} \beta_i X_i}} \dots \dots \dots \text{equation 7}$$

A transformation of P known as a logit transformation is defined as:

$$\text{Logit } P = \log \left[\frac{P}{1-P} \right] = \beta_0 + \sum_{i=1}^{10} \beta_i X_i \dots \dots \dots \text{equation 8}$$

In the model:

Y_i : Level of adoption of adaptation strategies (1 = adopters, 0 = non-adopters)

X_1 : District of the respondent

X_2 : Gender of household head

X_3 : Age of household head

X_4 : Level of education of household head

X_5 : Number of dairy cows owned

X_6 : Total household income

X_7 : Access to finance

X_8 : Access to extension services

X_9 : Years of experience in dairy farming

X_{10} : Food security

3.6.3.2 Dependent and explanatory variables

Dependent variables/improved practices

Further review of literature on adaptation strategies in dairy farming (Amamou et al., 2018; Acharya et al., 2025) confirmed the same common practices already mentioned above. These practices are the dependent variables.

Independent variables

Based on the review by (Anuga et al., 2019; Kurgat et al., 2020) and the available data, specific household and farm characteristics, including institutional factors, were selected. These were hypothesised to influence dairy farmers' adaptation choices. The selected characteristics and factors were district, gender, and education of the head of the household; land size; total household income; number of dairy cows; farming experience; access to extension services; access to finance; and food security. The ten independent variables hypothesised to influence smallholder dairy farmers' adoption of adaptation strategies are presented in Table 3.3.

Table 3.3: Explanatory variables and hypotheses, adoption of adaptation strategies by dairy farmers

Model 1. Factors influencing farmers' knowledge and perceptions of climate change		
Variable	Description of variable	Hypotheses
X ₁	District of respondent (1 – Chipinge; 0 – Mutasa)	Respondents from Chipinge district are more likely to adopt adaptation strategies due to a longer history of dairy production and may have more income coming from their dairy enterprises.
X ₂	Gender of household head (1 – male; 0 – female)	Female dairy farmers are less likely to adopt adaptation strategies due to labour and cost constraints.
X ₃	Land size (ha) (continuous)	Dairy farmers with larger landholdings are more likely to adopt adaptation strategies due to greater flexibility in enterprise choices.
X ₄	Level of education (denoted as years of schooling) (continuous)	Dairy farmers with higher levels of education are more likely to adopt adaptation strategies.
X ₅	Number of dairy cows owned (continuous)	The more dairy cows a farmer owns, the more likely they are to adopt adaptation strategies.
X ₆	Total household income (USD) (continuous)	Dairy farmers with higher levels of income (total of on- and off-farm income) are more likely to adopt adaptation strategies.
X ₇	Access to finance in the past 12 months (1 – yes; otherwise - 0)	Dairy farmers with access to finance are more likely to adopt adaptation strategies.
X ₈	Access to extension services (1 – yes; otherwise - 0)	Dairy farmers with access to extension services are more likely to adopt adaptation strategies.
X ₉	Years of experience in dairy farming (continuous)	More experience in dairy farming positively impacts the adoption of adaptation strategies.
X ₁₀	Food security (1 – food secure; 0 – otherwise)	Food-secure dairy farmers are more likely to adopt adaptation strategies.

3.6.4 Research objective 4 – climate change mitigation practices adopted by dairy farmers

Literature review (Holly et al., 2017; Llonch, et al., 2017; Gross et al, 2022; Brandt et al., 2022), on mitigation strategies undertaken by dairy farmers revealed the following four practices: 1) Good manure management, 2) Tree planting and agroforestry, 3) Use of improved feeding regimes, 4) Use of solar energy. The use of any of them or a combination of them directly or indirectly reduces the environmental footprint of dairy farming systems.

3.6.4.1 Dependent and explanatory variables

The same empirical model used for research objective 3 was used for research objective 4. The dependent variables are the mitigation practices described above, and the independent variables are the same as for research objective 3. The hypotheses are also deemed similar.

3.6.5 Research objective 5 – Factors influencing the adoption of CSA practices by dairy farmers

The same binary logistic regression model as for research objectives 3 and 4 was used (see empirical model description in section 3.6.2.1 above).

3.6.5.1 Dependent and explanatory variables

Data were collected on socio-economic and demographic characteristics of farmers' households; in addition, data were collected on the use of improved herd health and feeding regime practices by smallholder dairy farmers.

Dependent and independent variables

The same empirical model used for research objectives 3 and 4 was used for research objective 5. The dependent variables are the CSA practices identified in the previously cited literature. Specifically, the study identified 5 practices to be CSA. These are: 1) use of breeding (including artificial insemination) to enhance herd quality, 2) use of vaccines to prevent and treat cow diseases, 3) use of enhanced feeding regimes, 4) using crop by-products and residues to feed the dairy cows and 5) conservation and storage of feed. The independent variables and the hypothesis are as given in Table 3.4.

Table 3.4: Explanatory variables and hypotheses, adoption of CSA practices by dairy farmers

Model 2. Factors influencing perceived impacts of climate change on dairy farming activities			
X ₁	Gender of household head (1 – female; 0 – male)	–	Female dairy farmers are less likely to adopt CSA practices due to a lack of knowledge and resources.
X ₂	Age of household head (Years) (Continuous)	–	Senior farmers are less likely to adopt CSA practices due to less interest in long-term investments.
X ₃	Size of household (Continuous)	+	Bigger families are more likely to adopt CSA practices due to labour availability.
X ₄	Land size in hectares (Continuous)	+	Dairy farmers with larger landholdings are more likely to adopt CSA due to the flexibility in allocating land to more enterprises.
X ₅	Level of education (denoted as years of schooling) (Continuous)	+	Dairy farmers with more years of schooling are more likely to adopt CSA practices.
X ₆	Access to extension services (1 – yes; 0 – otherwise)	+	Dairy farmers with access to extension services are more likely to adopt CSA practices.
X ₇	Farm income in USD (Continuous)	+	Farmers with higher farm income are more likely to adopt CSA practices.
X ₈	Non-farm income in USD (Continuous)	+	Farmers with other sources of income are more likely to adopt CSA practices.

X ₉	Access to finance (1-yes; 0 - otherwise)	+	Farmers with access to finance are more likely to adopt CSA practices.
X ₁₀	Dairy farming experience (years)	+	More experienced dairy farmers are more likely to adopt CSA practices.
X ₁₁	Market access (1 – yes; 0 - otherwise)	+	Market access is more likely to increase the adoption of CSA practices.
X ₁₂	Access to weather and climate change information (1 – yes: 0 – otherwise)	+	Dairy farmers with access to weather and climate change information are more likely to adopt CSA practices.
X ₁₃	Increase in drought frequency (1 – yes; 0 – otherwise)	+	Dairy farmers in Mutasa district are more likely to adopt CSA practices that reduce the drought impact.
X ₁₄	Increase in flooding frequency (1 – yes; 0 – otherwise)	+	Dairy farmers in Chipinge district are more likely to adopt CSA practices that reduce the impact of flooding.
X ₁₅	Erratic rainfall patterns (1 – yes; 0 – otherwise)	+	Dairy farmers in Mutasa district are more likely to adopt CSA practices based on erratic rainfall patterns.
X ₁₆	Increase in temperature (1 – yes; 0 – otherwise)	+	Dairy farmers in Mutasa district are more likely to adopt CSA practices, which reduce the impacts of high temperatures.

X ₁₇	Food security (1 – food secure: 0 – otherwise)	+	Food-secure dairy farmers are more likely to adopt CSA practices.
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3.7 Ethical considerations

Research ethics are the norms for research conduct that differentiate acceptable from unacceptable behaviour (Resnik, 2018). The researcher adhered to all ethical considerations to ensure the study's successful completion. The researcher obtained ethical clearance from the University. In addition, both letters of permission and verbal authorisation were granted by the relevant authorities (government and traditional leadership) to conduct the study. Respondents were not exposed to physical or emotional harm. The respondents were informed about the study's purpose and objectives before providing their informed consent. Obtaining informed consent from respondents is, therefore, a necessary step in research data collection. The researcher has an ethical responsibility to ensure that the participants are protected from any harm. Participants were allowed to withdraw from the study at any time. Participants were fully briefed on the importance of participating in the study and given the option to decline. Key to protecting the participants was the guarantee of anonymity of the data collection instruments.

The researcher clearly informed the respondents that the sought information was solely for research purposes. The researcher assured confidentiality and maintained it throughout the research process and thereafter. The data are stored in a safe with a locking facility. Emphasis was placed on respondents' privacy to ensure that their identities (names) were not written or coded in the research instruments. This was done to ensure that no information would be linked to anyone. Respect for individuals and groups, and for their privacy, is an essential element of research data collection processes. It is also important that the researcher ensures that participants are not disadvantaged by the study but benefit from it. The right to privacy was upheld during data collection and throughout the study.

All authorities, including statutory, customary and political authorities that preside over the governance affairs of the study areas, were approached. This was done to explain the study's purpose and to seek permission from these authorities to undertake the study in their area. These

included provincial and district administrative authorities, chiefs, headmen and political leadership in the study area.

3.8 COVID-19 considerations

The COVID-19 pandemic added to the protocols researchers must observe when conducting research. National governments implemented regulations in place to curb the spread of the coronavirus, and Zimbabwe was no exception. These regulations were set and adjusted in response to the infection and the daily number of coronavirus cases. The researcher therefore undertook to continuously monitor the COVID-19 situation in both South Africa and Zimbabwe, as the situation in both countries at any given time would affect project activities.

We observed alternating loosening and hardening of restrictions in both Zimbabwe and South Africa. Generally, activities were allowed to continue provided that certain precautionary and/or safety measures were followed. The most common measures were the use of face masks, hand sanitisers, temperature testing, and social distancing (at least 1.5 m between individuals at all times). This research was done in full compliance with the COVID-19 regulations in both Zimbabwe and South Africa. No research was conducted during the high-level lockdown in either country. However, once restrictions on movement and gatherings were lifted, research activities were conducted in accordance with the law. The researcher ensured that the health of respondents, enumerators, researchers and community members in the area where the research was conducted was prioritised. Some of the measures the researcher put in place include ensuring that the research team (researcher and enumerators) always carry enough face masks, hand sanitisers, and functional body temperature test meters to last a day's work. The procurement of the expected equipment and resources increased the project budget. Observance of social distancing, avoidance of large gatherings, and adherence to COVID-19 regulations gazetted by governments informed the COVID-19 strategy. This also led to the removal of focus group discussions from the data collection process. This strategy was presented and discussed with the enumerators' induction process at workshops conducted before data collection.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the findings of the study, structured around five main research objectives:

1. To assess smallholder dairy farmers' perceptions of climate change in Zimbabwe
2. To determine the factors influencing dairy farmers' perceptions of climate change
3. To identify the current climate change adaptation and coping strategies employed by smallholder dairy farmers and the factors influencing their adoption
4. To identify mitigation-based CSA practices and the factors influencing their adoption
5. To determine the overall factors influencing the adoption of CSA practices by smallholder dairy farmers.

The presentation of results follows a logical sequence. The chapter begins with the socio-demographic characteristics of smallholder dairy farmers, followed by findings from the baseline survey questions. Results on farmers' perceptions of climate change and the factors influencing these perceptions are then presented, addressing research objectives one and two.

The subsequent section focuses on the adoption of climate change adaptation and mitigation CSA practices, including the factors influencing their uptake. In this study, the assessment of adaptation and mitigation practices is presented separately to allow for clearer analysis. The final section of the chapter examines the key factors influencing farmers' decisions to adopt CSA practices, integrating findings across the study objectives.

4.2 Household characteristics and descriptive statistics

The socio-economic characteristics of the sampled smallholder dairy farmers, at both household and farm level, are presented in Table 4.1.

Table 4.5 Household socio-economic characteristics of respondents

Socio-economic characteristic	Mean $\pm$ SD
Age of household head (<i>year</i>)	49.54 $\pm$ 14.98
Size of household (<i>people</i>)	5.73 $\pm$ 3.05
Number of cows per household (<i>cows</i>)	5.55 $\pm$ 4.20
Dairy farming experience (<i>years</i>)	20.67 $\pm$ 13.96
Total income/month (<i>farm plus non-farm, USD</i>)	128.00 $\pm$ 145.67
Total income/month from dairy farming (<i>USD</i>)	119.42 $\pm$ 156.04

Note: USD is the United States Dollar

As shown in Table 4.1, the average age of household heads was 49.54 years (SD = 14.98). This suggests that smallholder dairy farming in the study area is largely dominated by middle-aged farmers, who are still economically active and likely to possess substantial farming experience. Greyling et al. (2023) reported an average age of 53.8 years in a study of smallholder dairy farm productivity in Eswatini. In South Africa, Manyike et al. (2025) found an even higher average age of 56.6 years in a study of livestock ownership and herd intensity, thereby suggesting varied demographic characteristics within the smallholder farming sector across southern Africa. Quddus (2018), however, found a lower average age (40.8 years) in a socio-economic analysis of smallholder dairy farmers in Bangladesh, signifying a younger generation of farmers in Asia

Male-headed households constituted 58% of the sample, while 42% were female-headed, indicating a relatively strong participation of women in smallholder dairy farming, although men remain the majority. Abiola et al. (2019) found a higher percentage of male farmers (63.64%) than female dairy farmers (36.36%) in Oyo State, Nigeria. Hence, the results of this study show comparably higher levels of women's participation in dairy farming. Contrary to these results, Arakelyan (2018), however, found a higher percentage (53.3%) of respondents were women farmers in a smallholder dairy farmer survey in Malawi.

The mean household size was 5.73 persons, which is lower than the 5.9 found by Manyike et al. (2025) in the Eastern Cape Province of South Africa. These average household sizes are relatively high and may raise concerns regarding food and nutrition security. In SSA, larger households are

frequently associated with higher dependency ratios and increased vulnerability to food insecurity, particularly under conditions of climate variability (Food and Agriculture Organization, 2023). Empirical evidence from Southern Africa shows that large household sizes can intensify pressure on household food consumption where income diversification is limited, particularly among climate-exposed smallholder farming households (Moyo, 2023). Household-level studies in Zimbabwe further demonstrate that higher dependency ratios are significantly associated with greater vulnerability to food insecurity, especially where agricultural production is the dominant livelihood source (Maketho, 2024).

However, larger households may also confer productive advantages in smallholder dairy systems by providing family labour for labour-intensive activities such as milking, feed collection, stall cleaning, and herd management. This supports earlier findings by Mareya and Barrett (2007). Recent evidence from smallholder dairy and CSA studies indicates that household labour availability significantly enhances adoption of improved dairy practices, including fodder production, manure management, and feed conservation technologies (FAO, 2021). Studies in Southern Africa further demonstrate that labour-rich households are more likely to adopt climate adaptation measures due to reduced reliance on hired labour and improved flexibility in farm management (International Food Policy Research Institute, 2023). Thus, while larger household sizes may increase consumption demands, they can simultaneously strengthen dairy productivity and adaptive capacity by enhancing family labour endowments. This suggests a dual effect that warrants contextual interpretation.

The average number of dairy cows per household was 5.55, which is relatively high for smallholder dairy systems and reflects the importance of dairy farming in the study area. In Zimbabwe, smallholder dairy farmers typically keep between 2 and 5 lactating cows under mixed crop-livestock systems, often constrained by feed availability and capital limitations (Nkomboni et al., 2014; Chamboko & Mwakiwa, 2016). Compared to these averages, a mean herd size of 5.55 suggests a relatively asset-endowed and commercially oriented smallholder segment. Empirical evidence further shows that herd size positively influences milk output, market participation, and resilience to climatic shocks, as larger herds provide risk-buffering capacity and enable reinvestment in productivity-enhancing technologies (Makate et al., 2016; Ojango et al., 2017). Therefore, the observed herd size in this study not only reflects dairy's economic importance but may also signal enhanced adaptive capacity among sampled households.

This is further supported by the average dairy farming experience of 20.67 years, indicating that most respondents are long-established dairy farmers. Farming experience is widely recognised as a critical determinant of productivity, technology adoption, and adaptive capacity in smallholder systems. Empirical evidence from Zimbabwe and Southern Africa shows that experienced farmers are more likely to adopt improved dairy management practices and climate adaptation strategies due to accumulated knowledge, social capital, and risk management skills (Makate et al., 2016). In dairy systems specifically, longer farming experience has been associated with better herd health management, improved feeding practices, and higher milk productivity (Ojango et al., 2017). Furthermore, studies on CSA adoption indicate that farming experience enhances farmers' ability to interpret climatic signals and adjust production strategies, accordingly, thereby strengthening resilience (Khatri-Chhetri et al., 2020). Therefore, the mean experience of over two decades suggests a relatively knowledgeable farming population with potentially strong adaptive capacity, although entrenched practices may also slow the uptake of novel technologies in some contexts.

The total household income averaged USD 128.00, while income from dairy farming alone averaged USD 119.42, suggesting that dairy farming is the dominant source of household income and that livelihoods are highly dependent on dairy production. In smallholder systems across Eastern and Southern Africa, dairy enterprises are widely recognised as a primary source of regular cash income due to daily or weekly milk sales, often exceeding returns from seasonal crop production (Ojango et al., 2017).

Empirical evidence further shows that high income concentration in a single enterprise, while indicative of commercial orientation, may increase vulnerability to climatic shocks, feed shortages, and market disruptions if diversification is limited (Makate et al., 2016). In the Zimbabwean context, dairy-dependent households are particularly sensitive to drought-induced feed scarcity and price volatility, which can directly affect milk output and household cash flow. Therefore, while the income structure observed in this study highlights the economic centrality of dairy farming, it also suggests potential exposure to production and market risks without diversified livelihood strategies.

Information on land size was excluded from the final analysis after the questionnaire pre-testing phase, as most respondents were unable to accurately state the size of the land they owned. This can be explained by two factors. First, landholdings are often fragmented across different

locations, including residential stands, crop fields, and communal grazing areas. Second, land sizes have progressively decreased due to subdivision and inheritance among family members. Similar challenges in accurately quantifying land size among smallholder farmers have been reported by Nyang'au et al. (2021) in Kenya.

4.2.1 Summary descriptive statistics by district

A comparison of household characteristics between Chipinge and Mutasa Districts is presented in Table 4.2.

Table 4.6: Summary descriptive statistics by district

Household characteristic	Chipinge (n=109) Mean $\pm$ SD	Mutasa (n=45) Mean $\pm$ SD	t-value	p-value
Age (years)	51.31 $\pm$ 15.80	45.16 $\pm$ 11.78	2.51	0.013*
Household size (number)	6.53 $\pm$ 3.17	3.78 $\pm$ 1.49	5.43	0.001***
Number of cows	6.29 $\pm$ 3.75	3.76 $\pm$ 4.7	4.28	0.001***
Dairy farming experience, years	25.92 $\pm$ 12.35	7.07 $\pm$ 6.94	9.90	0.001***
Total income/month (USD)	166.54 $\pm$ 201.2	90.89 $\pm$ 65.31	2.25	0.027*

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (Welch's independent samples t-test used).

The results of the independent samples t-test revealed statistically significant differences between Chipinge and Mutasa Districts across all household characteristics examined. Farmers in Chipinge were significantly older than those in Mutasa ($p = 0.013$). Household size was also significantly larger in Chipinge ($p < 0.001$). Similarly, the number of cows owned differed significantly between the two districts ($p < 0.001$). Dairy farming experience showed the most substantial difference, with Chipinge farmers having significantly more years of experience compared to Mutasa farmers ($p < 0.001$). Total household income was also significantly higher in Chipinge than in Mutasa ($p = 0.027$). These findings suggest notable socioeconomic differences between the two districts,

which may influence the adoption of climate-smart agricultural practices. Overall, respondents from Chipinge District consistently exhibited higher mean values compared to those from Mutasa District across most variables. Chipinge farmers were, on average, older, had larger household sizes, owned more dairy cows, had significantly longer dairy farming experience, and reported higher total household incomes. These differences suggest that dairy farming is more established and commercially oriented in Chipinge District, whereas Mutasa appears to have a relatively younger and less experienced dairy farming population.

4.2.2 Age distribution of respondents

Using age class intervals as follows: 17-35; 36-50; 51 and above, the findings reveal that the majority of respondents were concentrated in the mid-age (36-50 years) and older age (51 years and above) categories, accounting for 41.8 and 42.5%, respectively (Figure 4.1). This pattern reflects the well-documented ageing trend within the agricultural sector across sub-Saharan Africa. Recent studies confirm that farming populations are increasingly dominated by middle-aged or older individuals due to out-migration of youth and declining interest in agricultural livelihoods (Debnath & Kumar, 2022; Zulu et al., 2023).

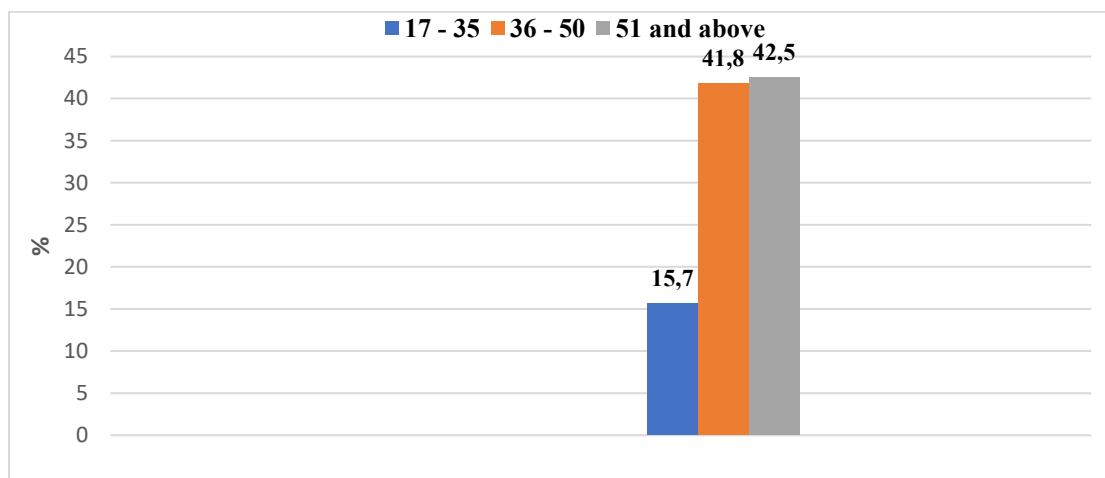


Figure 4.2: Segregation of respondents by age groups

Only 15.7% of respondents were classified as young farmers, demonstrating limited youth participation in smallholder dairy farming. This low representation of youth aligns with recent research results indicating pervasive youth disengagement from agriculture in sub-Saharan

contexts (Mwanza, 2025). Youth are often constrained by limited access to land, capital, and markets and perceive farming as less profitable than alternative employment.

Disaggregation by district (Figure 4.2) revealed significant differences. Chipinge had a substantially higher proportion of older farmers (36.4%) compared to Mutasa (6.5%), indicating a relatively older farming population in Chipinge. In contrast, Mutasa recorded a higher proportion of young farmers (11.7%), suggesting comparatively greater youth involvement in dairy farming. Chipinge had only 3.9% of respondents in the young category. The proportion of mid-age respondents was relatively similar across districts, indicating comparable participation among economically active age groups.

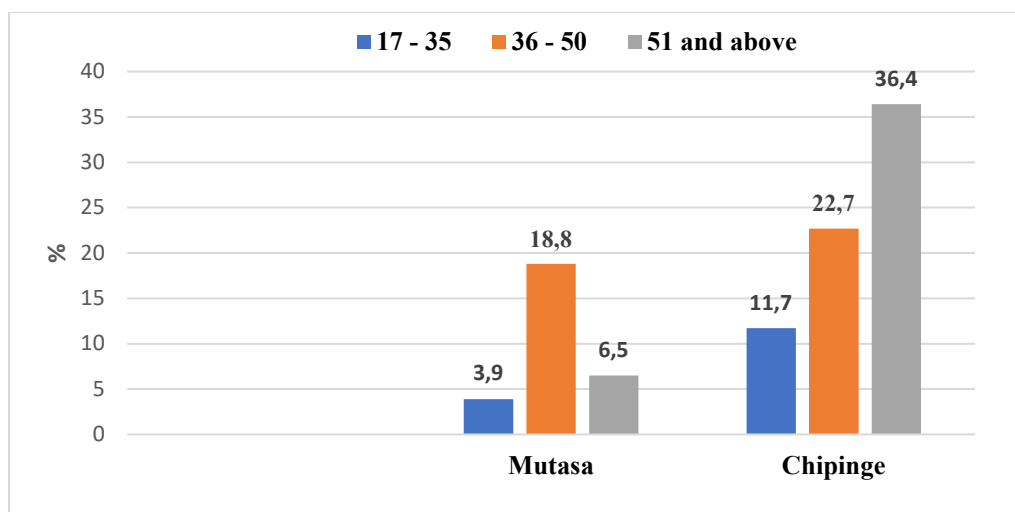


Figure 4.3: Segregation of respondents by age groups by district

The statistical analysis confirmed that the mean age differed significantly between the two districts ($p = 0.013$), with farmers in Chipinge being older on average than those in Mutasa. Age as a demographic factor has been shown to influence agricultural decision-making and the uptake of innovation, including climate-smart practices (Ngoma et al., 2025). Older farmers may rely more on traditional strategies and exhibit lower adoption rates of new technologies compared to younger farmers, who are generally more open to innovation.

From a theoretical perspective, age is frequently associated with adoption behaviour in agricultural innovation models. According to Rogers' diffusion of innovations framework, younger farmers

tend to adopt new technologies more rapidly due to higher risk tolerance, greater access to information, and longer planning horizons. Young people’s familiarity with digital extension platforms and climate information tools can be an asset in enhancing CSA uptake. Conversely, older farmers may be constrained by risk aversion and limited exposure to novel inputs or practices. Thus, the relatively lower proportion of young farmers, particularly in Chipinge, could influence the pace of adoption of climate-smart dairy practices in the study area. This finding is consistent with evidence from smallholder systems where age dynamics shape innovation diffusion and resilience outcomes (Olabanji & Chitakira, 2025).

4.2.3 Educational attainment of respondents

More than half of the respondents (54.6%) had attained secondary level education (Figure 4.3). A notable proportion (16.1%) were illiterate, while 21.1 per cent had completed primary education. Only 8.2% of respondents had attained a tertiary education (college or university).

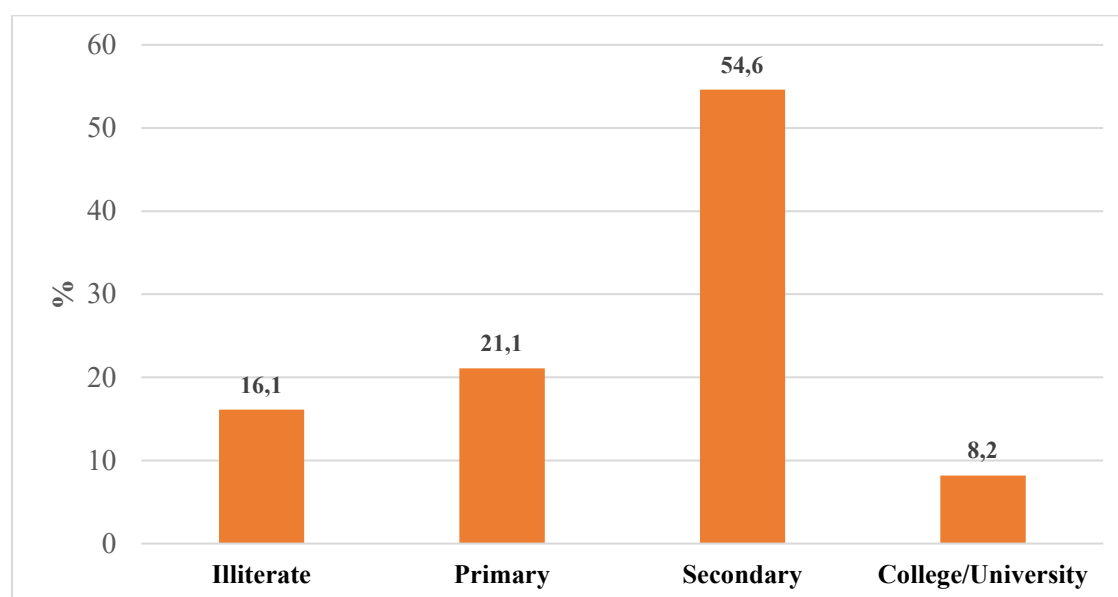


Figure 4.4: Segregation by level of education attained

Marked differences were observed between districts (Figure 4.4). Mutasa district had a substantially higher proportion of respondents with secondary education (90.2%) compared to Chipinge (47.6%). Interestingly, no respondents in Mutasa were found to be illiterate or to have attained only primary education, suggesting comparatively higher educational attainment among dairy farmers in the district.

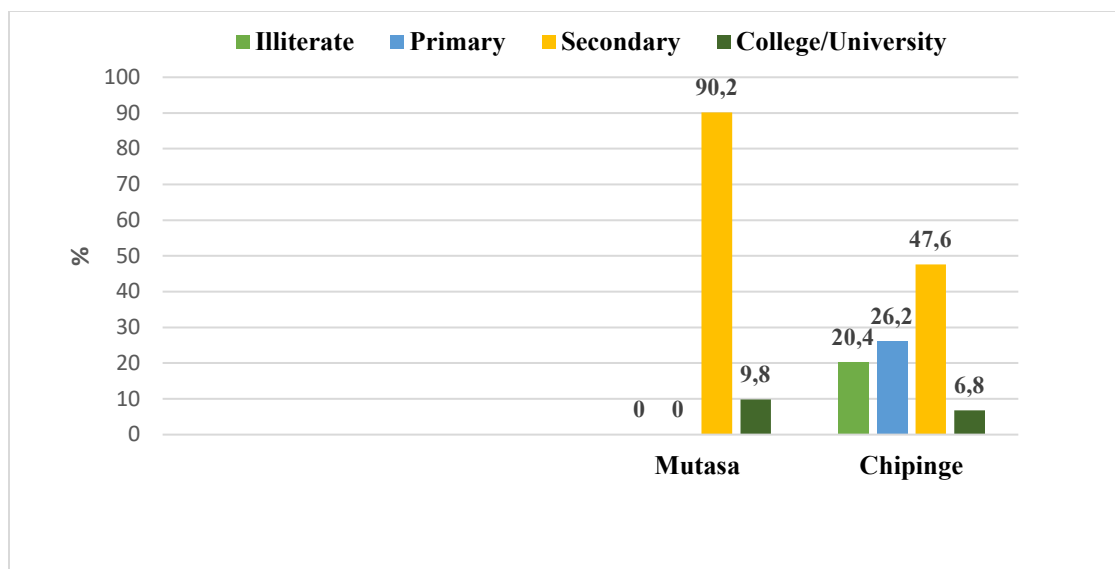


Figure 4.5: Segregation of respondents by level of education attained by district

The chi-square test revealed a statistically significant association between district and educational attainment ($\chi^2 (3, N = 154) = 30.86, p < 0.001$), indicating that education levels differ meaningfully between Chipinge and Mutasa Districts. The effect size (Cramér's $V = 0.45$) indicates a moderate-to-strong association, suggesting that district context is substantially linked to differences in the distribution of human capital. Interestingly, no respondents in Mutasa were found to be illiterate or to have attained only primary education, suggesting comparatively higher educational attainment among dairy farmers in the district. The lowest level of education in the Mutasa District was at secondary (90.2). Chipinge showed greater variability, including illiteracy and primary education levels. These differences may reflect underlying socioeconomic, infrastructural, or historical disparities between the districts. From a development and agricultural innovation perspective, educational attainment enhances farmers' ability to interpret extension messages, access climate information services, and evaluate new technologies. Education strengthens cognitive processing, reduces uncertainty, and improves risk assessment in technology adoption decisions.

Within the framework of Diffusion of Innovations theory, education accelerates the progression movement from awareness to decision and implementation. In the context of CSA, education facilitates understanding of climate risks, adaptive strategies, and long-term sustainability investments. Consequently, higher educational attainment in Mutasa may enhance adaptive

capacity and improve the potential for CSA adoption outcomes compared to Chipinge. Empirical evidence confirms that farmers with higher educational attainment are more likely to adopt CSA practices due to improved access to information, enhanced analytical capacity, and stronger engagement with extension services (Kurgat et al., 2020; Waaswa et al., 2024). According to Antwi-Agyei et al. (2021), education improves understanding of climate risk and adoption pathways. Omotoso et al. (2024) add that human capital is a key driver of agricultural adaptation in SSA. These findings underscore the importance of targeted capacity-building programs, especially in districts with lower formal education levels, to promote equitable technological diffusion and climate resilience

4.2.4 Survey evidence on structural and management-related constraints

Table 4.3 summarises responses to key survey questions related to pasture and feed management, milk production, manure management, agroforestry, animal health, and supply chain efficiency. The responses reveal several structural and management-related constraints that affect productivity and contribute to elevated methane emissions, while also highlighting potential mitigation entry points at the household level. Table 4.3 summarises the survey responses to the survey questions and the observations on the constraints and barriers.

Table 4.7: Main survey questions and summary of responses

Question	Proportion of responses	Observation on constraints and barriers
<i>Pasture and feed management</i>		
What type of grazing do you practice?	Free grazing in pasture: (39.5%); Free grazing in communal land: (53.3%); Semi-zero grazing: (28.9%); Zero grazing: (0.0 %)	A high dependence on free grazing in communal land (53.3%) increases risks (diseases, heat stress, grazing space and land degradation).
Do you make conserved feeds (e.g. hay)?	Only 17% of the respondents did not make conserved feed.	Poor-quality conserved feeds with low digestibility increase methane emissions per unit of production (cow).
Do you regularly experience a shortage of feed?	Almost all respondents (99.3%) expressed regularly experiencing a shortage of feed.	Regular feed shortages affect productivity, herd health and ultimately increase methane emissions per cow.
Do you have enough fodder for your animals for the whole year?	81.2% of respondents reported not having enough fodder for their animals.	Lean periods affect productivity, and cows are vulnerable to diseases during these periods.
Do you purchase crop by-products during the year (as feed for dairy animals)?	The majority (68.2%) of respondents do not purchase crop by-products.	Crop by-products contribute significantly to feed availability, dairy cow productivity and methane emission reduction.
Do you use feed concentrate?	Only 16.2% of respondents use feed concentrate.	Feed concentrate improves the nutritional value of feed and enhances productivity and helps reduce methane emissions per kilogram of milk.

Milk production

Do you plan to increase the milk you produce?	Almost all respondents (99.3%) plan to increase the amount of milk they produce.	Despite the challenges, farmers still want to improve animal husbandry practices to increase milk production.
Do you think they are serious constraints to dairy farming on the farm?	Almost all respondents (99.3%) think there are serious constraints to their dairy farming activities. Among the constraints are the high cost of feed concentrate, shortage of feed, high disease incidence level, and shortage of water.	The mentioned constraints affect productivity, farmers' income, and ultimately increase methane emissions as cows lack adequate nutrition for efficient milk production.

Manure management

Most common manure storage system?	Dry lot/heap: 83.1% Pit storage: 16.9%. The majority (83.1%) keep their manure as dry lots or heaps.	Poor management and uneconomic use of manure lead to loss of income and increased methane emissions
Biogas production from manure?	No respondent produced biogas.	This presents both a challenge and an opportunity. A challenge of increased methane emissions. An opportunity to promote biogas production to produce clean energy for domestic and farm use.

Agroforestry

Are you involved in agroforestry work?	Agroforestry is not a prominent practice, as only 23.4% of respondents reported being involved in agroforestry work.	Smallholder dairy farmers are generally not fully aware of the benefits of agroforestry for their dairy activities (for example, forage trees and shade trees) and the environmental benefits (for example, carbon sequestration, reducing soil
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		erosion, fixing nitrogen in soils).
<i>Animal health</i>		
Did you see any diseased animals on the farm in the last 12 months?	The percentage (35.9%) of respondents mentioned noticing diseased animals.	Although not very high, the percentage of respondents noticing diseased animals still signifies a constant threat to herd health. Diseased animals are less productive and have higher methane emissions than healthy animals.
<i>Supply chain</i>		
Do you have difficulties selling your milk?	71.5% of respondents did not experience difficulties selling their milk.	Difficulties in selling milk affect farmers' income and ultimately contribute to food loss and waste.
Do you have your milk rejected by the MCC?	Almost half (49.0%) of the respondents stated that their milk was rejected by the MCCs.	Quality and hygiene issues often affect farmers at MCCs, as a result, other dairy farmers end up selling their milk through informal markets.
Experience delays in being paid for milk sold?	No major issues with payments as only 10% of respondents mentioned delays in payment for their milk.	Delayed payments affect farmers' cash flow and can delay purchasing of other inputs, such as vaccines, feed, and other necessary dairy equipment.
Are there incentives at your local MCC when delivering milk in low season?	A fraction of the respondents (32.2%) stated that there are incentives for delivering high-quality milk.	Incentivising farmers for high-quality milk is both motivational and rewarding, but the way it is done should be transparent.

The responses to the survey questions reveal critical entry points for designing and implementing mitigation-based CSA practices that can reduce emissions of greenhouse gases at the household level while at the same time improving profitability of the dairy enterprises, as they are discussed as per the subheadings below.

4.2.4.a Feed production and management

Feed shortage emerged as one of the most critical challenges facing smallholder dairy farmers in the study area. Almost all respondents (99.3%) reported experiencing regular feed shortages (Table 4.3). Grazing systems were dominated by free grazing on communal land (53.3%) and free grazing on private pasture (39.5%), with only 28.9% practising semi-zero grazing and none practising full zero grazing. The heavy reliance on communal grazing areas exposes dairy cattle to multiple production and health risks, including overgrazing, heat stress, disease transmission, and seasonal feed scarcity. Communal grazing systems are often characterised by limited pasture management, high stocking densities, and competition for the available forage resources. During the dry season, communal pastures become severely depleted, exacerbating feed shortages and resulting in poor animal nutrition. These conditions compromise body condition, reproductive performance, and milk yield, thereby reducing overall herd efficiency. In extensive grazing systems, poor-quality forage and irregular feeding contribute to lower feed digestibility and inefficient rumen fermentation. This inefficiency increases enteric methane emissions per unit of milk, as undigested fibre undergoes prolonged anaerobic fermentation in the rumen. Findings from other studies show that low-quality diets and irregular feeding patterns are associated with elevated methane output in smallholder systems (Smith et al., 2021; Zhang et al., 2023). Improving feed quality is therefore central to reducing greenhouse gas intensity in dairy production. The heavy reliance on communal grazing areas exposes dairy cattle to multiple production and health risks, including overgrazing, heat stress, disease transmission, and seasonal feed scarcity. Communal grazing systems are often characterised by limited pasture management, high stocking densities, and competition for available forage.

Zero grazing (cut-and-carry systems), by contrast, offers a structured alternative that can enhance both productivity and environmental sustainability. In zero-grazing systems, fodder is harvested and transported to confined animals, enabling better control over feed quality, nutrient balance, and intake. Evidence from smallholder dairy systems shows that zero grazing improves dry matter intake, feed conversion efficiency, and milk production when high-quality fodder is consistently

available (Mapiye., 2022). High-quality diets increase rumen efficiency and reduce methane emissions per unit of milk through improved feed utilisation. From a climate change perspective, zero grazing aligns with the three pillars of CSA. Productivity enhances the production of improved fodder quality, while controlled feeding also increases milk yield and animal health outcomes compared to unpredictable communal grazing. By buffering animals against seasonal forage scarcity and by reducing vulnerability to drought and heat stress, which are intensifying under climate change, zero grazing enhances the adaptive capacity of dairy systems. Zero grazing enhances feed conversion efficiency, thereby providing mitigation benefits by lowering emissions per unit of product.

Empirical studies increasingly support the potential of zero-grazing systems to reduce emissions intensity in smallholder contexts. For example, Raji et al. (2024) observed significant declines in methane intensity when dairy cattle diets included higher proportions of cultivated fodder species. Similarly, Zhang et al. (2023) found that structured feeding systems reduced methane output compared to traditional communal grazing. However, adoption of zero grazing is not automatic. It requires access to land for fodder production, labour for harvesting and feeding, and knowledge to manage confinement systems. Education, extension support, and institutional incentives play crucial roles in enabling farmers to adopt and sustain zero-grazing systems. Zero grazing (cut-and-carry systems), by contrast, offers a structured alternative that can enhance both productivity and environmental sustainability. In zero-grazing systems, fodder is harvested and transported to confined animals, enabling better control over feed quality, nutrient balance, and intake.

From a climate change perspective, zero grazing aligns with the three pillars of CSA: productivity enhancement, climate adaptation, and mitigation. On productivity, improved fodder quality and controlled feeding increase milk yield and animal health outcomes, compared to unpredictable communal grazing. In terms of adaptation, zero grazing can buffer animals against seasonal forage scarcity, reducing vulnerability to drought and heat stress, which are intensifying under climate change. Mitigation is also enhanced by feed conversion efficiency. By improving the conversion efficiency, zero grazing contributes to lower emissions per unit of product.

Despite these challenges, 83.0% of respondents reported producing and conserving hay, while 31.8% reported purchasing crop by-products for use as livestock feed. Conserved feed and crop residues represent important mitigation opportunities by improving feed availability and quality during lean periods. The use of crop by-products, supplemented with appropriate additives,

provides a cost-effective means of improving nutrient intake, forage quality and animal productivity. Improved feeding regimes enhance feed conversion efficiency and reduce methane emissions per unit of milk produced. The results suggest that strengthening farmers' capacity in crop production efficiency, feed conservation techniques, cover crops, and irrigation development could substantially improve feed availability and quality. Feed production and feed management, therefore, represent a critical mitigation leverage point for improving dairy productivity and reducing emissions in the study area.

4.2.4.b Biogas production and manure management

Manure management represents a significant GHG mitigation opportunity within smallholder dairy systems. Methane (CH₄) emissions arise both from enteric fermentation and from manure stored under anaerobic conditions, while nitrous oxide (N₂O) emissions occur during manure deposition, handling, and field application. Therefore, effective manure management is critical for reducing the emission intensity of smallholder dairy production (Wavhal et al., 2025). The majority of respondents (83.1%) stored manure in uncovered dry-lot heaps for extended periods (4-8 months) before application to crop fields. Prolonged storage under such conditions promotes anaerobic microbial activity, resulting in increased methane emissions (Zhang et al., 2023). Furthermore, more than 90% of respondents did not cover manure heaps, indicating limited uptake of improved storage practices such as covered composting or controlled aerobic systems, which have been shown to reduce methane and nitrous oxide emissions (Ward et al., 2024). Only 16.9% of respondents used pit storage, further suggesting that structured manure management remains uncommon.

None of the respondents reported using biogas technology, an integrated manure management approach that can mitigate methane emissions while producing renewable energy. Biogas systems capture methane during anaerobic digestion, converting it into usable energy (for example, for cooking or lighting) and producing nutrient-rich digestate that can improve soil fertility. Studies in smallholder contexts across East Africa and South Asia have demonstrated that biogas adoption can reduce emission intensity, enhance household energy security, and improve nutrient cycling (Kebede et al., 2016; Sharma et al., 2025). Barriers to adoption in smallholder systems typically include high upfront investment costs, limited technical expertise, and inadequate access to credit or institutional support (Park & Fufa, 2025). From a CSA perspective, improved manure management and biogas production contribute to the CSA objectives of enhancing productivity,

strengthening resilience, and reducing emissions. Biogas systems mitigate methane emissions, increase access to clean energy, and produce nutrient-rich by-products that can reduce dependence on synthetic fertilisers (Kebede et al., 2016). The adoption of such systems within smallholder dairy production, therefore, offers a pathway to climate-resilient intensification. However, realising the mitigation potential of biogas and improved manure storage requires enabling institutional and financial environments. Targeted policy incentives, extension training, and credit facilities are essential to overcome resource constraints and drive adoption among smallholder farmers.

4.2.4.c Tree planting and agroforestry practices

Adoption of agroforestry and tree-planting practices in the study area was relatively low, with only 23.4% of respondents reporting involvement. Although uptake remains modest, the presence of early adopters signals latent potential for scaling agroforestry within smallholder dairy systems. Early adopters often serve as catalysts for the diffusion of innovation by demonstrating contextual benefits, reducing perceived risks, and facilitating farmer-to-farmer learning. Agroforestry integrates trees with crops and livestock, offering multifaceted mitigation and adaptation co-benefits that align tightly with the three pillars of CSA: increasing productivity, enhancing resilience, and reducing GHG emissions. Trees contribute directly to carbon sequestration by storing carbon in biomass and soils and thereby lowering net emissions at the farm level (Mbow et al., 2020; Singh et al., 2023). This sequestration potential is especially relevant in mixed crop-livestock systems, where soil organic carbon can be enhanced beneath tree canopies and in associated root zones (van Noordwijk et al., 2021). From a mitigation perspective, improved fodder trees and shrubs can elevate forage quality by increasing crude protein and digestibility. Enhanced diet quality promotes more efficient rumen fermentation, which has been shown to reduce enteric methane yield per unit of feed intake (Beauchemin et al., 2023; Alemayehu et al., 2024). In this way, agroforestry can indirectly lower methane emissions intensity in dairy systems by improving feed conversion efficiency. From an adaptation standpoint, agroforestry enhances system resilience by diversifying productive options and buffering against climate variability. Trees improve microclimate regulation through shade provision, reduce heat stress in dairy cattle, and contribute to soil water conservation, act as a windbreak, all of which support animal welfare and sustained productivity under increasing temperature and drought pressures (Kuyah et al., 2019; Zomer et al., 2022). Furthermore, agroforestry reduces overgrazing pressure on communal

pastures by providing supplemental forage and mitigating land degradation, thereby promoting ecosystem stability (Kehinde et al., 2024).

Mburu et al. (2024) found that inclusion of multipurpose trees enhanced resilience to drought while lowering enteric methane intensity per litre of milk produced. Despite these benefits, adoption remains constrained by a range of socioeconomic and institutional factors. Barriers include limited access to quality tree germplasm, competition for land resources, lack of extension support tailored to integrated systems, and insufficient incentives for long-term investment in trees (Zhang et al., 2023; Sileshi et al., 2025). Addressing these constraints through targeted policies, farmer training, supply of appropriate tree species, and integration of agroforestry into dairy support programmes can accelerate uptake and amplify both productivity and climate outcomes. In conclusion, while agroforestry adoption is currently low in the study area, its demonstrated benefits for carbon sequestration, forage supply, microclimate regulation, and livestock performance position it as a strategic climate-smart intervention. Scaling agroforestry within dairy systems offers an integrated pathway to enhance ecological sustainability, diversify farm income sources, and contribute to climate mitigation and adaptation objectives.

4.2.4.d Supply chain efficiency

The results reveal significant inefficiencies within the dairy supply chain. Nearly half of respondents (49.0%) reported experiencing milk rejection at MCCs, while 28.5% reported difficulties selling their milk. Given milk's highly perishable nature, such bottlenecks amplify post-harvest losses, reduce realised marketable output, and undermine producer incentives. These inefficiencies are symptomatic of structural and institutional constraints that limit smallholder integration into formal dairy value chains. From an emissions perspective, value chain inefficiencies can increase emission intensity, defined as GHG emissions per unit of marketed product. When milk is rejected or unsold, upstream emissions associated with feed production, enteric fermentation, and manure management are 'wasted' relative to outputs that reach consumers. Consequently, farms with high loss rates exhibit higher emissions per litre of marketed milk compared to systems with efficient quality assurance and marketing linkages. Reducing post-harvest losses is therefore an important mitigation strategy, as it improves the output viability while lowering emissions intensity.

Only 32.2% of respondents reported receiving incentives for delivering high-quality milk, primarily in the form of price premiums. Incentive mechanisms play a pivotal role in aligning

farmer behaviour with quality standards and enhancing value chain coordination. Quality-based pricing encourages investments in improved animal health, hygiene practices, and milk handling, all of which contribute to reduced losses and higher returns (Thornton et al., 2024). Well-designed incentive structures can also foster trust between producers and MCCs, thereby strengthening contractual relations and stabilising market participation.

Within the framework of CSA, improvements in the dairy value chain efficiency contribute to all three pillars of CSA. Improved market access, reduced milk rejection at MCCs and efficient payment systems increase the farmer's realised income. This income supports reinvestment in productive assets, which in turn enhances productivity. Stable market linkages reduce vulnerability to market shocks and income volatility, thereby enhancing household resilience to climate variability and strengthening farmers' adaptive capacity (Donatti et al., 2020). By increasing the proportion of produced milk reaching consumers, value chain improvements reduce GHG emissions per litre of marketed milk, delivering climate mitigation benefits at the farm level without necessarily decreasing total production.

Incentive mechanisms that reward quality also interact with other CSA practices. For example, quality premiums have been shown to encourage better feeding practices and health management, both of which can improve feed conversion efficiency and reduce enteric methane per unit of milk produced (Frederick et al., 2024). Thus, efficient value chains not only enhance economic returns but also facilitate the adoption of climate-smart practices by altering farmers' risk-reward structures. Addressing value chain inefficiencies in smallholder systems requires investments in milk-cooling infrastructure, rapid quality testing, transport logistics, and institutional coordination among farmers, cooperatives, and processors. Strengthening extension services to support quality management and improving access to market information also enhances farmer capacity to meet quality requirements and reduce losses. Overall, the evidence indicates that improving dairy supply chain efficiency and expanding incentive mechanisms are critical entry points for enhancing farmer incomes, reducing milk loss, lowering emission intensity, and fostering a more sustainable and climate-resilient dairy sector.

4.2.5 Constraints faced by smallholder dairy farmers

The high cost of concentrate feed emerged as the most substantial constraint, cited by 78.1% of respondents (Figure 4.5). Structural feed shortages and competition for protein sources such as

soybeans have been identified as major drivers of rising livestock feed costs in low-income systems (Thornton et al., 2024). Concentrate price volatility is largely attributable to shortages of key raw materials, particularly soybeans, a primary protein source in dairy feed formulation. These shortages reflect structural interdependencies within agricultural value chains. Limited domestic soybean production, coupled with strong competition from other livestock subsectors such as poultry, piggery, and aquaculture, has intensified demand pressures and driven up feed prices. Van Frederick et al. (2024) posits that diet formulation strategies that prioritise cost-effective feed mixes can mitigate methane emissions without disproportionately increasing feed expenditures.

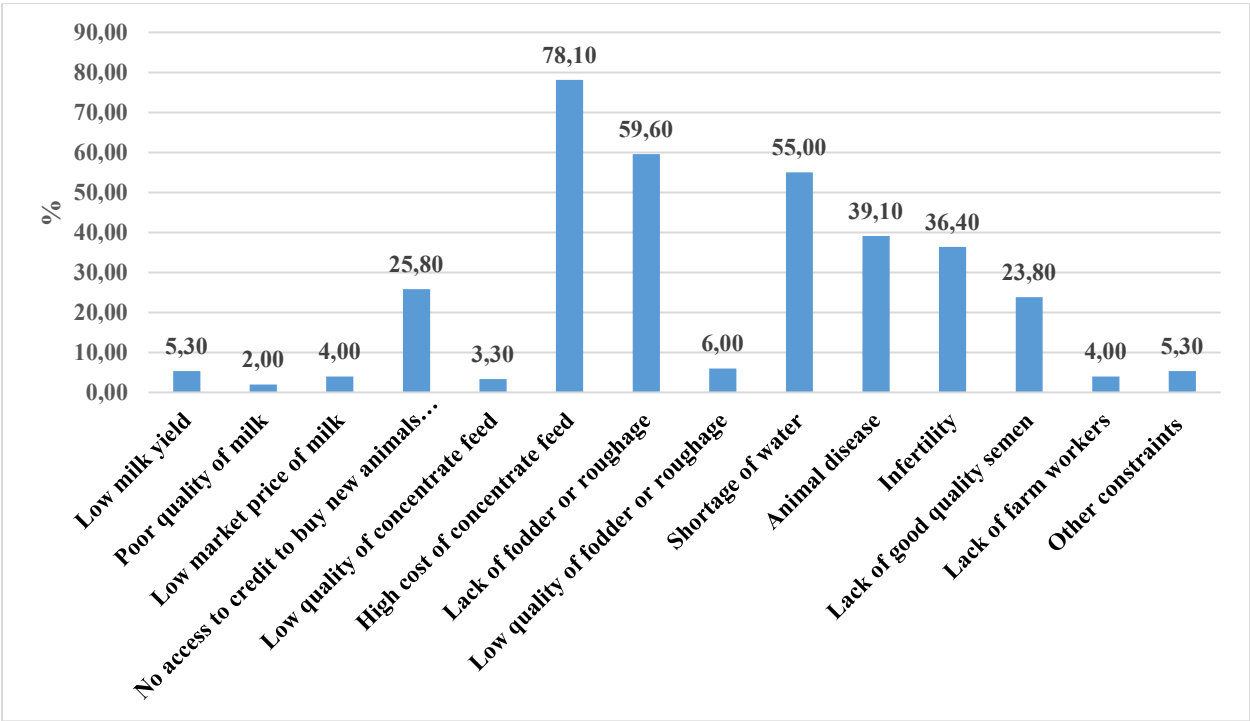


Figure 4.6: Main constraints facing smallholder dairy farmers

Zimbabwe’s reliance on imported soybeans further compounds the problem. Foreign currency shortages constrain import capacity, not only for feed ingredients but also for complementary inputs such as fuel and veterinary supplies. Dependence on imported soybeans exposes smallholder feed markets to global price volatility and foreign exchange constraints, creating systemic supply risks. Soybean market inefficiencies can limit the availability of protein ingredients critical for dairy feed quality. This macroeconomic dimension illustrates how national-

level economic instability can translate directly into farm-level production inefficiencies. Rising feed costs increase production risk, reduce profit margins, and constrain farmers' ability to adopt productivity-enhancing technologies.

Despite these constraints, farmers demonstrated awareness of the importance of concentrate supplementation for dairy productivity. The high proportion of respondents identifying feed costs as a major constraint suggests that producers recognise the productivity gains associated with improved feeding but are financially constrained from fully adopting optimal feeding regimes. This finding reflects a classic “knowledge-capital gap,” in which awareness does not translate into adoption due to liquidity limitations. Comparatively, these results differ from findings reported by Arakelyan (2017) in Malawi, where low milk prices were identified as the primary constraint. However, the present findings are consistent with Quddus (2018), who reported high feed costs as a dominant constraint in Bangladesh. These variations underscore the context-specific nature of dairy production bottlenecks, shaped by market structures, macroeconomic conditions, and input supply systems.

The lack of fodder or roughage was ranked as the second most significant constraint (56.5%). The adoption of climate-resilient forages demonstrates positive effects on livestock productivity and drought tolerance in smallholder systems (Tulu et al., 2023). The challenge of fodder shortage is closely linked to water scarcity, which was identified by 55.0% of respondents. In predominantly rainfed dairy systems, water availability directly determines fodder production capacity. Increasing drought frequency and rainfall variability in the study districts have reduced pasture regeneration and forage yields, thereby intensifying feed shortages during dry seasons. These findings reinforce earlier evidence of heightened climate variability and increasing aridity in the region. Recent empirical evidence strengthens this interpretation; for instance, the IPCC (2023), confirms that Southern Africa is experiencing increased drought intensity and intra-seasonal rainfall variability, with direct implications for pasture biomass production and livestock feed security. In addition, another study's findings show that rainfall variability in Southern Africa significantly reduces rangeland productivity, particularly in smallholder mixed crop-livestock systems dependent on unimproved natural pastures (Moyo, 2023). Similarly, recent work on climate-resilient fodder systems demonstrates that recurrent droughts reduce both forage quantity and crude protein content, exacerbating seasonal feed gaps and lowering milk productivity (Tulu et al., 2023). Evidence from literature further indicates that water scarcity not only constrains

biomass growth but also affects species composition, often favouring low-nutrient, drought-tolerant grasses over higher-quality forage species (Moyo et al., 2023). This compositional shift increases methane emission intensity per litre of milk due to reduced feed digestibility and greater enteric fermentation losses.

From a CSA perspective, fodder scarcity linked to water stress represents a systemic vulnerability affecting all three CSA pillars; reduced forage availability lowers milk yields and herd condition, thereby affecting the dairy farm's productivity. Rainfed fodder systems exhibit high climate sensitivity, increasing their exposure to drought risk and thereby affecting dairy systems' adaptation to climate change. Poor-quality forage increases methane emissions intensity per unit of milk produced, thereby increasing the dairy system's carbon footprint.

Recent CSA-focused analyses emphasise drought-tolerant forage species (for instance, *Brachiaria* hybrids), fodder banks, silage production, and water harvesting as integrated adaptation-mitigation strategies (Mwangi et al., 2024). These interventions stabilise feed supply during dry seasons, improve digestibility, and reduce methane intensity by enhancing feed conversion efficiency. In this context, the 55.0% of respondents who reported water scarcity as the major constraint is not merely a resource constraint but a structural climate-risk indicator within the dairy production system. Addressing fodder shortages, therefore, requires climate-resilient feed strategies embedded within broader water management and landscape-level adaptation planning. Such integration is consistent with evolving CSA theory, which emphasises system-level resilience and emissions intensity reduction rather than isolated technological fixes.

Beyond feed and water constraints, respondents reported animal diseases, infertility, limited access to credit facilities, and lack of high-quality semen as additional bottlenecks. These constraints interact synergistically: inadequate nutrition weakens immune function, increasing susceptibility to disease; limited access restricts investment in improved breeds and veterinary services; and reproductive inefficiencies reduce lifetime productivity per cow, thereby increasing emission intensity per litre of milk produced.

4.2.6 Constraints faced by smallholder dairy farmers disaggregated by district

The disaggregated results indicate that smallholder dairy farmers in Chipinge and Mutasa faced several production and marketing constraints, although the severity of these constraints varied considerably between the two districts. As shown in Figure 4.6, the most prominent constraint in

both districts was the high cost of concentrate feed, reported by approximately 79% of farmers in Mutasa and 77% in Chipinge, giving a combined proportion of about 78%.

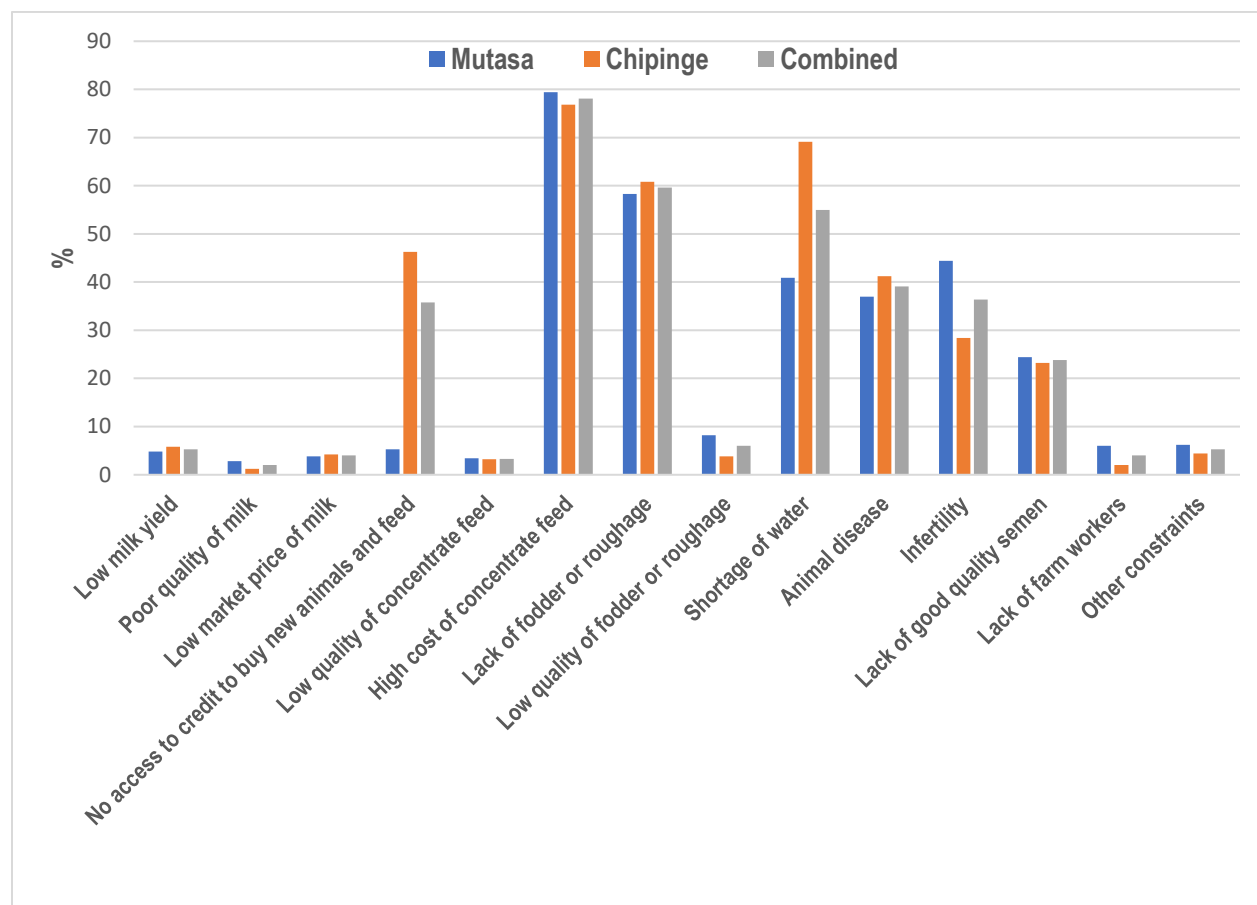


Figure 4.7: Main constraints facing smallholder dairy farmers, by district

This finding suggests that the affordability of supplementary feed remains a major limitation to dairy productivity, particularly where farmers depend on purchased concentrates to maintain milk production. The relatively high prevalence of this constraint in both districts indicates that feed costs pose a structural challenge rather than a constraint confined to a single production environment.

Fodder availability was another major constraint, although its manifestation varied across the districts. Approximately 59% of farmers in Mutasa and 61% in Chipinge, resulting in a combined prevalence of about 60%. In addition, around 8% of Mutasa farmers and 4% of Chipinge farmers

reported low-quality of fodder or roughage as a constraint. The combination of inadequate fodder availability and poor-quality roughage is particularly important because it can reduce the quantity and nutritional quality of feed available to dairy cattle, especially during dry periods. This finding is consistent with the broader results of the study, which showed that feed shortages were widespread and that farmers relied heavily on crop residues, cut-and-carry grass and conserved fodder as coping mechanisms.

A marked district difference was observed with respect to water availability. Water shortage was reported by approximately 41% of farmers in Mutasa, compared to 69% in Chipinge, making it one of the most important constraints in Chipinge. Overall, approximately 55% of the sampled farmers reported water shortage as a constraint. The substantially higher prevalence in Chipinge suggests greater exposure to water-related production challenges in that district. Water scarcity can affect dairy production directly through reduced water intake and indirectly through its effects on fodder production, pasture availability and animal health. This finding is particularly relevant to the study's climate-smart agriculture focus because farmers experiencing water shortages may require more sustainable water-management and harvesting interventions.

Access to credit also showed a substantial difference between the districts. Approximately 46% of farmers in Chipinge reported having no access to credit to purchase new animals and feed, compared with only about 5% in Mutasa. The combined proportion was approximately 36%. This large disparity suggests that financial constraints may be particularly restrictive for dairy farmers in Chipinge, limiting their capacity to invest in productive assets, purchase supplementary feed, replace or expand herds, and adopt improved dairy technologies. Limited access to finance can therefore constrain both conventional productivity-enhancing investments and the adoption of climate-smart practices that require upfront capital.

Animal health problems were reported by approximately 37% of farmers in Mutasa and 41% in Chipinge, giving a combined proportion of about 39%. Similarly, infertility was more frequently reported in Mutasa (44%) than in Chipinge (28%), with an overall prevalence of approximately 36%. These constraints indicate that productivity challenges were not solely related to feed and water availability but also involved animal health and reproductive performance. Poor reproductive performance can reduce herd replacement and expansion, while disease incidence can increase production costs and reduce milk yields, thereby weakening farmers' incentives and capacity to invest in improved production systems.

Other constraints were reported less frequently. Low milk yield affected approximately 5% of farmers in Mutasa and 6% in Chipinge, while low market prices for milk were reported by around 4% of farmers in both districts. Approximately 3% of Mutasa farmers and 2% of Chipinge farmers reported poor milk quality. Similarly, approximately 3% of farmers in each district identified low-quality concentrate feed as a constraint. These relatively low percentages suggest that farmers perceived input costs, feed availability, water and animal-related problems as more immediate constraints than milk pricing or milk quality.

The availability of labour was also not a dominant constraint. Approximately 6% of farmers in Mutasa reported a lack of farm workers, compared to only 2% in Chipinge, while other constraints accounted for approximately 6% and 4%, respectively. Overall, the findings demonstrate that the constraints facing smallholder dairy farmers were multidimensional but were dominated by high feed costs, inadequate fodder, water shortages, limited access to finance, animal diseases and infertility. Importantly, the district-level differences suggest that farmers operate under different resource and institutional conditions. Chipinge farmers experienced particularly severe constraints related to water shortages and access to credit, whereas infertility was more prominent among farmers in Mutasa. These differences have implications for the design of CSA interventions, suggesting that a uniform intervention package may not adequately address the location-specific constraints affecting smallholder dairy production.

The CSA implications for these constraints can be summarised under the three pillars, with productivity adversely affected by feed shortages, reproductive inefficiencies, and disease burdens, reducing milk yields and overall herd performance. Dependence on rainfed fodder systems heightens vulnerability to climate variability, and drought shocks weaken farm-level adaptive capacity. Lower productivity per animal increases GHG emissions intensity, as methane emissions from enteric fermentation remain relatively constant while milk output declines. Therefore, addressing feed constraints through climate-resilient fodder production, forage diversification, feed conservation technologies (e.g., silage, hay), and integration of protein-rich fodder trees could substantially improve both productivity and resilience. Similarly, strengthening access to credit and veterinary services and improving breeding technologies can also enhance technical efficiency and reduce emissions intensity per unit of output. Based on evidence from both the main survey responses and the direct assessment of constraints, Table 4.4 presents categories of CSA practices that address, directly or indirectly, the principal bottlenecks affecting smallholder dairy

production in the study area. These practices represent targeted interventions designed to enhance productivity, strengthen resilience to climate variability, and reduce emissions intensity within the dairy system.

Table 4.8: Proposed categories of climate-smart agriculture practices for improved smallholder dairy production systems in Zimbabwe

Category	Proposed CSA practice	Benefits	Constraints
Feeding practices	Use of high-quality feed, use of high-quality concentrate, use of improved feeding regimes, increased use of high-quality crop residues and additives, agroforestry options, and small-scale irrigation for feed production	Improved animal health, increased milk yield, low methane emission per litre of milk produced, increased carbon sequestration (agroforestry)	Not enough land to establish pastures, lack of access to finance to install irrigated pastures, high cost of high-quality feed, concentrate and additives.
Biogas production	Installation of biogas digesters for household energy supply	Good use of manure, a source of low-cost energy for the household, reduced methane emissions from manure heap-lots	High costs of installing biogas digesters and a lack of proper training on use and maintenance.
Manure management	Proper manure handling, storage and use	Improved crop yields, reduced dependence on inorganic fertilisers and reduced methane emissions from manure heap-lots	Lack of knowledge and lack of incentives render good manure management an unnecessary burden.
Renewable energy	Adoption of solar and wind energy in dairy production systems.	Source of energy for the household and milk storage facilities, with low running costs	High cost of installation and lack of access to finance.
Animal health	Improved animal husbandry practices, vaccination, artificial insemination and use of high-quality semen to improve herd quality	Improved animal health, improved milk yield, improved reproduction and reduced mortality,	Lack of knowledge, high costs of vaccines, communal grazing increases disease risk,

		improved breeds of cows	and poor extension services.
Supply chain	Organizing farmers to work as cooperatives or a dairy farmers' organization	Reduced transaction costs when buying inputs or selling milk, improved information sharing and improved capacity to lobby and advocate	Lack of capacity, lack of knowledge and lack of institutional support.
Tree planting and agroforestry	Promotion of tree planting and agroforestry initiatives	Improved carbon sequestration, trees provide shade for dairy cows and forage trees provide improved feed quality	Limited land, lack of knowledge and incentives.

Efficient utilisation of available feed resources, combined with improved animal husbandry practices, can enhance animal health and productivity. Healthier, more productive animals emit lower levels of methane per unit of milk produced, contributing to mitigation outcomes. Redirecting government and donor funding towards comprehensive adaptation and mitigation strategies focused on feed production and management within the smallholder dairy sector has the potential to significantly improve the sustainability, resilience, and climate performance of dairy production systems in Zimbabwe. The proposed interventions outlined in Table 4.4 emphasise the importance of sustainable water sourcing, smallholder irrigation development, improved feed production and conservation, and better herd management. Establishing self-contained pasture fields can improve control of the feeding regime while reducing disease risks associated with communal grazing. In addition, farmers with relatively larger landholdings and greater capacity may exploit feed production as a commercial opportunity, supplying fodder to other dairy farmers.

4.3 Dairy farmers' perception of climate change and adaptation of climate-smart agriculture practices in Zimbabwe

4.3.1 Respondents' knowledge and awareness of climate change

This section presents findings on smallholder dairy farmers' knowledge and awareness of climate change, and their perceptions of its impacts on dairy farming systems. Understanding farmers' climate perceptions is foundational to explaining behavioural responses and the adoption of CSA practices, as perception shapes risk appraisal, adaptation motivation, and investment decisions (Gandure et al., 2013).

Farmers' awareness was assessed through an open-ended question asking whether respondents had heard about climate change. Results show that 84.7% of respondents had heard about climate change, indicating a relatively high level of awareness. Similarly, 84.7% reported that climate change was affecting their dairy farming activities. Perceived impacts included more frequent droughts, increased flooding, erratic rainfall patterns, changes in crop field performance, and shifting disease outbreaks. The high awareness level aligns with recent empirical evidence from Southern Africa, which shows increased climate literacy among smallholder farmers, particularly in areas exposed to recurrent climate shocks (Moyo, 2023). The IPCC (2023) confirms that Southern Africa is experiencing rising temperatures, increased rainfall variability, and more intense extreme weather events, which disproportionately affect rainfed crop–livestock systems. Thus, farmers' perceptions in this study are consistent with observed climatic trends rather than mere subjective impressions.

4.3.1.a Spatial variability in perceived climate impacts

To deepen the analysis, respondents were asked to indicate perceived changes in key weather-related events over the past five years (Figure 4.7). In Chipinge District, 95.4% of respondents perceived an increase in flooding events. This finding reflects the lingering socio-economic memory of Cyclone Idai, which caused extensive damage to infrastructure, livestock, and agricultural land, as well as loss of life in 2019. Although data collection occurred approximately three years after the event, its continued salience highlights the role of extreme events in shaping climate risk perception. Studies in disaster-affected regions demonstrate that recent extreme events significantly increase perceived climate risk and can accelerate adaptation behaviour (Zebisch et al., 2021). In contrast, only 6.7% of respondents in Mutasa District reported increased flooding,

indicating strong spatial heterogeneity in the climate shocks experienced. This divergence underscores the importance of district-level agroecological differences and microclimatic variability when designing CSA interventions.

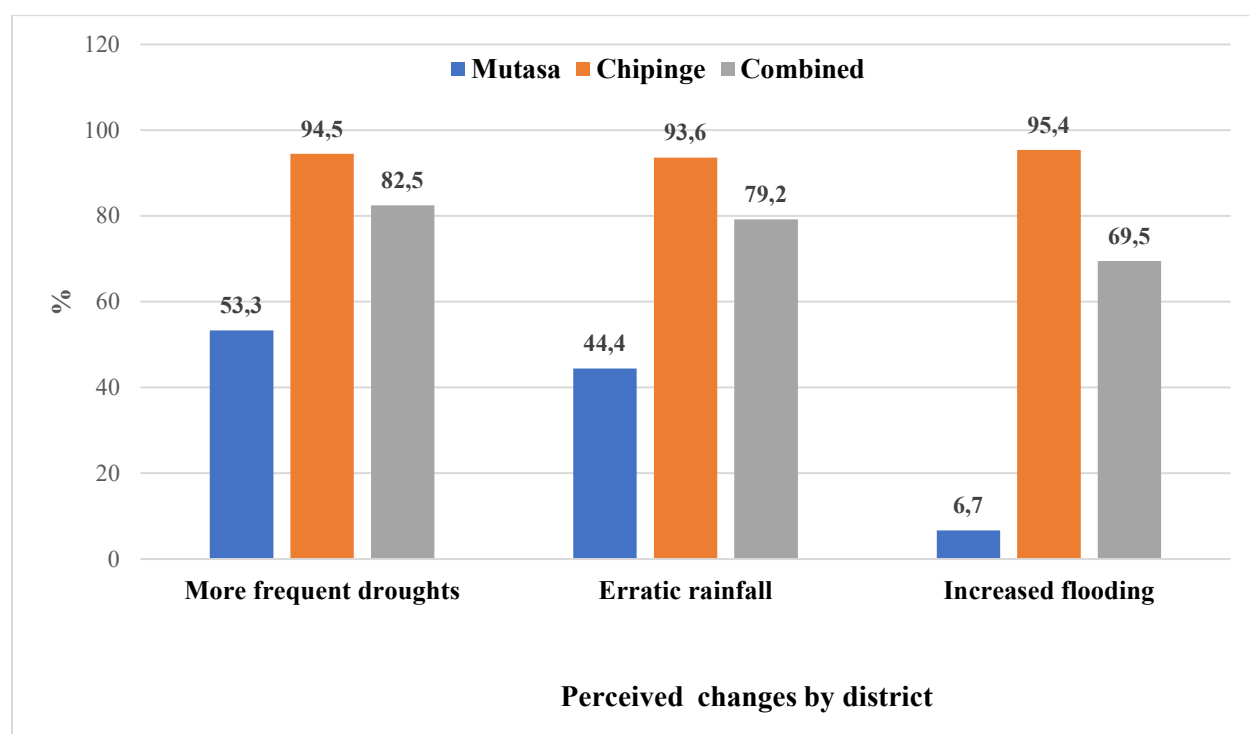


Figure 4.8: Perceived changes in regular weather patterns by district, percent of respondents (N = 154)

Erratic rainfall was widely perceived as a major constraint, particularly in Chipinge (93.6%), compared to 44.4% in Mutasa. Similarly, perceived increases in drought frequency were substantially higher in Chipinge (94.5%) than in Mutasa (53.3%). In addition to droughts, farmers reported experiencing prolonged dry spells within the growing season, which constitute a distinct climate-related challenge. Unlike droughts, which are characterised by extended periods of below-average rainfall over a season or longer, prolonged dry spells refer to extended intervals without rainfall during the cropping season. These dry spells can disrupt pasture regeneration, reduce fodder production, limit water availability for livestock, and negatively affect dairy productivity even in years with relatively normal total rainfall. The higher prevalence of perceived droughts and prolonged dry spells in Chipinge reflects the district's greater exposure to climate variability

and rainfall uncertainty. Empirical studies have shown that rainfall variability, droughts, and prolonged dry spells significantly constrain livestock production by reducing feed and water availability and increasing production risks in mixed farming systems (Thornton & Herrero, 2014; Thornton et al., 2022b). From a Climate-Smart Agriculture (CSA) perspective, farmers' perceptions of these climate-related risks are important drivers of adaptation behaviour, as households experiencing frequent droughts and prolonged dry spells are more likely to adopt resilience-enhancing practices such as water harvesting, feed conservation, improved breeds, and drought-tolerant fodder production.

4.3.1.b Perceived changes in disease outbreaks and crop field conditions

Respondents were also asked about perceived changes in disease outbreaks and crop field conditions. A notably high proportion of respondents in Mutasa District (91.1%) perceived changes in disease outbreaks, compared to 30.3% in Chipinge (Figure 4.8). This suggests that animal health challenges may be more pronounced in Mutasa and potentially linked to local agroecological conditions such as higher humidity, temperature variability, and vector ecology.

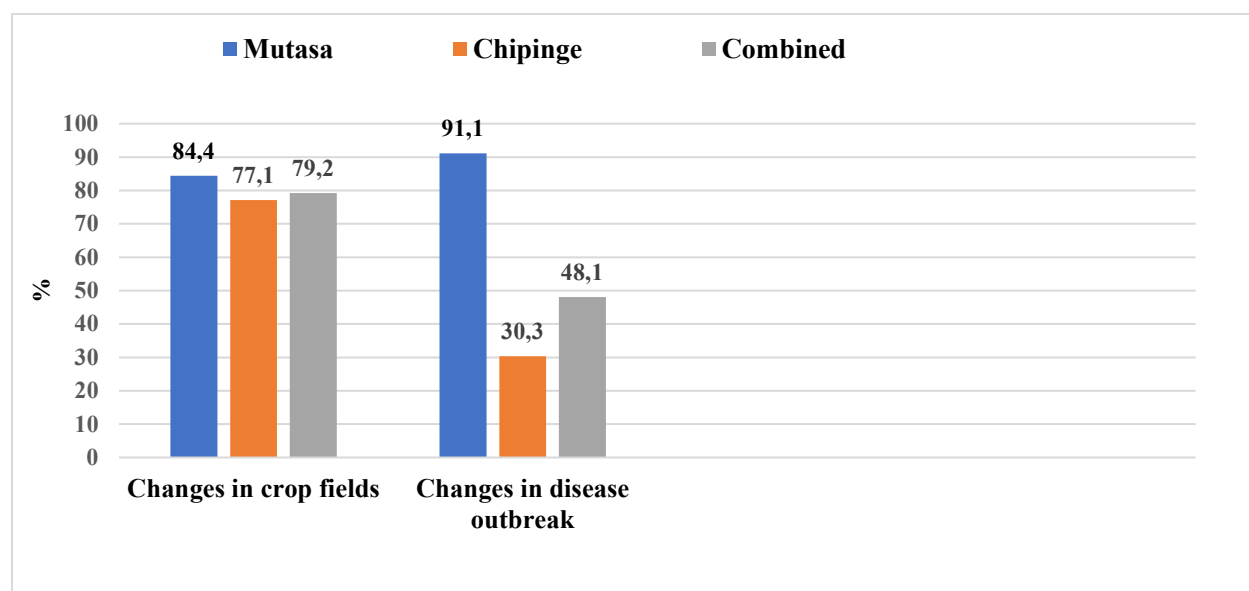


Figure 4.9: Other perceived changes by district, percent of respondents (N = 154)

The FAO (2023) reports that rising temperatures and altered rainfall patterns are expanding the geographic range of tick-borne and vector-borne diseases affecting cattle. Similarly, modelling

studies synthesised by the IPCC (2023) highlight increased risks of parasitic infections and heat-stress-related immunosuppression in tropical livestock systems. Empirical studies in Eastern and Southern Africa (Bett et al., 2022; Moyo, 2023) demonstrate that warmer and wetter microclimates can increase tick survival rates and pathogen transmission cycles, thereby elevating disease incidence in dairy herds.

The district-level contrast observed in this study may therefore reflect microclimatic differences influencing disease vectors rather than uniform national trends. From a CSA perspective, shifting disease dynamics represent a critical adaptation challenge. Animal health management, through improved housing, vaccination, tick control, and breed selection constitutes both an adaptation strategy (reducing vulnerability to climate-induced disease stress) and a mitigation co-benefit, as healthier animals exhibit improved feed conversion efficiency and lower methane emission intensity per unit of milk produced.

Perceived changes in crop field conditions were also widespread, with 84.4% of respondents in Mutasa and 77.1% in Chipinge reporting such changes. These findings suggest increasing difficulty in relying on rainfed crop production systems, consistent with earlier results on erratic rainfall and drought frequency. Declining crop performance directly affects dairy systems by reducing the availability of crop residues (for example, maize stover) traditionally used as livestock feed. There is empirical evidence that shows that rainfall variability reduces both crop yields and residue quality, thereby intensifying seasonal feed shortages in mixed crop-livestock systems (Thornton et al., 2022b). In Southern Africa, increased rainfall unpredictability has been linked to shorter growing seasons, higher crop failure rates, and declining soil moisture retention, all of which undermine fodder security.

From a systems perspective, the convergence of disease pressures and declining crop productivity illustrates the interconnected nature of climate risk in smallholder dairy systems. These perceived changes are not isolated phenomena; rather, they signal compound climate stressors affecting animal health, feed availability, and overall system resilience. Within the CSA framework, integrated responses, that combine climate-resilient fodder production, improved veterinary services, and adaptive herd management, are therefore essential to simultaneously enhance productivity, strengthen adaptation, and reduce emissions intensity. Collectively, the findings demonstrate that climate change perception among dairy farmers is both great and spatially differentiated. Importantly, farmers are not merely aware of climate change in abstract terms; they

link it directly to tangible production challenges such as droughts, floods, disease outbreaks, and declining crop performance. In CSA theory, perception functions as a prerequisite for behavioural change. Awareness alone does not guarantee adoption, but it lowers cognitive barriers to investment in adaptation and mitigation technologies. The strong perception signals observed, particularly in Chipinge, suggest favourable conditions for scaling CSA interventions such as drought-resilient fodder systems, improved manure management, agroforestry, and breed upgrading. However, district-specific climate realities imply that adaptation strategies must be context-sensitive rather than uniformly applied. Overall, the evidence indicates that climate change is not a distant or abstract phenomenon for smallholder dairy farmers in the study area. It is a lived and economically consequential reality that shapes both production decisions and future adaptation trajectories within Zimbabwe's dairy sector.

4.3.1.c Smallholder dairy farmers' perception by level of education and gender

Two socio-demographic factors, level of education and gender, were examined to assess their influence on farmers' perceptions of climate and weather-related characteristics (Tables 4.5 and 4.6).

Table 4.9: Smallholder dairy farmers' perception of weather variability by level of education

	Primary	Secondary	College/University	Other
Erratic rainfall	96.3	70.2	81.8	100.0
Generally noticed climate change	100.0	89.3	100.0	100.0
Increased flooding	96.3	57.1	63.6	100.0
More frequent droughts	96.3	72.6	90.9	100.0

4.3.1.d Perception by level of education

Overall, the level of education did not appear to significantly influence farmers' perceptions of climate variability. Across all education categories, a high proportion of respondents reported erratic rainfall, more frequent droughts, increased flooding, and general climate change. This suggests that climate variability in the study districts is sufficiently pronounced and experiential to be recognised irrespective of formal schooling. In other words, perception appears to be driven more by lived exposure than by formal climate literacy.

Empirical evidence supports this interpretation in Southern Africa, where direct exposure to climate shocks such as droughts and cyclones is often a stronger determinant of perception than

years of schooling (Moyo, 2023). The IPCC (2022) similarly notes that in highly climate-sensitive livelihoods, experiential knowledge frequently substitutes for formal climate education in shaping risk perception. Respondents with secondary education consistently reported slightly lower proportions for most characteristics, except for increased flooding. While no definitive explanation emerges from the data, this pattern may reflect variation in occupational diversification, information sources, or differing interpretations of climate terminology rather than genuine differences in exposure. Importantly, the absence of sharp perceptual divides across education categories implies that CSA awareness campaigns need not be restricted to specific schooling levels and can build upon widespread baseline climate awareness. From a theoretical perspective, CSA adoption models increasingly recognise that perception is a necessary but not sufficient condition for behavioural change. Education may influence the type of adaptation chosen (for example, more knowledge-intensive practices such as biogas systems or improved breeds), even when it does not significantly affect perception itself. Thus, while perception levels are broadly similar, education may still shape the depth of adaptation and technological sophistication.

4.3.1.e Perception by gender

Gender-disaggregated analysis shows that male respondents reported marginally higher levels of perception across most climate characteristics. However, the differences between men and women are minimal (Table 4.6), indicating that both male and female dairy farmers perceive climate and weather variability in largely similar ways.

Table 4.10: Smallholder dairy farmers’ perception of climate change by gender, % of respondents

Main characteristics	Agree	
	Male	Female
Generally noticed climate change	88.8	81.0
More frequent droughts	87.2	82.5
Increased flooding	72.1	71.4
Erratic rainfall	82.6	81.0

This finding is noteworthy in the context of gendered climate vulnerability debates. The findings of other studies show mixed evidence regarding gender differences in climate perception. In some contexts, women demonstrate higher risk awareness due to their roles in water and household food management; in others, men report higher awareness due to greater access to extension services and market networks. The FAO (2023) emphasises that gender differences in perception are highly context-specific and mediated by access to information, resources, and decision-making authority. The minimal gender gap observed in this study may reflect the commercial orientation of dairy farming in the study districts, where both men and women are actively involved in herd management and milk marketing. In such systems, climate impacts, particularly drought, fodder scarcity, and disease outbreaks, directly affect household income, making climate risks salient across gender roles.

The results suggest that perceptions of climate change are broadly shared across socio-demographic groups in the study area. High perception levels across education and gender categories provide a favourable foundation for promoting adaptation and mitigation practices. Since perception is already widespread, barriers to CSA adoption are likely structural (credit access, input costs, institutional support) rather than informational. Although perception levels are similar, gender-sensitive programming remains essential to ensure equitable access to resources, training, and technology adoption. In summary, climate variability in the study districts is a lived and observable reality transcending educational attainment and gender divisions. This reinforces the argument that adaptation strategies must move beyond awareness creation towards enabling conditions that translate perception into effective and sustained climate-smart action.

4.3.2 Perceived impacts of climate change on dairy farming activities

Respondents were further asked to assess the perceived impacts of climate change on specific dairy farming activities. Declining feed availability was identified as the most significant impact, reported by 99.2% of respondents, followed by declining water availability (96.6%) and declining milk yield (92.6%) (Figure 4.9). These findings align with broader evidence Southern Africa, indicating that feed and water constraints are the primary transmission channels through which climate variability affects dairy systems. Recent IPCC (2022) assessments confirm that drought frequency and rainfall variability are increasing in Southern Africa, with direct consequences for pasture biomass, fodder crops, and water resources. Likewise, the FAO (2023) reports that feed scarcity is the dominant climate-related constraint in smallholder dairy systems, often leading to

reduced milk yields and herd destocking. From a CSA perspective, feed availability is a cross-cutting variable that affects all three CSA pillars: productivity (milk yield), adaptation (resilience to drought), and mitigation (methane emission intensity per litre of milk). Poor-quality or insufficient feed reduces digestibility and increases enteric methane emissions per unit of output, thereby worsening emissions intensity.

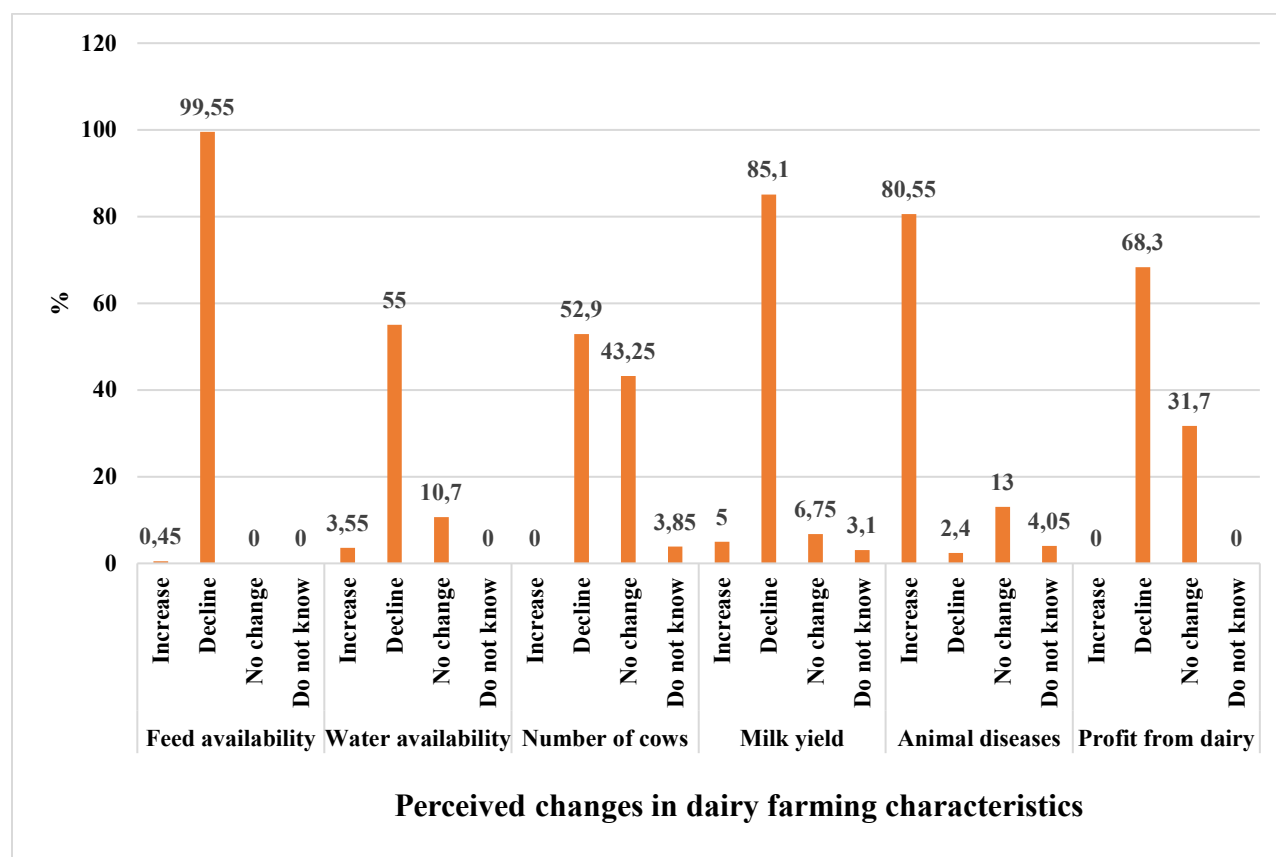


Figure 4.10: Distribution of perceived impacts of climate change on dairy farming activities, % respondents, (N = 154)

Water scarcity (96.6%) was similarly pervasive. Water constraints affect dairy systems through multiple pathways: reduced pasture growth, limited fodder irrigation, heat stress in cattle, and increased disease susceptibility. Studies show that water stress reduces dry matter intake and milk output while increasing physiological stress responses in dairy cattle (Thornton et al., 2022b). Thus, the combined feed-water nexus represents the central vulnerability node in these systems. Declining herd size was reported by 88.0% of respondents and likely reflects distress-based herd

liquidation as a coping strategy under feed shortages. While destocking may temporarily reduce feed demand and absolute methane emissions, it also reduces household income and long-term productive capacity. Increased animal diseases (70.8%) and declining milk quality (70.3%) were also widely perceived. Climate-induced shifts in vector ecology and heat stress are known to elevate disease incidence and compromise milk hygiene standards, further undermining profitability and market participation.

4.3.2.a District-level disparities

District-level analysis (Figure 4.10) revealed that perceived impacts were substantially more severe in Chipinge than in Mutasa. For example, 96.3% of respondents in Chipinge reported declining feed availability compared to 37.8% in Mutasa, where 42.2% reported no change. Similarly, water availability decline was reported by 95.4% of respondents in Chipinge, compared to 22.2% in Mutasa.

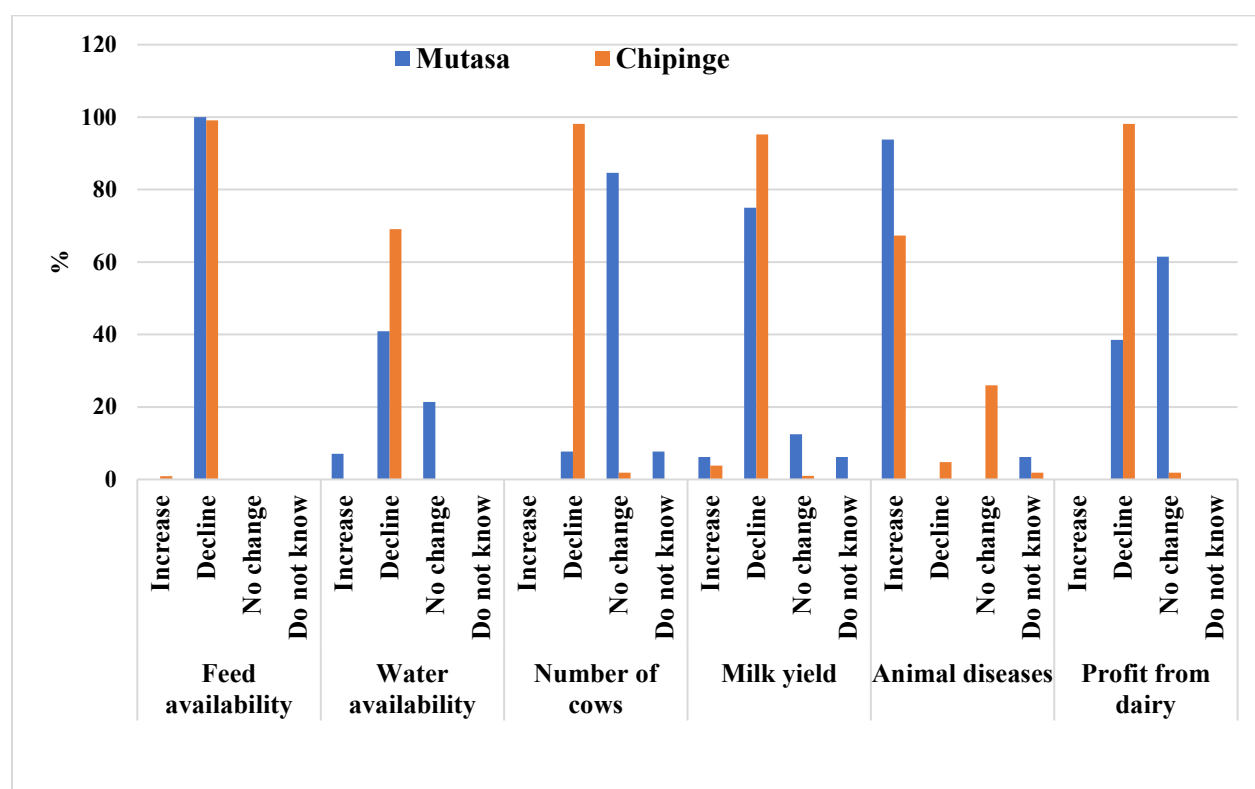


Figure 4.11: Distribution of perceived impacts of climate change on dairy farming activities by district, % respondents, (N = 109; N = 45)

These disparities indicate agroecological and climatic heterogeneity between the districts. Chipinge appears to be experiencing more acute climate stress, reflected in sharper declines in herd size, milk yield, and profit margins. Mutasa, by contrast, shows relatively more stable perceptions across several indicators, suggesting comparatively better rainfall distribution, water access, or agroecological buffering capacity. Declining herd size, milk yield, and profit margins were also significantly more pronounced in Chipinge, indicating greater vulnerability of the dairy subsector in this district. The results, therefore, point to differentiated climate risk profiles rather than uniform national patterns.

4.3.2.b Statistical significance and spatial effects

Chi-square test results (Table 4.7) showed no statistically significant association between district and feed availability. However, statistically significant associations were observed between district and all other perceived impacts ($p < 0.001$), indicating that geographic location plays a critical role in shaping climate change impacts on dairy production.

Table 4.11: Distribution of perceived impacts of climate change on dairy farming activities, % respondents, by districts (N = 154)

Dairy farming characteristics		Perceived change (% of respondents)		X ² value
		Mutasa	Chipinge	
Feed availability	Increase	0.00	0.90	0.00
	Decline	100.00	99.10	
	No change	0.00	0.00	
	Do not know	0.00	0.00	
Water availability	Increase	7.10	0.00	30.76
	Decline	40.90	69.10	
	No change	21.40	0.00	
	Do not know	0.00	0.00	
Number of cows	Increase	0.00	0.00	89.84
	Decline	7.70	98.10	
	None	84.60	1.90	
	Do not know	7.70	0.00	

Milk yield	Increase	6.20	3.80	14.84
	Decline	75.00	95.20	
	No change	12.50	1.00	
	Do not know	6.20	0.00	
Animal diseases	Increase	93.80	67.30	7.33
	Decline	0.00	4.80	
	No change	0.00	26.00	
	Do not know	6.20	1.90	
Profit from dairy	Increase	0.00	0.00	44.75
	Decline	38.50	98.10	
	No change	61.50	1.90	
	Do not know	0.00	0.00	

The absence of a significant district difference for feed availability, despite high reported declines, may reflect the near-universal perception of feed shortages across both districts, reducing variability in responses. In contrast, water availability, herd size, milk yield, disease incidence, and profit margins showed strong spatial differentiation, reinforcing the importance of context-specific adaptation planning. Climate impacts are transmitted primarily through constraints on feed and water. CSA interventions such as drought-tolerant fodder species, fodder banks, silage production, water harvesting, and small-scale irrigation should therefore be prioritised. Given the statistically significant spatial differences, uniform policy responses are unlikely to be effective. Chipinge requires urgent resilience-building interventions, while Mutasa may benefit from preventive and stabilisation strategies. Climate impacts, therefore, risk undermining progress on mitigation unless productivity-enhancing adaptation measures are implemented. Overall, the results demonstrate that climate change is materially reshaping dairy production systems in the study area, with particularly acute effects in Chipinge. The statistically significant district differences confirm that climate vulnerability is geographically differentiated and must be addressed through targeted, context-sensitive CSA frameworks rather than generic national ones.

4.4 Factors influencing smallholder dairy farmers' perception of climate change

Results presented in Section 4.4 demonstrate that climate change is materially affecting smallholder dairy systems in the study districts. Within the CSA framework, perception constitutes a critical precursor to behavioural response: farmers typically adopt adaptation and mitigation practices in response to perceived climate risks (Nyang'au et al., 2021). Empirical evidence increasingly confirms that risk perception mediates the relationship between climate exposure and technology adoption decisions (Moyo, 2023). CSA theory conceptualises adoption as the outcome of interactions among environmental, socio-economic, farm-level, and institutional drivers, as illustrated in this study's conceptual framework (Figure 1.1). The multinomial logit results (Table 4.8) provide empirical support for this integrated perspective.

Table 4.12: Factors influencing perception of climate change, marginal effect

Variable	More frequent droughts	Increased flooding	Erratic rainfall	Changes in crop fields	Changes in diseases outbreak
Age of hh head	0.002***	-0.002***	-0.004***	-0.002***	0.001***
Gender of hh head (Male)	0.012*	0.051*	0.064*	-0.079*	0.101*
Level of education of hh	-0.219	-0.012*	-0.136	-0.161	-0.040*
Number of cows	-0.010**	0.003***	0.003**	0.005**	0.010**
Access to extension services	0	0	0	0	0
Years of experience in dairy farming of hh head	0.006***	0.000***	0.001***	0.004***	-0.002***
Access to finance	-0.005*	0.012*	-0.078*	-0.095*	-0.177*
District	0.298*	0.292*	0.334*	-0.13	-0.465*
	84	106	106	122	122

Note: Abbreviations: household (hh). Average marginal effects from logit models

Table 4.8a: Model goodness-of-fit tests diagnostics (logit models)

Model	N	Covariate patterns	Pearson chi2 (df)	Prob > chi2
Drought	131	130	188.58 (121)	0.0001
Flood	131	130	188.58 (121)	0.6376
Rain variation	131	130	126.05 (121)	0.3584
Crop field	131	130	135.44 (121)	0.1745
Crop field	131	130	135.44 (121)	0.6761

Table 4.8b: Multicollinearity diagnostics (Variance Inflation Factors, VIF)

Variables	VIF	1/VIF
Gender of hh head: Female	1.17	0.852659
Level of education on hh	1.31	0.761558
Number of cows	1.22	0.820098
Access to extension services: Yes	1.02	0.98462
Years of experience in dairy farming of hh head	1.81	0.553924
Access to finance in the last 12 months: Yes	1.19	0.841408
District: Chipinge	1.74	0.576217
Mean VIF	1.35	

4.4.1 Socio-economic determinants of climate change perception

The analysis shows that the age of the household head is significantly associated with all perceived climate change indicators. Older farmers are more likely to perceive shifts in drought frequency, flooding, rainfall variability, crop field changes, and disease outbreaks. This supports experiential learning theory, which posits that cumulative exposure enhances risk recognition. The IPCC (2022) similarly emphasises the importance of local knowledge systems in identifying long-term climatic shifts. The study results suggest that in Zimbabwe's dairy systems, age strengthens the detection of climate signals.

Gender of the household head is also significantly associated with all perceived climate changes, with male farmers more likely to report climate variability. This may reflect gendered access to extension services, climate information, and decision-making authority in rural contexts. However, earlier descriptive statistics showed only small gender differences in perception levels, suggesting that while gender affects the statistical probability of reporting change, experiential exposure is widespread across both men and women. Recent synthesis by the FAO (2023) confirms that gendered differences in perception are context-specific and mediated by institutional access rather than biological vulnerability.

Level of education shows selective significance: it is significantly associated with perceptions of increased flooding and disease outbreaks, but not with drought, erratic rainfall, or changes in crop fields. This suggests that certain climate impacts, particularly those requiring interpretative or technical understanding (for example, disease epidemiology) may be more cognitively mediated than others. In contrast, drought and rainfall variability are highly visible phenomena and are less dependent on formal education for recognition.

Herd size (number of cows) is significantly associated with all perceived climate change indicators. Farmers managing larger herds face higher production risks and greater exposure to climate-induced losses, increasing sensitivity to climatic signals. This finding aligns with risk exposure theory, which predicts stronger perception among asset-intensive producers. Years of dairy farming experience that they are strongly and positively associated with all perceived climate changes. Experience strengthens adaptive capacity by improving pattern recognition and anticipatory decision-making. This reinforces the central role of experiential knowledge in shaping perception and supports behavioural adaptation models embedded in CSA theory.

Access to finance is significantly associated with all perceived changes. Financial inclusion may enhance exposure to information networks, extension programmes, and risk-management tools. Alternatively, farmers seeking credit who are already aware of climate risks and attempting to invest in adaptive responses. District of origin significantly influences all perceived climate changes except crop field changes, confirming spatial heterogeneity in climate exposure between Chipinge and Mutasa. This aligns with earlier district-level findings and underscores the importance of geographically differentiated adaptation strategies. Overall, the multinomial logit results support the study hypotheses and reinforce the proposition that farmers behave as rational

decision-makers who integrate experiential knowledge, socio-economic characteristics, and institutional access when forming climate perceptions.

4.4.1.a Model diagnostics

The goodness-of-fit statistics indicate acceptable model performance for most specifications. Pearson chi-square probabilities above conventional thresholds for the flood, rainfall variation, crop field, and disease models show an adequate fit, while the drought model shows stronger overall explanatory power. Multicollinearity diagnostics indicate low collinearity (Mean VIF = 1.35), well below the commonly accepted threshold of 5.0. This confirms that coefficient estimates are stable and not distorted by inter-variable correlations.

4.4.2 Determinants of perceived impacts on dairy farming activities

Table 4.9 presents marginal effects for determinants of perceived impacts on feed availability, water availability, disease incidence, and milk yield.

Table 4.13: Factors influencing perception of impacts on dairy farming activities, marginal effects (N = 154)

Variable	Feed availability (base: no change)			Water availability (base: no change)			Diseases (base: no change)			Milk yield (base: no change)		
	Increase	Decrease	No change	Increase	Decrease	No change	Increase	Decrease	No change	Increase	Decrease	Do not know
Age of hh head	0.0000	-0.002	0.002	0.0000	-0.003	-0.0038	-0.007*	0.0031	-0.007***	0.0031	-0.011***	0.0001
Gender of hh head: Female	0.0003	-0.045	0.045	-0.0325	-0.014	0.0375	0.0341	0.0067	-0.039	0.0343	0.044	-0.07
Household size	0.0000	0.022	-0.022	0.0000	-0.017	0.0894	0.054***	-0.0005	0.0072	0.0002	0.041**	-0.021
Number of cows	0.0000	0.001	-0.001	0.0000	0.0097	-0.0243	-0.021**	0.006	0.0080	0.0030	0.0061	0.0062
Extension contacts frequency (last 12 months)	0.0000	0.009	-0.009	0.0000	-0.022	0.1913	-0.2971	0.420	-0.0177	0.5323	-0.379	0.0644
Education of hh head: Secondary school	0.0000	-0.212	0.212	0.0000	-0.290	0.049	-0.339***	-0.01	0.0876	0.0189	-0.040	-0.198
Education of hh head: College/University	0.186	-0.266	0.080	0.0000	-0.2303	0.005	0.1301	-0.065	-0.128*	-0.0386	-0.031	-0.222

Education of hh head: Other	0.0567	-0.0567	0.0000	0.0000	-0.395***	0.008	-0.182	-0.0003	-0.1002	0.004	-0.059	-0.217
Years of experience in dairy farming	0.0000	0.006**	-0.0067	0.0000	0.009**	0.009	0.010**	-0.004	0.009***	-0.0009	0.021***	-0.008
Access to credit: Yes	-0.064	0.159	-0.095	0.0000	0.081 *	0.052	0.344***	-0.048	-0.209***	-0.023	0.044	0.043**
Perceived increase in droughts: Yes	-0.450	0.407	0.0435	-0.341	0.388	-0.072	-0.197***	0.046	0.192***			
Perceived increase in floods: Yes	0.057	0.248	-0.3045	0.098	0.332	-0.139						
Perceived increase in rainfall variability: Yes	0.033***	-0.078	0.0452							-0.046	0.176**	0.006
N	123.0000	123.0000	123.0000	123.0000	123.0000	123.0000	123.0000	123.0000	123.0000	123.0000	123.0000	123.0000

p < 0.1; **p < .05; *p < .01 Abbreviations: household (hh)*

Age significantly influences perceptions of disease incidence and milk yield but not feed or water availability. This partially contradicts the initial hypothesis. Feed and water shortages may be so widely experienced that perception is nearly universal, reducing age-based variation. Gender shows no statistically significant association with perceptions of specific impacts, reinforcing earlier findings that climate experiences are broadly shared across male- and female-headed households. Household size significantly influences perceptions of disease incidence and milk yield. Larger households may rely more heavily on dairy income, heightening sensitivity to production changes. Herd size significantly influences perceptions of disease prevalence only, consistent with exposure theory; larger herds increase the probability of observing disease outbreaks. Access to extension services does not significantly influence perceptions of assessed impacts. This is a notable finding, suggesting that extension systems may not be effectively transmitting climate-risk information or that experiential knowledge outweighs formal advisory input. Education significantly influences perceptions of water availability and disease prevalence, indicating that certain impact domains may require interpretive or technical awareness. Years of experience significantly influence perceptions across all assessed impacts, further confirming the centrality of experiential knowledge. Access to credit significantly influences perceptions of water availability, disease prevalence, and milk yield. Financially connected farmers may be more responsive to climate-related productivity signals.

4.4.2.a Influence of perceived climate variability indicators

Perceived increases in drought frequency significantly influence perceptions of disease prevalence and milk yield but not feed or water availability. This suggests that farmers cognitively associate drought more strongly with animal health and productivity than with immediate feed supply constraints, possibly because feed scarcity is already normalised. Perceived flooding does not significantly influence assessed impacts, indicating that flood events may be episodic rather than structurally embedded in dairy production risk. In contrast, perceived rainfall variability significantly influences perceptions of feed availability and milk yield. Rainfall unpredictability disrupts fodder planning, pasture regeneration, and milk production cycles, making it a critical driver of dairy system vulnerability.

Collectively, the results demonstrate that climate perception is not random but systematically shaped by socio-economic characteristics, experiential learning, financial access, and spatial

exposure. In summary, experience and herd size enhance climate signal detection, finance and education influence interpretive capacity; geographic location determines exposure intensity, and extension services appear to be underperforming in shaping perception. From a CSA perspective, these findings imply that adoption strategies must move beyond awareness campaigns financial inclusion, developing experiential learning platforms, and targeting risks at the district level. The results confirm that perception is an endogenous process shaped by rational evaluation of observed climate signals. Farmers integrate experiential evidence, socio-economic context, and environmental exposure to form perceptions that subsequently guide CSA adoption decisions. In highly climate-sensitive dairy systems such as those studied here, strengthening adaptive capacity therefore requires interventions that address both structural constraints (finance, inputs, services) and cognitive pathways (risk awareness, knowledge co-production, participatory extension).

4.5 Adoption of adaptation-based climate-smart agriculture practices by dairy farmers

Results in Sections 4.3 and 4.4 established that smallholder dairy farmers in the study area are experiencing severe climate-related challenges, particularly feed and water shortages. Within the CSA framework, such stressors trigger adaptive responses aimed at stabilising productivity and reducing vulnerability. Adaptation-based CSA practices in dairy systems primarily aim to improve feed security, water management, herd resilience, and risk buffering. This section presents findings on feed-related adaptation strategies adopted by dairy farmers and analyses district-level variation in adoption patterns. The discussion situates empirical findings within contemporary CSA and livestock resilience literature.

4.5.1 Smallholder dairy farmers' feed shortage adaptation strategies

The most common feed shortage adaptation strategy was the use of crop by-products, reported by 51.4% of respondents (Figure 4.11). The diversion of maize stover and other residues for livestock feed is a long-established coping mechanism in mixed crop-livestock systems across sub-Saharan Africa. Findings from other studies confirm that crop residue feeding remains a dominant short-term adaptation to drought-induced pasture failure (Thornton et al., 2022a).

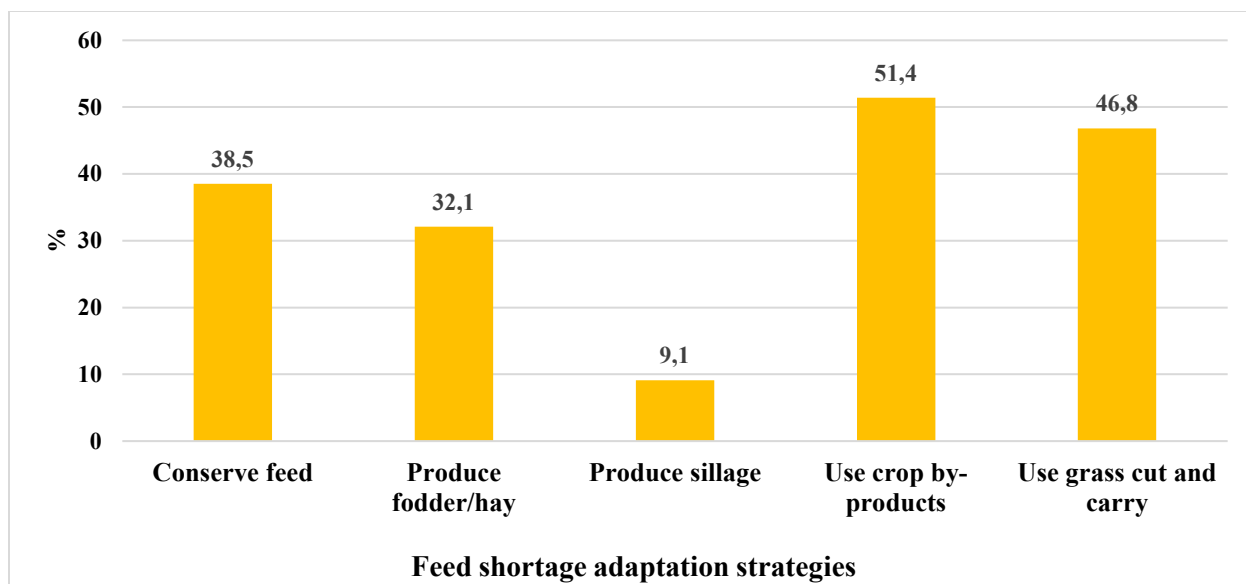


Figure 4.12: Feed shortage adaptation strategies, % of respondents (N = 154)

However, while residue use enhances short-term feed availability, it presents trade-offs. Removal of crop residues reduces soil organic matter inputs and ground cover, increasing susceptibility to erosion and declining soil fertility. The FAO (2023) cautions that excessive residue extraction may undermine long-term system resilience unless integrated with conservation agriculture practices. From a mitigation standpoint, low-quality residues typically have low digestibility, leading to higher enteric methane emissions per unit of milk produced.

The second most common strategy was reliance on cut-and-carry grass systems, mainly sourced from communal grazing areas (46.8%). While this strategy temporarily supplements feed supply, it often results in overharvesting of communal pastures and accelerated land degradation. The results of a study in Southern Africa demonstrate that unmanaged communal grazing systems experience declining biomass productivity under increasing rainfall variability (Moyo, 2023). Furthermore, poor-quality natural grasses exhibit lower crude protein content and higher fibre fractions, which increase methane intensity due to reduced feed conversion efficiency.

Feed conservation was reported by 38.5% of respondents, and fodder production by 32.1%. These practices represent more proactive and resilience-enhancing adaptation strategies. Feed conservation, including haymaking and limited silage production, improves seasonal feed availability and smoothens intra-annual feed gaps. Fodder production (for example, planted forage crops) represents a structural adaptation that reduces dependence on communal grazing systems.

Nevertheless, adoption of improved feed preservation technologies such as silage remains low. This aligns with regional evidence indicating that smallholder uptake of silage technologies is constrained by labour requirements, input costs, and technical knowledge gaps (Khatri-Chhetri et al., 2022). The IPCC (2022) emphasises that improving feed quality and preservation is one of the most effective adaptation-mitigation synergies in livestock systems, as better digestibility simultaneously enhances productivity and lowers methane emissions intensity.

4.5.1.a District-level differences in feed adaptation strategies

District-level analysis (Figure 4.12) reveals pronounced spatial heterogeneity in adaptation strategies. In Mutasa District, 95.3% of farmers relied on crop by-products, compared to 51.4% in Chipinge. Similarly, 88.8% of farmers in Mutasa depended on cut-and-carry grass systems, compared to only 4.7% in Chipinge. Figure 4.12 suggests stronger reliance on opportunistic and communal-resource-based strategies in Mutasa.

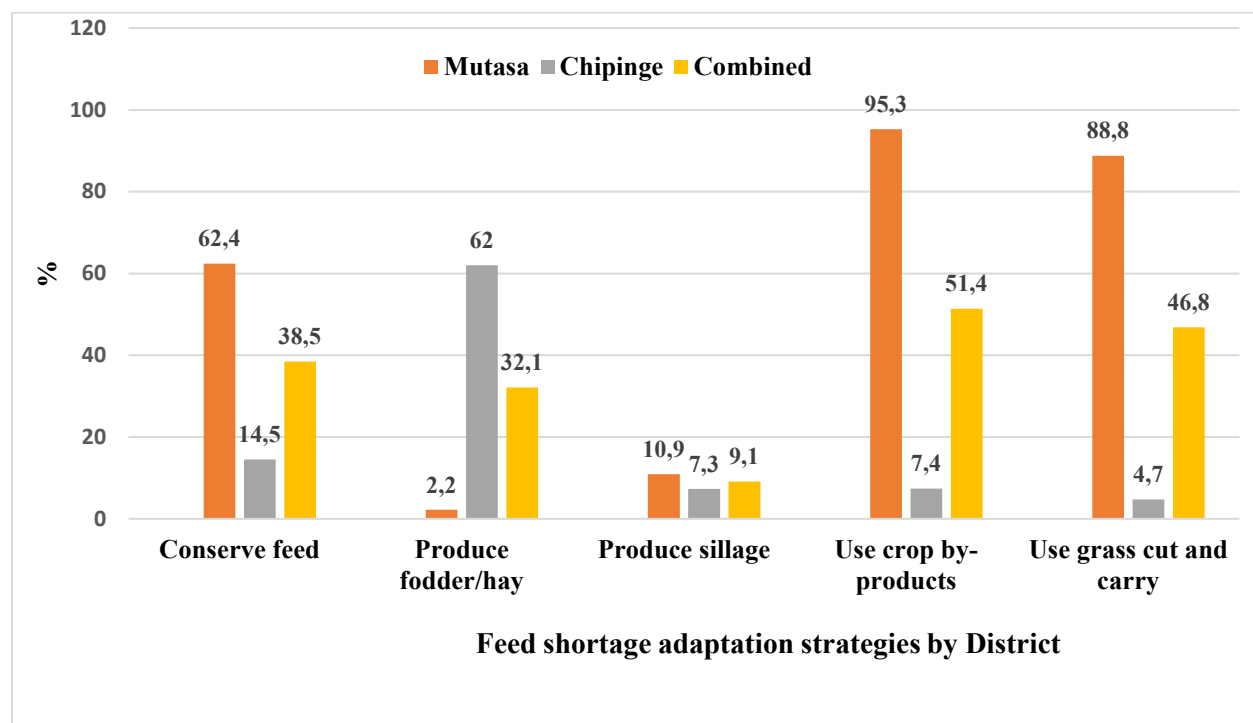


Figure 4.13: Feed shortage adaptation strategies by District, % of respondents (N = 154)

In contrast, fodder production was substantially more prevalent in Chipinge (62%) than in Mutasa (2.2%). This indicates greater adoption of planted forage systems in Chipinge, potentially as a response to more severe and recurrent drought conditions documented earlier in the study. Farmers

facing higher climate stress may be compelled to transition from reactive coping strategies toward more structural adaptation investments. Feed conservation practices were also more common in Mutasa than in Chipinge, suggesting variation in labour availability, land access, or exposure to extension services. These differences reflect agroecological variation, land tenure arrangements, water access, and climate exposure between the two districts. Chipinge appears to exhibit stronger structural adaptation (fodder production), likely due to higher perceived severity of climate risk, while Mutasa relies more heavily on communal resource extraction strategies.

4.5.1.b Implications for climate-smart agriculture theory and mitigation

From a CSA lens, fodder production and feed conservation enhance milk yield and feed stability, thereby improving productivity. Structural feed systems reduce vulnerability to rainfall variability and therefore enhance the adaptive capacity to feed shortages. Improved feed quality reduces methane emissions intensity. By contrast, reliance on low-quality residues and communal grasses may stabilise short-term feed supply but risks long-term land degradation and higher emissions intensity. The findings, therefore, suggest that while farmers are actively adapting, much of the adaptation remains coping-oriented rather than transformational. Transformational CSA in dairy systems would require scaling of drought-tolerant forage species, silage technologies, fodder banks, and integrated crop-livestock nutrient recycling systems. Overall, adaptation-based CSA adoption among smallholder dairy farmers in the study area is heterogeneous and strongly shaped by district-level climate exposure and resource endowments. The transition from reactive coping strategies to proactive resilience-building interventions remains a critical pathway for strengthening dairy system sustainability under increasing climate variability.

4.5.2 Factors influencing smallholder dairy farmers' adaptation to feed shortages

The results demonstrate that adaptation to feed and water shortages among smallholder dairy farmers in Chipinge and Mutasa districts is shaped by a combination of human, financial, physical, and perceptual factors rather than by climate exposure alone. The significant association between age and the “do-nothing” category suggests that older farmers are less likely to implement active adaptation strategies. Similar findings have been reported in Sub-Saharan Africa, where older household heads exhibit greater risk aversion and lower propensity to invest in labour- or capital-intensive climate-smart practices (Khatri-Chhetri et al., 2022). This pattern may reflect shorter planning horizons and reduced physical capacity for labour-intensive activities such as fodder establishment and silage preparation. Household size emerged as a strong determinant of

adaptation, significantly influencing feed conservation, cut-and-carry systems, and fodder production. Labour availability remains a critical constraint in smallholder dairy systems, particularly for practices requiring harvesting, transport, and storage of biomass. These findings are consistent with empirical work showing that labour endowment strongly predicts adoption of climate-resilient fodder technologies and improved feeding systems in mixed crop-livestock systems (Owino et al., 2020b). Labour-intensive practices are less accessible to households with limited family labour or financial capacity to hire workers, reinforcing structural inequalities in adaptive capacity.

Herd size also significantly influenced feed conservation and cut-and-carry practices. Farmers with larger herds face higher feed demand and greater exposure to productivity losses during drought periods. Similar relationships between herd size and adoption of improved feeding practices have been observed in East and Southern Africa (Chikwanha et al., 2024). In contrast, the use of crop residues did not vary significantly by herd size, suggesting that residue feeding functions as a low-cost coping mechanism accessible across asset categories.

Education significantly influenced several feed adaptation strategies, including silage production and feed conservation. Education enhances farmers' ability to access, interpret, and apply technical information related to feed preservation and drought management. Empirical evidence confirms that formal education positively correlates with the adoption of CSA practices, particularly those requiring technical knowledge and planning (Khatri-Chhetri et al., 2022). However, fodder production was not significantly associated with education level, suggesting that structural constraints, such as access to land and water, may override the effects of knowledge. Experience in dairy farming was strongly associated with proactive feed management strategies. Experienced farmers accumulate contextual knowledge regarding seasonal variability and drought cycles, thereby enhancing anticipatory adaptation. This finding aligns with behavioural climate adaptation literature, demonstrating that experiential learning strengthens adaptive decision-making.

Access to finance significantly influenced feed conservation, crop by-product utilisation, and silage production, underscoring the importance of liquidity in enabling adaptation. Capital-intensive strategies such as silage pits, storage facilities, and mechanised chopping equipment require upfront investment that many smallholder farmers cannot afford. Recent studies on livestock-based CSA indicate that access to credit is among the strongest predictors of adoption of improved feeding technologies (Chikwanha et al., 2022). Without financial inclusion mechanisms,

adaptation remains constrained to low-cost coping strategies rather than transformative responses. Similarly, water adaptation strategies such as borehole drilling and water storage were strongly associated with herd size and financial access. Water infrastructure investments are capital-intensive and typically undertaken by farmers with sufficient livestock assets to justify the cost. These findings are consistent with broader climate finance literature, which emphasises that smallholder adaptation is often limited by credit market failures and high transaction costs.

Perceived increases in drought frequency, rainfall variability, and flooding were significantly associated with most adaptation strategies. This confirms that adaptation is strongly mediated by farmers' subjective risk perception rather than objective climate data alone. Perception-driven adaptation has been widely documented in recent CSA research, where awareness of increasing climate variability increases the likelihood of adopting risk-reduction strategies. Notably, climate perceptions were not associated with the "do-nothing" category, suggesting that farmers who do not perceive worsening climate conditions are less inclined to adopt adaptive practices. This highlights the importance of climate information services and early warning systems in strengthening behavioural responses.

Contrary to expectations, access to extension services did not significantly influence the adoption of feed or water adaptation strategies. This finding raises concerns regarding the effectiveness of livestock-oriented climate advisory services in the study districts. Several recent reviews report similar limitations in extension systems across Sub-Saharan Africa, particularly where advisory services remain crop-focused and lack technical capacity in livestock feed management and climate adaptation. The absence of a strong extension effect suggests that adaptation decisions are driven more by experiential learning and peer networks than by formal advisory structures. Strengthening dairy-specific CSA extension services could enhance the adoption of higher-impact strategies such as silage production and climate-resilient fodder systems.

The strong association between district of residence and adaptation strategies confirms that adaptation is context-specific. Agroecological conditions, rainfall patterns, landholding structures, and water availability differ between Mutasa and Chipinge, shaping feasible adaptation options. Spatial heterogeneity in CSA adoption has been consistently documented in Southern Africa, where agroclimatic gradients significantly influence fodder productivity and feed system choices (Chikwanha et al., 2024). These findings underscore the need for place-based CSA programming rather than uniform policy prescriptions.

Overall, the results suggest that adaptation among smallholder dairy farmers remains predominantly incremental rather than transformative. Reliance on crop residues and communal cut-and-carry systems may alleviate short-term feed shortages but can exacerbate land degradation and methane intensity if not combined with improved feed quality interventions. Transformational adaptation in livestock systems requires integrated investments in climate-resilient fodder production, feed conservation technologies, water infrastructure, financial inclusion mechanisms and strengthened livestock-focused extension services. Without addressing labour and capital constraints, CSA adoption will remain uneven and structurally constrained.

4.5.3 Smallholder dairy farmers' water shortage adaptation strategies

Water scarcity emerged as a major production constraint, with 55% of respondents identifying it as a key limitation to dairy productivity. This finding is consistent with increasing evidence that water insecurity is becoming one of the most binding constraints in smallholder livestock systems under climate change in Southern Africa (Thornton et al., 2022a; Moyo, 2023). Rising temperatures, erratic rainfall, and declining surface water reliability directly affect dairy production through reduced intake, impaired rumen function and elevated heat stress. As shown in Figure 4.13, the predominant adaptation strategy, walking long distances to rivers and streams (58.9%), reflects a mobility-based coping response rather than structural adaptation. However, this strategy carries multiple productivity and health costs.

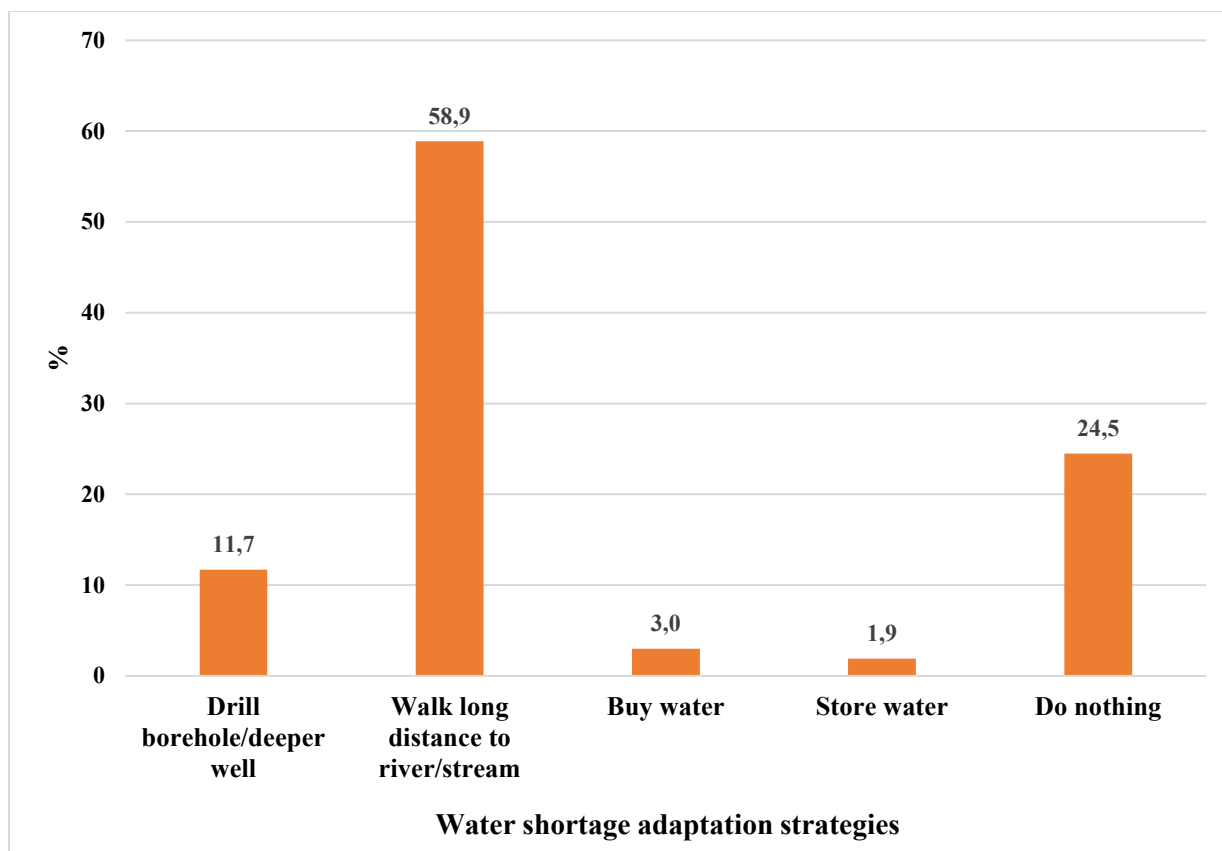


Figure 4.14: Water shortage adaptation strategies

Long-distance walking increases energy expenditure and heat stress, which reduces milk yield and reproductive performance. According to the FAO (2023), water deprivation and heat stress are among the leading drivers of reduced dairy efficiency in climate-stressed regions. Furthermore, the concentration of livestock around shrinking water bodies elevates pathogen exposure, consistent with findings linking climate variability and increased livestock disease outbreaks in Southern Africa (Moyo, 2023). Thus, while mobility enables short-term survival, it may inadvertently reduce productivity and increase methane intensity per litre of milk due to stress-induced inefficiencies.

Approximately 24.5% of farmers reported taking no action in response to water shortages. Rather than indicating indifference, this likely reflects limited financial and infrastructural capacity to implement water security measures. Water infrastructure investments such as boreholes, pumps, and storage tanks require capital outlays beyond the reach of many smallholder households. In

credit-constrained rural economies, adaptation options are frequently limited to low-cost coping strategies (Thornton et al., 2022b).

Only 11.7% of respondents invested in boreholes or deeper wells, though ownership was higher in Mutasa (15.4%) than in Chipinge (7.9%). Borehole development represents a more proactive and potentially transformative adaptation strategy, as it reduces seasonal dependence on surface water and stabilises dairy production. However, manual extraction systems common in smallholder settings are labour-intensive and may limit their scale of use. Without mechanised pumping or solar-powered systems, water extraction can divert household labour away from feed preparation, hygiene, and marketing activities. The district-level variation observed in the study likely reflects differences in hydrogeological conditions, income levels, and institutional support. Agroecological heterogeneity has been shown to shape the feasibility of groundwater-based adaptation strategies in Southern Africa (Moyo, 2023). Nearly half of respondents (49%) reported milk rejection at collection centres, which may be indirectly linked to water scarcity. Insufficient water compromises udder hygiene, equipment sanitation, and cooling practices, factors that influence microbial contamination and quality standards. This creates a feedback loop, water shortages reduce productivity and marketable output, compounding income losses. Therefore, water adaptation is not only a climate resilience issue but also a value chain competitiveness issue. District-level comparisons (Figure 4.14) reveal higher reliance on long-distance walking in Chipinge (65.8%) compared to Mutasa (52.0%), alongside higher borehole ownership in Mutasa. These differences highlight the importance of localised agro-ecological and institutional conditions in shaping adaptation pathways.

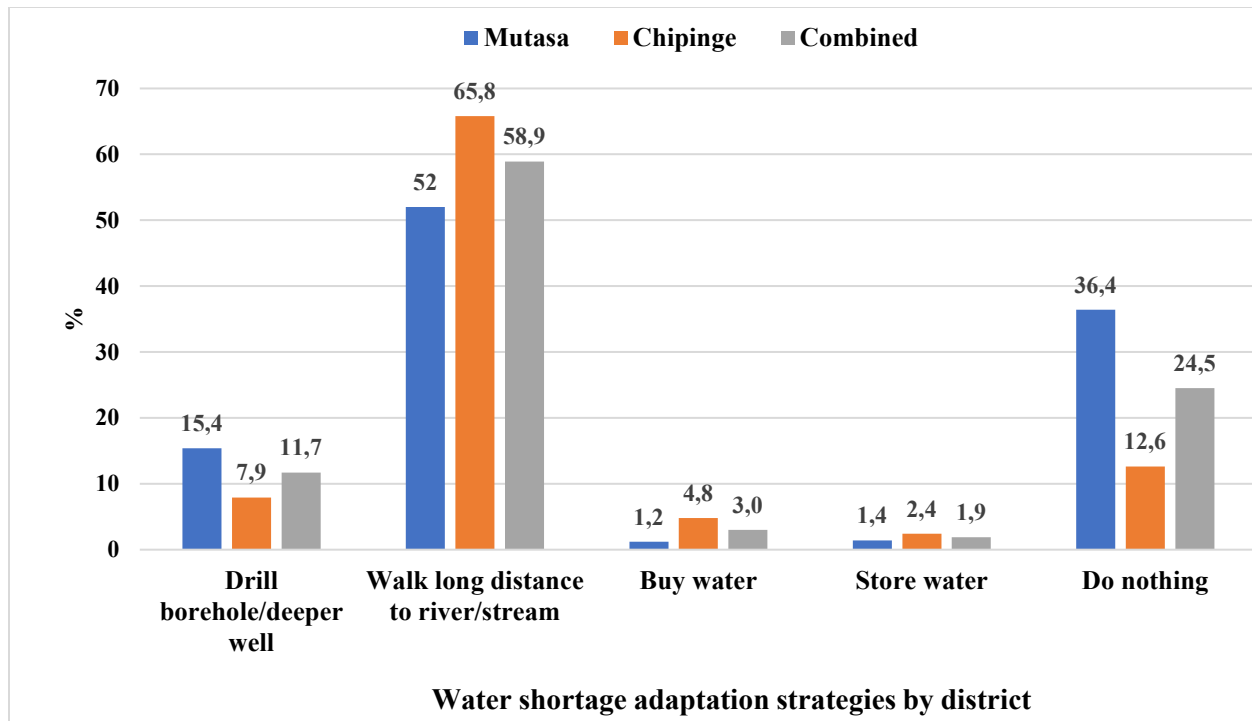


Figure 4.15: Water shortage adaptation strategies by district, % of respondents (N = 154)

Spatial heterogeneity in adaptation choices has been widely documented in CSA research, where differences in rainfall patterns, water table depth, and infrastructure access significantly influence the adoption of water security technologies (Khatri-Chhetri et al., 2022). The stronger non-adoption rate in Chipinge (36.4%) suggests higher structural vulnerability, possibly linked to deeper groundwater tables, lower income levels, or weaker institutional support. This reinforces the need for place-based climate adaptation planning rather than uniform provincial strategies. Overall, water adaptation strategies in the study districts remain largely incremental and reactive. Walking long distances for water represents coping, not systemic transformation. Transformative adaptation in dairy systems involves investment in climate-resilient water infrastructure, solar-powered pumping systems, water harvesting and storage technologies and integration of water-efficient dairy management practices. Without institutional and financial support mechanisms, smallholder dairy systems risk crossing adaptation limits. The findings point to three critical intervention areas: climate finance targeting water infrastructure, livestock-focused extension services and integrated dairy value chain support. Strengthening water resilience is essential not only for adaptation but also for safeguarding dairy-based livelihoods and nutritional security.

4.5.4 Factors influencing smallholder dairy farmers' adaptation to water shortages

Chi-square test results presented in Table 4.10 also show factors influencing the adoption of water shortage adaptation strategies. Age of the household head was significantly associated only with the do-nothing group, while gender showed no significant association with any strategy.

Table 4.14: Chi-square test results between characteristics of household head and the use of adaptation strategies, p-values

	Decrease in feed availability.					
Variables	Conserv e feed (38.5%)	Use grass cut and carry (92.1%)	Use crop by- products (51.4%)	Produce silage (9.1%)	Produce fodder/hay (9.1%)	Do nothing (38.5%)
Age of hh head	47.74	53.89	45.32	44.24	56.53	97.99***
Gender of hh head	0.76	0.02	2.71*	5.20**	0.04	0.05
Size of hh	27.22**	28.60**	9.54	21.80*	26.91**	5.75
Number of cows	24.99*	29.61**	18.2	22.92	21.94	5.18
Education of hh head	8.83**	11.79***	13.19***	8.24**	2.86	0.66
Years of experience in dairy farming	60.61***	63.03***	37.75	40.88	52.19**	14.13
Access to extension services	0.31	0.26	0.11	0	0.36	0.15
Access to finance	8.83***	0.17	7.91***	3.44*	0.27	0.01
Perceived increase in frequency of droughts	3.24*	15.26***	4.94**	0.95	8.51***	0.43
Perceived increase in rainfall variability	5.59**	11.13***	4.70**	2.97*	13.63***	0.55
Perceived increase in flooding	14.41***	39.22***	12.61***	5.26**	32.60***	0.91
Mutasa district	17.72***	48.52***	18.18***	5.36**	43.28***	0.85
Chipinge district	17.72***	52.06***	17.36***	6.16**	44.69***	0.88
	Decrease in water availability.					
Variables	Conserv e feed (38.5%)	Drill borehole/deep er well (11.7%)	Walk long distances to the river (58.9%)	Buy water (3%)	Reserve water (1.9%)	Do nothing (24.5%)
Age of hh head	50.62	34.51	45.31	49.32	24.56	82.36***
Gender of hh head	0.77	0	0.02	0.01	1.85	1.46
Size of household	33.01***	8.18	15.4	16.17	5.91	6.52
Number of cows	28.82**	30.94**	15.23	26.02*	42.81***	41.73***
Education of hh head	11.28**	0.28	3.84	3.03	10.60**	6.99*
Years of experience in dairy farming	69.16***	49.23**	39.08	49.83**	30.38	8.73
Access to extension services	0.73	0	0.47	0.42	2.2	0.15

Access to finance	3.93**	2.36	6.02**	0.05	4.85**	0.01
Perceived increase in frequency of droughts	8.88***	0	4.90**	5.52**	3.02*	0.43
Perceived increase in rainfall variability	11.07***	0.38	1.15	11.58***	1.98	0.55
Perceived increase in flooding	26.03***	0	8.69***	18.49***	9.20***	0.91
Mutasa district	35.02***	1.35	9.90***	23.93***	9.81***	0.85
Chipinge district	35.02***	1.55	10.51***	24.80***	9.50***	0.88
Number	154	154	154	154	154	154

*Note. Values are Pearson chi-square (χ^2). (N = 154). Significance is indicated by stars: *** $p < .01$, ** $p < .05$, * $p < .10$.*

Household size was significantly associated with feed conservation, while herd size influenced the adoption of all strategies except walking long distances to rivers or streams. Level of education influenced feed conservation, water reservation or storage, and the do-nothing category. Years of dairy farming experience significantly influenced feed conservation, borehole or deep well drilling, and water purchasing. Access to extension services again showed no significant influence, whereas access to finance significantly influenced feed conservation, long-distance water sourcing, and water reservation or storage. Perceived increases in drought frequency were associated with most strategies except borehole drilling and the do-nothing group. Perceived rainfall variability influenced feed conservation and water purchasing, while perceived flooding influenced feed conservation, long-distance water sourcing, water purchasing, and reservation. District of residence influenced all strategies except borehole drilling and the do-nothing category.

4.6 Adoption of mitigation-based climate-smart agriculture practices by dairy farmers

The results indicate that mitigation-based CSA practices among smallholder dairy farmers are largely adopted for productivity enhancement rather than explicit GHG reduction. Results (Figure 4.15) show that improved feeding regimes (94.5%) and animal health and breeding interventions (56.5%) were widely adopted yet primarily motivated by improvement in milk yield.

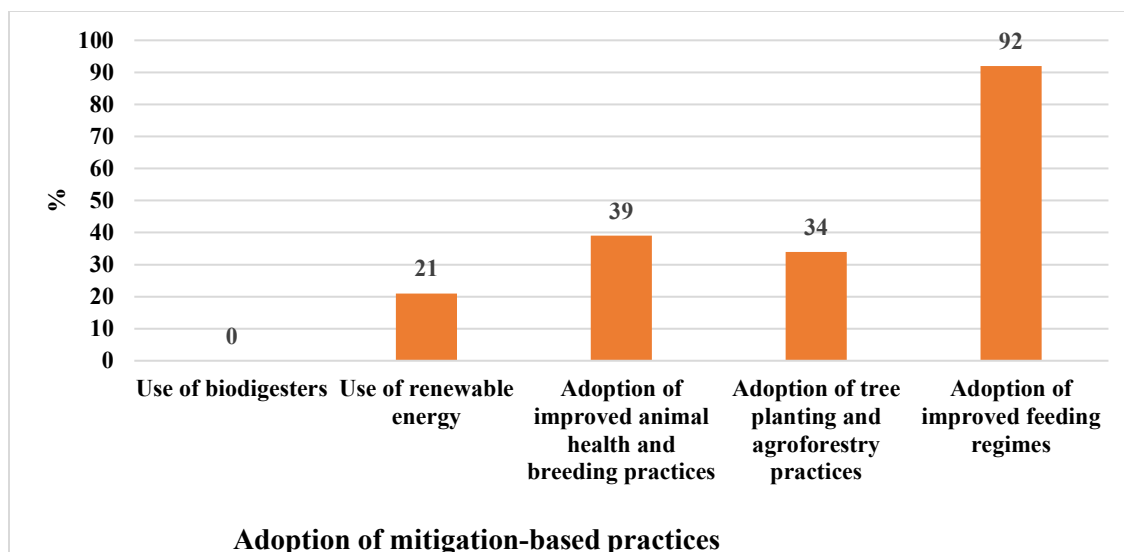


Figure 4.16: Adopted mitigation CSA practices

This aligns with livestock mitigation literature, which shows that smallholder farmers rarely adopt practices explicitly to reduce emissions; instead, mitigation occurs as a co-benefit of productivity-oriented intensification (FAO, 2023). Improving feed quality enhances nutrient digestibility and feed conversion efficiency, thereby reducing enteric methane emissions per unit of milk produced. According to the FAO (FAO), increasing feed digestibility by approximately 5% can reduce methane emissions per unit of milk output by 10 - 25%, while strategic supplementation of low-quality diets can lower emission intensity by 25 - 75% through substantial improvements in animal productivity and feed-use efficiency. Furthermore, poor-quality feeds are associated with higher methane emissions because a larger proportion of feed energy is lost during rumen fermentation. FAO estimates that up to 12% of a ruminant's energy intake may be lost as methane, with feed quality and digestibility being key determinants of emission levels. Similarly, improved dairy genetics and effective herd health management increase milk yield and production efficiency, thereby spreading maintenance-related emissions over a larger volume of milk and reducing greenhouse gas emissions per unit of output. Studies have shown that combining improved feeding regimes with superior-genetic-merit animals can reduce greenhouse gas emission intensity in dairy systems by up to 24%, with feeding improvements contributing approximately 16% and genetic improvements 9% of the reduction in emission intensity. Thus, mitigation in these systems is largely intensity-based rather than absolute, consistent with global findings in low-income dairy sectors.

4.6.1 Smallholder farmer adoption of mitigation-based climate-smart agriculture practices

Chi-square results show that adoption of concentrates, crop by-products, and feed conservation is strongly associated with access to finance, food security, district of origin and knowledge and experience. Financial access emerged as a central enabling factor, reinforcing findings from other SSA studies that show that liquidity constraints are a major barrier to low-emission feeding technologies (Tamasiga et al., 2023). Concentrates and purchased crop by-products require consistent cash flow, making them more accessible to financially stable households. Food security was also significantly associated with adoption. Food-secure households may have surplus resources and reduced exposure to risk, allowing them to invest in improved feeding systems. This supports the resilience-investment linkage identified in recent CSA scaling literature (Khatri-Chhetri et al., 2022). Interestingly, age, gender, and herd size were not significant predictors of the adoption of improved feeding, suggesting that feeding intensification may have become normalised across demographic categories in the study districts.

Adoption of improved breeds, artificial insemination (AI), and vaccination was influenced by household size, education, herd size, access to finance, food security and district of origin. The strong association between education and AI adoption confirms that breeding interventions are knowledge intensive. Artificial Insemination requires technical understanding, timing, and access to veterinary services. Recent reviews on livestock genetic improvement in Africa emphasise that education and technical support are critical determinants of uptake (Mrode et al., 2025). Herd size influenced AI adoption, suggesting that farmers with larger herds perceive greater returns from investments in genetic improvement. This reflects a shift toward semi-commercialisation in some households, particularly in Mutasa District, where adoption rates were substantially higher.

Vaccination, which showed near-universal adoption, was strongly associated with age, household size, and dairy experience. Disease prevention remains a productivity and risk management priority as shown by results of a study that highlights rising disease pressure under warming conditions (Thornton et al., 2022b). Thus, vaccination functions as both an adaptation and mitigation co-benefit strategy by improving productivity efficiency.

A striking finding is the complete absence of biodigester adoption and good manure management practices. Only tree planting and agroforestry showed limited uptake (36%). Manure management represents a significant mitigation opportunity in dairy systems, particularly through anaerobic

digestion and methane capture. Yet biogas systems remain rare in smallholder agriculture in Africa due to high installation costs, technical maintenance requirements, and limited policy incentives (Roubík et al., 2020). The absence of biodigesters in the study districts reflects high capital costs, limited technical support, weak integration of livestock and renewable energy policies, and a lack of access to carbon finance. This gap is critical, as manure methane contributes significantly to total dairy emissions. Without improved manure handling, mitigation remains partial and intensity-based rather than system-wide.

Tree planting and agroforestry (36%) offer both mitigation and adaptation benefits, including carbon sequestration, fodder provision, shade, and erosion control. Agroforestry adoption was associated with age, education, and dairy experience, indicating that long-term investments are more likely among experienced and informed farmers. However, its moderate adoption level in this study suggests land, labour, or tenure constraints may limit expansion. Renewable energy adoption (31%), notably higher in Mutasa than Chipinge (Figure 4.16), reflects adaptation to electricity insecurity rather than for climate mitigation. Solar technologies reduce reliance on fossil-based grid energy and improve the reliability of milk cooling. This aligns with growing evidence that decentralised renewable systems enhance resilience in rural dairy value chains (Dechamps, 2022).

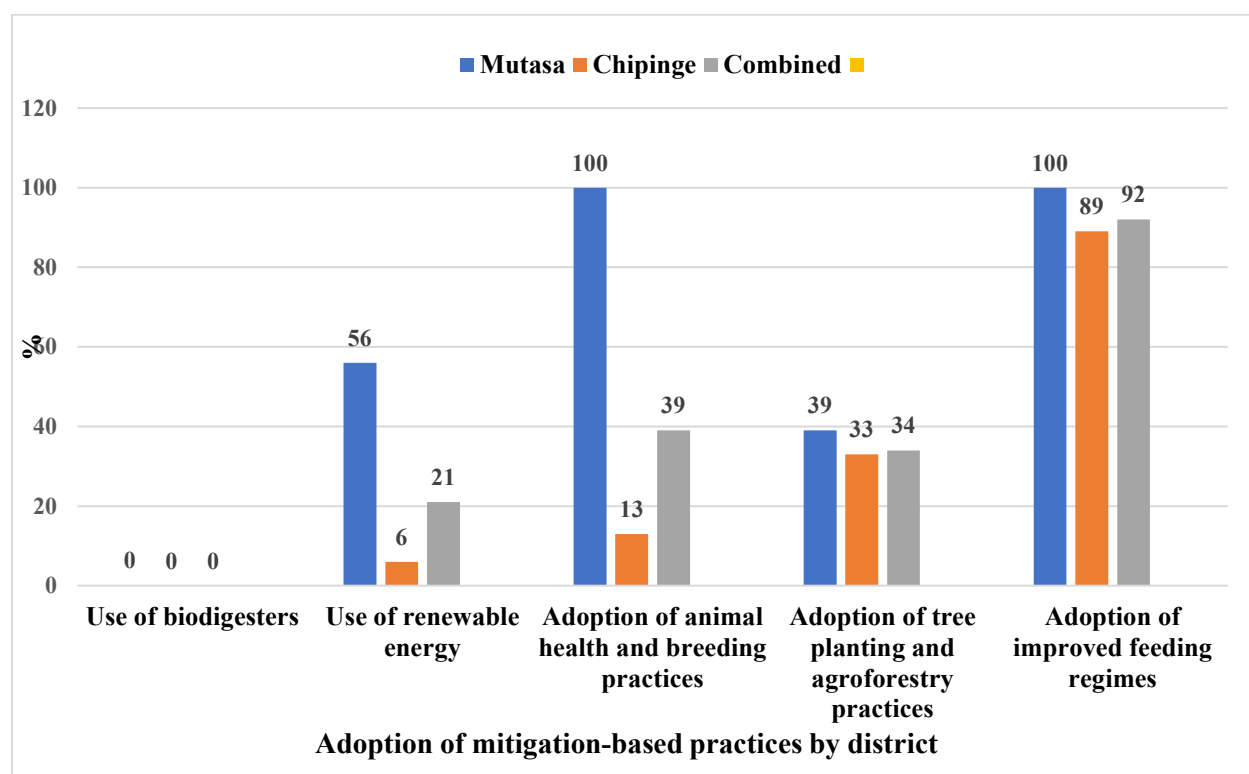


Figure 4.17: Adoption of mitigation CSA practices by district, % of respondents (N = 154)

District-level differences were pronounced: near-universal adoption of improved feeding and breeding in Mutasa, significantly lower adoption in Chipinge, and higher renewable energy uptake in Mutasa. These disparities likely reflect variations in agro-ecological conditions, market access, income levels, and institutional support. The findings underscore the importance of place-based mitigation policy design rather than uniform national prescriptions.

Overall, mitigation practices in the study area remain incremental and productivity-driven. Improved feeding and breeding reduce emission intensity but do not address absolute methane reductions, manure methane capture and system-wide carbon accounting. Transformational mitigation in smallholder dairy systems would require scaled-up manure biodigester programmes, integrated feed-manure nutrient cycling, carbon finance incentives and strengthened extension services on low-emission livestock systems. Therefore, improved adoption of mitigation-based CSA practices will require targeted credit schemes for improved feeding, AI services and manure infrastructure, as well as shifting extension services towards integrated low-emission dairy systems. Provision of subsidies or results-based financing mechanisms can also enhance biodigester adoption. Without structural support, mitigation will remain incidental rather than intentional.

4.6.2 Factors influencing the adoption of mitigation-based CSA practices

Chi-square results (Tables 4.11-4.13) indicate weaker adoption of mitigation practices than of adaptation practices. In manure management, no farmers adopted good manure management or biodigesters, and only tree planting/agroforestry showed limited adoption. Adoption was associated with age, education level, and dairy experience, reflecting the knowledge- and time-dependent nature of these practices. For improved feeding regimes, adoption of all strategies was associated with access to finance, food security, and the district of origin. Household size was associated only with the use of concentrates, whereas years of experience and level of knowledge influenced the use of concentrates and crop by-products. Age, gender, and herd size were not significantly associated. In animal health and breeding practices, household size, age, education, number of cows, access to finance, food security, and district of origin influenced the adoption of specific practices. Gender and access to extension services were not significant predictors. The

chi-square statistic could not be computed for good manure management and use of biodigesters due to low expected cell counts.

Table 4.15: Manure management and tree planting

	Tree planting and agroforestry		
	Adopters	Non-adopters	Chi-square
Age of hh head	51	97	62.75 *
Gender of hh head	51	97	0.33
Household size	51	97	14.1
Level of education on hh	47	92	9.16 **
Number of cows	51	97	17.63
Land size, ha	0	148	
Access to finance in the last 12 months	51	95	0.31
Access to finance in the last 12 months	49	90	
Years of experience in dairy farming of hh head	48	94	47.41 **
Level of knowledge of dairy farming	50	94	0.95
Food security	51	94	0.48
District	51	97	0.31

Note: Use of biodigesters has only “No” observed values, so chi-square was not computed.

Note. Adopter and non-adopter columns report frequencies (n). The Chi-square column reports the chi-square test value with significance indicated as *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table 4.16: Improved feeding regimes

	Use of concentrates			Purchase of crop by-products			Feed conservation		
	Adopter s	Non- adopter s	Chi- suar e	Adopter s	Non- adopter s	Chi- suar e	Adopter s	Non- adopter s	Chi- suar e
Age of hh head	125	23	49.3	46	99	98.69	122	25	70.99
Gender of hh head	125	23	0.39	46	99	4.31	122	25	1.92
Household size	125	23	26.79 **	46	99	36.24	122	25	22.92
Level of education on hh	118	21	1.57	42	94	31.71 ***	115	23	7.6
Number of cows	125	23		46	99	34.66	122	25	28.53
Land size, ha			9.72						
Access to finance in the last 12 months	123	23	6.41 **	46	97	13.67 ***	120	25	18.61 ***
Access to extension services	118	21	6.41 **	45	92		114	24	
Years of experience in dairy farming of hh head	119	23	44.57 *	43	96	01.24 ***	116	25	70.19
Level of knowledge of dairy farming	121	23	6.30 *	44	97	45.76 ***	118	25	10.26

Food security	123	22	10.77 ***	46	97	47.39 ***	120	24	12.33 **
District	125	23	11.52 ***	46	99	110.45 ***	122	25	11.57 ***

*Note. Adopters and non-adopters are reported as frequencies. Values in the “Chi-square” columns are chi-square test statistics with significance indicated by stars: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. NOTE:*

For Access to extension services, the chi-square was not computed because the variable has only a single value.

Table 4.17: Animal health and breeding

	Use of improved breeds			Use of AI			Use of vaccination		
	Adopters	Non-adopters	Chi-square	Adopters	Non-adopters	Chi-square	Adopters	Non-adopters	Chi-square
Age of hh head	133	15	53.59	59	88	64.75 **	147	1	148.00 ***
Gender of hh head	133	15	0.02	59	88	0.27	147	1	0.73
Household size	133	15	26.96 **	59	88	26.98 **	147	1	36.24 ***
Level of education on hh	125	14	3.69	54	84	24.57 ***	138	1	0.66
Number of cows	133	15	9.85	59	88	29.66 **	147	1	
Land size, ha									4.31
Access to finance in the last 12 months	131	15	1.06	59	86	6.88 ***	145	1	
Access to extension services	124	15		56	82		138	1	0.85
Years of experience in dairy farming of hh head	127	15	45.33 **	55	86	71.55 ***	141	1	46.66 **
Level of knowledge of dairy farming	129	15	2.44	56	87	36.73 ***	143	1	2.37
Access to finance	131	15	1.06	59	86	6.88 ***	145	1	0.85
Food security	130	15	4.53 *	59	85	54.17 ***	144	1	2.39
District	133	15	7.06 ***	59	88	93.66 ***	147	1	0.43

*Note. Adopters and non-adopters are reported as frequencies. Values in the “Chi-square” columns are chi-square test statistics with significance indicated by stars: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. For access to extension services, the chi-square test was not computed because the variable was constant.*

4.6.3 Logistic regression results: determinants of mitigation practice adoption

4.6.3.1 Manure management and tree planting (Models 1–3)

Logistic regression (Table 4.14) was run for good manure management, biodigesters, and tree planting. Models 1 and 2 could not be estimated because there were zero adopters. The inability to estimate Models 1 and 2 due to zero adopters of biodigesters and good manure management reflects structural financial and technical barriers typical of smallholder dairy systems in SSA. Capital-intensive mitigation technologies such as biodigesters require upfront investment, technical knowledge, and reliable herd sizes to be viable. Similar findings are reported by Khatri-Chhetri et al. (2022), who observed extremely low adoption rates of high-investment climate-smart technologies unless supported by subsidies or donor programmes. Likewise, Manda et al. (2019) found that liquidity constraints significantly reduce the probability of adopting conservation-oriented technologies among smallholder farmers in Southern Africa.

Table 4.18: Results of logistic regression model predicting the likelihood of adoption of good manure practices, tree planting and agroforestry

Characteristic	Model 3: Tree planting and agroforestry (N = 154)		
	Coefficient	SE	Exp (B)
Constant	-5.180255**	2.023263	0.005627
Age of hh the head	0.028728	0.019882	1.029145
Gender of hh head: Female	0.748833	0.490483	2.114531
Household size	0.056752	0.076123	1.058394
Level of education on hh: Secondary School	1.679241**	0.737721	5.361484
Level of education on hh: College/University	2.950984***	1.07176	19.12477
Level of education on hh: Other	1.619268*	0.957431	5.04939
Number of cows	0.055644	0.066969	1.057221
Access to finance in the last 12 months: Yes	-0.03594	0.496623	0.964698
Access to extension services: Yes	0.789845	1.001674	2.203055
Years of experience in dairy farming of hh head	0.012013	0.023483	1.012085
Level of knowledge of dairy farming: Good	-0.859167	0.6668	0.423515
Level of knowledge of dairy farming: Fair	-1.849162**	0.884139	0.157369
Level of knowledge of dairy farming: Needs to be improved	-1.293816	0.818458	0.274222
Food security: Food insecure for most of the year	1.451270*	0.771401	4.268533
Food security: Secure most of the year (depends on outside aid)	1.128634*	0.654787	3.091432
District: Chipinge	-0.349015	0.9588	0.705383
Model X ²	24.22*		

H-L test	11.56		
Nagelkerke Pseudo-R ²	0.1513		
N used in Model	124		

Note: Coefficients are log-odds from binary logistic regression. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

The chi-square statistic could not be computed for good manure management and use of biodigesters due to low expected cell counts. In contrast, Model 3 (tree planting and agroforestry) was statistically significant ($\chi^2 = 24.22$; $p < .10$), suggesting moderate explanatory power (Nagelkerke $R^2 = 0.1513$). Education emerged as a strong predictor, particularly at secondary and tertiary education levels. This aligns with human capital theory, which posits that education enhances farmers' ability to process information, evaluate long-term benefits, and manage risk (Wossen et al., 2017). The FAO (2021) similarly identify education as a key driver of agroforestry adoption due to improved environmental awareness and planning capacity.

Interestingly, households experiencing seasonal food insecurity were more likely to adopt tree planting. This suggests that agroforestry is perceived as a livelihood buffering mechanism rather than purely a mitigation strategy. This finding supports arguments by Newell and Taylor (2020), who contend that mitigation practices gain traction when they generate immediate co-benefits such as fodder, fuelwood, or improved soil fertility. The lack of significance for extension services suggests that existing advisory systems may not be effectively promoting mitigation technologies. Recent CSA scaling literature similarly questions the effectiveness of traditional extension approaches in promoting technically complex mitigation practices (Khatri-Chhetri et al., 2022).

4.6.3.2 Improved feeding regimes (Models 4–6)

Models predicting purchase of crop by-products ($\chi^2 = 83.37$; $p < .01$; Nagelkerke $R^2 = 0.7385$) and feed conservation ($\chi^2 = 29.16$; $p < .05$; $R^2 = 0.2627$) demonstrated strong explanatory power, particularly for crop by-products (Table 4.15). These findings indicate that feeding regimes represent a key entry point for mitigation in dairy systems. Access to finance significantly increased the likelihood of adopting feed conservation practices. Financial liquidity is widely recognised as a central determinant of CSA adoption (Wossen et al., 2017a, 2022). In smallholder dairy systems, improved feeding regimes often require investments in storage facilities, purchased inputs, or labour allocation, making credit access essential.

Table 4.19: Results of logistic regression model predicting likelihood of adoption of improved feeding regime

Adoption of improved feeding regimes									
Characteristic	Model 4: Use of concentrates (N = 154)			Model 5: Purchase of crop by-products (N = 154)			Model 6: Feed conservation (N = 154)		
	Coefficient	SE	Exp (B)	Coefficient	SE	Exp (B)	Coefficient	SE	Exp (B)
Constant	2.359	2.236	10.583	53.929	9010.924	2.64E+23	5.466**	2.640	236.517
Age of hh head	0.020	0.030	1.020	0.058	0.059	1.060	0.005	0.026	1.005
Gender of hh head: Female	0.233	0.669	1.263	-0.056	1.434	0.946	-0.377	0.611	0.686
Household size	-0.076	0.094	0.927	0.154	0.252	1.166	-0.016	0.094	0.984
Level of education on hh: Secondary School	-0.608	0.767	0.544	-1.652	1.844	0.192	-0.365	0.677	0.694
Level of education on hh: College/University	0.224	1.668	1.251						
Level of education on hh: Other	0.696	1.231	2.005			0.000	1.108	1.390	3.028
Number of cows	0.215248*	0.125	1.240	-0.071	0.149	0.931	-0.049	0.103	0.953
Access to finance in the last 12 months: Yes	0.748	0.755	2.113	1.598	1.314	4.941	2.057**	0.845	7.829
Access to extension services: Yes	0.489	1.070	1.631	-1.367	1.790	0.255	-1.223	1.298	0.294
Years of experience in dairy farming of hh head	-0.071**	0.031	0.932	-0.077	0.061	0.926	0.016	0.028	1.016
Level of knowledge of dairy farming: Good	-1.021	1.171	0.360	-2.115	1.424	0.121	-0.180	0.952	0.835
Level of knowledge of dairy farming: Fair	-2.201557*	1.289	0.111	-32.438	7244.306	0.000	-0.474	1.101	0.623
Level of knowledge of dairy farming: Needs to be improved	-1.860	1.270	0.156	-18.119	3983.493	0.000	-0.327	0.912	0.721

Food security: Food insecure for most of the year	-0.465	0.961	0.628	-18.368	5358.802	0.000	-1.248	1.014	0.287
Food security: Secure most of the year (depends on outside aid)	-0.192	0.882	0.825	-0.929	1.568	0.395	-1.546069*	0.941	0.213
District: Chipinge				-53.33044	9010.923	6.93E-24	-2.294758	1.443054	0.100757
Model X ²	20.85			83.37***			29.16**		
H-L test	5.61			1.42			6.23		
Nagelkerke Pseudo-R ²	0.2187			0.7385			0.2627		
N used in Model	90			82			112		

*Note: Coefficients are log-odds from binary logistic regression. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$*

Table 4.15a: Multicollinearity diagnostic (VIF)

Characteristic	VIF	1/VIF
Age of hh head	.	.
Gender of hh head: Female	1.22	0.820741
Household size	1.28	0.779722
Level of education on hh: Secondary School	2.18	0.459314
Level of education on hh: College/University	1.83	0.546
Level of education on hh: Other	2.08	0.480135
Number of cows	1.51	0.663125
Years of experience in dairy farming of hh head	1.97	0.507292
Level of knowledge: Good	2.61	0.38263
Level of knowledge: Fair	3.62	0.276511
Level of knowledge: Needs to be improved	2.21	0.452315
Food security: Food insecure for most of the year	3.07	0.326263
Food security: Secure most of the year (depends on outside aid)	1.87	0.536014
Access to finance in the last 12 months: Yes	1.39	0.719643
Access to extension services: Yes	1.1	0.911401
District: Chipinge	3.83	0.261166
Land size, ha	.	.
Mean VIF	2.12	

Herd size positively influenced concentrate use, reflecting economies of scale. Farmers with larger herds have stronger incentives to intensify feeding strategies to maximise milk output. Similar scale effects were observed by Owino et al. (2020b), who reported that herd size significantly increases the likelihood of investing in productivity-enhancing feeding technologies. Years of dairy farming experience showed mixed effects. The negative association with concentrate use may reflect conservatism among older or more experienced farmers, consistent with transformational adaptation theory, which suggests that deeply entrenched production practices reduce openness to input-intensive innovations. District-level effects were particularly strong in crop by-product adoption, indicating spatial heterogeneity in market access, agroecological conditions, and infrastructure. This finding reinforces the importance of location-specific CSA policy design.

4.6.3.3 Animal health and breeding (Models 7–9)

Models predicting improved breeds and artificial insemination (AI) were not statistically significant, while vaccination showed near-universal adoption (Table 4.16). The widespread uptake of vaccination

reflects its low cost, high visibility of benefits, and strong productivity gains. The FAO (2022) reports similarly high adoption rates for livestock vaccination across developing countries due to immediate economic returns. The limited uptake of improved breeds and AI reflects financial and knowledge constraints, as well as risk considerations. These technologies require both capital and technical expertise, increasing perceived uncertainty among smallholders (Manda et al., 2019).

Table 4.20: Results of the logistic regression model predicting the likelihood of adoption of improved animal health and breeding

Characteristic	Model 7: Use of improved breeds (N = 154)			Model 8: Use of AI (N = 154)		
	Coefficient	SE	Exp (B)	Coefficient t	SE	Exp (B)
Constant	0.789	2.112	2.202	-0.219	2.568	0.803
Age of hh head	0.0045	0.030	1.005	0.004	0.031	1.004
Gender of hh head: Female	0.779	0.737	2.181	0.468	0.835	1.596
Household size	-0.013	0.101	0.987	-0.048	0.132	0.952
Level of education on hh: Secondary School	0.548	0.769	1.730	0.712	1.036	2.037
Level of education on hh: College/University			0.325	1.475	1.384	
Level of education on hh: Other	0.607	1.248	1.835	-0.013	1.435	0.986
Number of cows	0.075	0.113	1.077	0.072	0.102	1.075
Access to finance in the last 12 months: Yes	-0.406	0.717	0.666	-0.726	0.796	0.483
Access to extension services: Yes			-0.727	1.258	0.483	
Years of experience in dairy farming of hh head	0.036	0.031	1.037	0.006	0.037	1.006
Level of knowledge of dairy farming: Good	-0.744	0.980	0.475	-1.317	0.856	0.268
Level of knowledge of dairy farming: Fair	-0.597	1.242	0.551	-1.464	1.463	0.231
Level of knowledge of dairy farming: Needs to be improved	-0.099	1.082	0.905	-2.355	1.451	0.095
Food security: Food insecure for most of the year	-0.855	1.047	0.425	0.007	0.860	1.007
Food security: Secure most of the year (depends on outside aid)	-1.183	0.959	0.306	-2.647**	1.214	0.071
District: Chipinge						
Model X ²	7.10 (0.897)			17.45 (0.293)		
H-L test	9.60 (0.294)			3.62 (0.889)		
Nagelkerke Pseudo-R ²	0.098			0.236		
N used in Model	75			89		

Note: Coefficients are log-odds from binary logistic regression. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Use of vaccine has almost a single value, i.e. yes

4.6.4 Summary of mitigation-based CSA adoption

Overall, mitigation-based practices are less widely adopted than adaptation-based practices. Farmers prioritise immediate production stabilisation over long-term emission reduction. This pattern is consistent with broader evidence across Sub-Saharan Africa (FAO, 2021). From the study results, three possible adoption pathways are: the reactive adaptation pathway, driven by climate stressors such as drought and rainfall variability; the productivity co-benefit mitigation pathway, in which mitigation enhances productivity; and the investment-constrained mitigation pathway, where technologies such as biodigesters remain unadopted due to capital and technical barriers. This typology strengthens the study's conceptual contribution by demonstrating that mitigation scaling depends heavily on productivity alignment and financial enablement.

4.7 Factors influencing adoption of Climate-Smart Agriculture Practices

This section synthesises findings from all previous analyses to address research objective 5: determine the factors influencing smallholder dairy farmers' adoption of CSA practices in Chipinge and Mutasa Districts. Both adaptation-based (feed and water management) and mitigation-based (feeding regimes, animal health, tree planting) practices are considered. Household labour, herd size, education, experience, and dairy knowledge consistently influenced adoption. These findings align with adoption theory, which identifies asset endowment and human capital as core drivers of technology uptake (Wossen et al., 2017). Education and knowledge, particularly, enhance the adoption of agroforestry and improved feeding regimes, supporting the argument that cognitive capacity reduces perceived risk and improves long-term planning. Access to finance emerged as one of the strongest predictors across practices. Financial constraints remain the primary barrier to the adoption of mitigation technology. This finding supports climate investment literature emphasising the importance of credit and subsidy mechanisms in CSA scaling (Khatri-Chhetri et al., 2022). Extension services showed limited influence, indicating potential institutional gaps in delivering mitigation-focused advisory services. Climate perception strongly influenced the adoption of adaptation but had a limited impact on mitigation practices. This confirms that adaptation is largely reactive, whereas mitigation requires deliberate incentives and policy support. District-level heterogeneity underscores the importance of localised CSA interventions. Context-specific ecological and socio-economic factors shape adoption patterns, reinforcing the need for decentralised implementation strategies.

The findings point to the need to leverage productivity-enhancing feeding regimes as entry points for mitigation. Bundling agroforestry with dairy productivity programmes is necessary to improve adoption. The expansion of climate finance instruments targeting biodigesters and manure management could increase the adoption of improved manure management practices. It may also be

necessary to reform extension services to integrate mitigation accounting. Lastly, interventions should be customised at the district level to improve their effectiveness. In conclusion, CSA adoption among smallholder dairy farmers is shaped by a combination of socio-economic, institutional, demographic, climatic, and geographic factors. Effective promotion of CSA requires addressing both enabling factors and barriers, and integrating adaptation and mitigation strategies to achieve sustainable productivity and climate resilience. See Figure 4.17 for factors influencing the adoption of CSA practices and the type of influence they have on the practices.

Factors influencing adoption of CSA practices

Factors	Feed Shortage Adaptation	Water Shortage Adaptation	Improved Feeding Regimes	Animal Health & Breeding	Tree Planting / Agroforestry	Renewable Energy	Biodigesters
Household size	No Significant Effect	Positive Influence	Positive Influence	Mixed/Context Dependent	Positive Influence	No Significant Effect	No Significant Effect
Herd size / Number of cows	No Significant Effect	Positive Influence	Positive Influence	Positive Influence	Positive Influence	No Significant Effect	Positive Influence
Education of household head	Positive Influence	No Significant Effect	Mixed/Context Dependent	Positive Influence	Mixed/Context Dependent	Mixed/Context Dependent	No Significant Effect
Years of dairy experience	Positive Influence	Mixed/Context Dependent	Positive Influence	Mixed/Context Dependent	Mixed/Context Dependent	Positive Influence	Mixed/Context Dependent
Knowledge of dairy farming	Mixed/Context Dependent	Positive Influence	Mixed/Context Dependent	Positive Influence	Mixed/Context Dependent	Mixed/Context Dependent	No Significant Effect
Access to finance	Mixed/Context Dependent	Mixed/Context Dependent	Positive Influence	Mixed/Context Dependent	Mixed/Context Dependent	No Significant Effect	No Significant Effect
Access to extension services	Positive Influence	Positive Influence	Mixed/Context Dependent	No Significant Effect	Positive Influence	No Significant Effect	No Significant Effect
Food security	No Significant Effect	Positive Influence	Negative Influence	Mixed/Context Dependent	Mixed/Context Dependent	Negative Influence	No Significant Effect
Age of household head	No Significant Effect	Mixed/Context Dependent	Mixed/Context Dependent	Positive Influence	Mixed/Context Dependent	No Significant Effect	Positive Influence
Gender of household head	No Significant Effect	Mixed/Context Dependent	Negative Influence	Mixed/Context Dependent	Negative Influence	Negative Influence	No Significant Effect
Perceived drought frequency	Positive Influence	Negative Influence	No Significant Effect	Positive Influence	Positive Influence	Mixed/Context Dependent	No Significant Effect
Perceived rainfall variability	Mixed/Context Dependent	Mixed/Context Dependent	Negative Influence	No Significant Effect	Positive Influence	No Significant Effect	No Significant Effect
Perceived flooding	Negative Influence	Negative Influence	Mixed/Context Dependent	No Significant Effect	No Significant Effect	No Significant Effect	Negative Influence
District / Location	Positive Influence	Positive Influence	Positive Influence	Mixed/Context Dependent	Positive Influence	No Significant Effect	Negative Influence

■ Positive Influence
 ■ Mixed/Context Dependent
 ■ Negative Influence
 ■ No Significant Effect

Figure 4.18: Factors influencing adoption of CSA practices

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This study set out to examine the adoption of climate-smart agriculture (CSA) practices among smallholder dairy farmers in Chipinge and Mutasa districts of Manicaland Province, Zimbabwe. Situated within Zimbabwe's broader national climate policy context, and aligned with the climate-smart agriculture framework promoted by the FAO, the research sought to understand how smallholder dairy systems are responding to climate variability through both adaptation and mitigation practices. The study was motivated by the increasing vulnerability of livestock systems to climate change and the need to reconcile productivity, resilience, and environmental sustainability within smallholder production systems. Drawing on empirical evidence presented in Chapter 4, this concluding chapter synthesizes the major findings, reflects on their theoretical and policy significance, and outlines recommendations for strengthening climate-smart dairy development.

5.2 Research summary

This study investigated the adoption of climate-smart agriculture (CSA) practices among smallholder dairy farmers in Chipinge and Mutasa districts of Manicaland Province, Zimbabwe. The study was motivated by growing concerns regarding the adverse effects of climate change on dairy production systems, particularly among smallholder farmers who depend heavily on climate-sensitive natural resources. The research sought to assess farmers' perceptions of climate change, identify the adaptation- and mitigation-based CSA practices being adopted, and analyse the socio-economic, institutional, and farm-level factors influencing their uptake. The study was guided by the hypothesis that household characteristics, access to resources and information, and institutional support significantly influence the adoption of CSA practices among smallholder dairy farmers.

A cross-sectional survey design was employed, using structured questionnaires administered to smallholder dairy farmers in the two districts. Key informant interviews and secondary sources complemented the household survey data, enhancing the reliability and validity of the findings through triangulation. Descriptive statistics were used to analyse farmers' perceptions of climate change and the adoption of CSA practices, while binary and multinomial logistic regression models were applied to determine the factors influencing the adoption of adaptation- and mitigation-based CSA practices.

The findings revealed that most farmers perceived climate change through increasing temperatures, erratic rainfall, recurrent droughts, and prolonged dry spells, with perceptions generally stronger in Chipinge than in Mutasa. Farmers adopted a range of adaptation practices, including the use of improved dairy breeds, water harvesting and storage, feed conservation and storage, and provision of shade to reduce heat stress. Mitigation practices commonly adopted included improved feed quality,

improved herd health management and tree planting. The study further established that adoption of CSA practices was influenced by several factors, including age, education, dairy farming experience, herd size, access to extension services, access to credit, membership in farmer organizations, and access to climate information.

The study concludes that smallholder dairy farmers in Manicaland Province are aware of climate change and are actively implementing CSA practices to enhance resilience and improve productivity. However, adoption levels vary across practices and are constrained by limited access to financial resources, technical support, and climate-related information. Strengthening extension services, improving access to credit and climate information, and promoting locally appropriate CSA technologies are therefore critical elements for enhancing the resilience, productivity, and sustainability of smallholder dairy farming systems in the face of climate change.

5.3 Synthesis of key findings

The study established that smallholder dairy farmers in Chipinge and Mutasa districts were highly aware of climate change and variability. Farmers perceived climate change through increasing temperatures, erratic rainfall patterns, prolonged dry spells, recurrent droughts, water shortages, and occasional flooding. These climatic changes were associated with declining pasture productivity, feed shortages, reduced water availability, increased prevalence of livestock disease, and lower milk yields. Perceptions of climate-related risks were generally stronger in Chipinge than in Mutasa, reflecting differences in agroecological conditions and exposure to climate variability.

The findings revealed that farmers' perceptions of climate change significantly influenced their adoption of climate-smart agriculture practices. Farmers who perceived greater exposure to droughts, prolonged dry spells, water scarcity, and rising temperatures were more likely to adopt CSA practices to reduce production risks. Climate change awareness, therefore, acted as an important catalyst for adaptation and management decisions, increasing farmers' willingness to invest in practices that enhance resilience and sustain dairy productivity under changing climatic conditions.

Adaptation-based CSA practices were more widely adopted than mitigation practices, reflecting farmers' priority to address immediate climate-related challenges affecting dairy production. The most commonly adopted adaptation strategies included the use of crop residues, cut-and-carry feeding systems, fodder production and conservation, water harvesting and storage, improved dairy breeds, and provision of shade to reduce heat stress. These practices were primarily intended to address feed shortages, water scarcity, and declining pasture productivity. The adoption of adaptation strategies was significantly influenced by factors such as education level, household size, dairy farming experience, herd size, access to extension services, access to credit, and access to climate information.

The study found relatively low adoption of mitigation-oriented CSA practices compared to adaptation practices. The most commonly adopted mitigation strategies included improved feeding practices, improved herd health management, improved breeding and tree planting. Farmers generally adopted these practices to improve milk production, animal performance, and farm profitability, with greenhouse gas mitigation occurring as a secondary benefit. Advanced mitigation technologies, such as biodigester and structured manure management systems, were rarely adopted due to financial, technical, and knowledge constraints. Adoption of mitigation practices was influenced by education, herd size, access to finance, extension support, and access to technical information.

The study demonstrated that CSA adoption decisions were shaped by a combination of socio-economic, institutional, and farm-level factors. Education, household size, dairy farming experience, herd size, access to extension services, access to credit, membership in farmer organizations, and access to climate information emerged as significant determinants of adoption. Access to finance was particularly important for the uptake of investment-intensive practices, while extension services and climate information enhanced farmers' awareness and technical capacity to adopt CSA technologies. In addition, district-level differences between Chipinge and Mutasa highlighted the influence of local agroecological conditions, market access, and institutional support structures on adoption pathways. These findings emphasize the need for location-specific interventions that address both resource constraints and information gaps among smallholder dairy farmers.

Overall, the study concludes that climate change has become a central factor influencing dairy farming decisions in the study area. While farmers are actively adopting climate-smart practices to improve resilience and productivity, sustained and widespread adoption will require strengthened institutional support, improved access to finance and climate information, and targeted interventions tailored to local farming conditions.

5.4 Theoretical and practical implications

The study contributes to climate adaptation and technology adoption literature by demonstrating that smallholder farmers' decisions are shaped by immediate livelihood security concerns, resource endowments, and institutional access. The findings align with adoption theory, which emphasises the role of human capital, asset ownership, and perceived relative advantage in shaping innovation uptake. However, the study extends this perspective by distinguishing between adaptation and mitigation logics within the same farming system.

Adaptation decisions are experiential, risk-driven, and closely tied to perceived climate variability. Mitigation-based decisions, by contrast, are opportunity-driven and contingent upon awareness, capital, and external incentives. This divergence suggests that promoting mitigation within smallholder systems requires reframing such practices in terms of productivity, income gains, and risk reduction

rather than abstract environmental objectives alone. Practically, the findings underscore the need to shift from reactive coping strategies towards integrated, sustainable feed and water systems. Without such transformation, current adaptation pathways may undermine long-term ecological sustainability.

5.5 Policy and institutional recommendations

The results indicate that improving access to finance is critical for enhancing CSA adoption, particularly as income level and herd size were significant predictors in the regression models. Accordingly, affordable credit schemes, targeted subsidies, and climate finance instruments should be expanded to relax liquidity constraints faced by low-income and small herd households. These mechanisms would enable investment in capital-intensive CSA technologies such as silage systems, biodigesters, improved manure management infrastructure, and renewable energy for milk cooling. The Ministry of Agriculture, in collaboration with financial institutions and climate finance partners, should prioritise tailored loan products for smallholder dairy systems.

The findings further show that access to extension services and cooperative membership significantly increase the likelihood of CSA adoption. Extension systems should therefore be strengthened to deliver integrated, demonstration-based CSA training that covers manure management, fodder production, agroforestry, and renewable energy use. Agricultural extension departments, NGOs, and dairy cooperatives should jointly implement farmer field schools and cooperative-based learning platforms to accelerate the technology diffusion.

In addition, policy support for sustainable feed systems is warranted given the role of herd-related production pressures in shaping adoption behaviour. Rotational grazing, crop-livestock integration, and community fodder banks should be promoted through coordinated interventions led by the Ministry of Agriculture and local government authorities, with support from development partners. These measures would improve forage availability while reducing environmental degradation.

Finally, investment in rural renewable energy infrastructure should be prioritized to address structural constraints identified in the model. Partnerships among the government energy agencies, private sector actors, and donor-funded rural electrification programmes are essential to scale solar-based milk cooling and biogas technologies, thereby improving productivity while reducing greenhouse gas emissions in energy-scarce areas.

5.6 Farmer-level pathways for strengthening climate-smart agriculture

At the farm level, peer learning mechanisms offer a cost-effective strategy for scaling adoption. Farmers already implementing improved feeding regimes and animal health practices can serve as demonstration cases within their communities. Encouraging farmer-field schools and cooperative learning platforms could accelerate the knowledge diffusion. Integrated water management systems

such as rainwater harvesting, borehole development, and water conservation techniques should be prioritised to reduce labour burdens and stabilise milk yields. Agroforestry expansion presents a particularly promising pathway, delivering shade, fodder, carbon sequestration, and diversified income streams simultaneously.

5.7 Directions for future research

While this study provides valuable insights, several research gaps remain. Future studies should conduct detailed economic analyses of CSA practices to determine their cost-effectiveness and long-term return on investment. This evidence is needed for decision-making at the farm level. Additionally, evaluation of locally adapted biodigesters and renewable energy technologies is needed to assess technical feasibility within smallholder systems. Southern Africa is generally experiencing energy insecurity, with many countries resorting to loadshedding to manage the situation. Therefore, research into low-cost options for biodigester installation and other renewable sources can help ease pressure on the national electricity grid while at the same time mitigating GHG emissions, especially from cow manure. Another benefit of adopting the use of renewable energy sources is the need for cold chain maintenance, especially for the dairy value chain.

5.8 Overall conclusion

This study demonstrates that smallholder dairy farmers in Chipinge and Mutasa operate under persistent climate stress, with feed and water shortages strongly shaping production decisions. While adaptation practices are widely adopted, they are largely reactive and, in some cases, environmentally unsustainable. Mitigation practices remain limited and are mainly adopted when they generate direct productivity benefits. Adoption behaviour is significantly influenced by socio-economic capacity, institutional support, and location-specific conditions.

Beyond these empirical findings, the study contributes to the literature on climate-smart agriculture by empirically demonstrating that adaptation and mitigation decisions in smallholder dairy systems are not independent choices but are jointly shaped by resource constraints and institutional access. By applying a multivariate adoption framework, the study advances understanding of how multiple CSA practices are simultaneously conditioned by household-level endowments and service delivery systems under climate stress. This provides a more integrated explanation of adoption behaviour than single-practice adoption models commonly used in prior studies.

Overall, the findings suggest that climate-smart dairy development in Manicaland requires a shift from isolated adaptation or mitigation approaches towards integrated systems that jointly enhances productivity, resilience, and environmental sustainability. Strengthening access to finance, improving extension services, and promoting sustainable resource management are key points for this transition.

When effectively implemented, these interventions can transform current coping-oriented strategies into resilient and climate-smart dairy production systems, enabling smallholder farmers in Zimbabwe to move beyond vulnerability towards long-term sustainability and climate resilience.

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APPENDICES

Appendix 1: Questionnaire for the Smallholder Dairy Baseline Survey in Zimbabwe

THE SURVEY IS BEING CONDUCTED BY THE UNIVERSITY OF SOUTH AFRICA COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

INTRODUCTION

Good (morning, afternoon). My name is Tinashe Chavhunduka. I am conducting a study concerning dairy production issues in your neighbourhood on behalf of UNISA. The study aims to understand dairy production systems, marketing and identify problems you encounter in your enterprise. This study will be conducted in Chipinge and Mutasa districts. While the general conclusions of the study may be used to help formulate government policy recommendations for improving dairy production in the country, all the specific information about you, your family and undertakings will be treated confidentially. We hope that you will be willing to help us in this study.

Enumerator's Name:

Date of Interview (DD/MM/YY): / / 2022

Time started:..... Time ended:.....

Cross-checked by (Enumerator's Name).....

Final check by (Supervisor's Name):

Questionnaire Sections:

- Section A: Basic Household Information**
- Section B: Dairy Farm Management and Milk Production**
- Section C: Dairy Marketing Chain and Market Access**
- Section D: Access to Animal Health and Livestock Extension Services**
- Section E: Food Security and Climate Change**

Section A: Basic Household Information

Section A 1. Background information

- 1) Respondent's Name:
- 2) Gender of the respondent: ☐ Male (1) ☐ Female (2)
- 3) Age of the respondent:.....years old
- 4) Farm address: Village.....Traditional authority.....
District.....
Milk Collection Centre.....
- 5) Respondent's position in the household (with respect to the head):
 - ☐ Husband (1) ☐ Wife (2)
 - ☐ Son (4) ☐ Relative living in the house (5)
 - ☐ Daughter (3)

☐ Farm Worker (6) ☐ Other (7), please specify.....

6) Respondent's educational background:

☐ Primary school (1) ☐ Secondary school (2)

☐ Vocational school (3) ☐ College / University (4)

☐ Other (5), please specify.....

Section A 2. Household socio-economic background

7) Size of the household.....people

8) Household composition by age

Male (tick)	Female (tick)	Position in the household (with respect to the head)	Age at the time of the survey, years

9) Land ownership

Land type	Ha	How acquired	If rented, how much rent do you pay, US\$ <i>(please specify whether it</i>	Land tenure status	When acquired, year	Can you pass on your land to Family members? ☐ Yes (1) ☐ No (0)
		1 Given by parents		1 Customary		
		2 Given by Chief/Village Headman		2 Freehold		
				3 Leased		
				4 State		

		3 Given by Govt.	<i>is per month, per year etc)</i>	5 Other, please specify).....		
		4 Rented land				
		5 Borrowed for free				
		6 Purchased				
Agricultural land						
Pasture and forest land						
Fallow land						
Other types						

10) Do you / or your farm own any of these (choose as many as apply)?

Implements:

- a) Silage/Grass cutter ☐ Yes (1) ☐ No (0)
- b) Treadle pump ☐ Yes (1) ☐ No (0)
- c) Baler ☐ Yes (1) ☐ No (0)
- d) Sprayer ☐ Yes (1) ☐ No (0)
- e) Dip tank (either household or communal, please specify...)
- ☐ Yes (1) ☐ No (0)

Machinery:

- a) Tractor ☐ Yes (1) ☐ No (0)
- b) Ox cart ☐ Yes (1) ☐ No (0)
- c) Water cart ☐ Yes (1) ☐ No (0)
- d) Cultivator ☐ Yes (1) ☐ No (0)
- e) Generator ☐ Yes (1) ☐ No (0)
- f) Motorised pump ☐ Yes (1) ☐ No (0)

Structures / Buildings:

- a) Livestock kraal ☐ Yes (1) ☐ No (0)
- b) Shed / Storage house ☐ Yes (1) ☐ No (0)
- c) Cattle crush (either household or communal, please specify.....)
- ☐ Yes (1) ☐ No (0)

11) If you don't have a kraal, where do you keep your animals?

- a) Open ground (1)
- b) Use other people's kraal (2)
- c) Communal kraal (3)
- d) Other (4), please specify.....

12) Livelihood sources

14a. Income sources of the family	14b. Rank (max. 5) of your sources of household income in ascending order as follows: (1 = most important to 5 = least important)	14c. Average amount per month in the High season ¹ , US\$	14d. Average amount per month in the Low season ² , US\$
1. Dairy farming			

¹High season means peak season for each source of income

² Low season is when production is at its lowest

2. Other livestock / Beef fattening/ rearing livestock			
3. Crop production (maize, wheat, tobacco)			
4. Formal employment			
5. Daily labour			
6. Social support			
7. Other.....			

Section B: Dairy Farming

Section B 1. General

13) When did you start dairy farming?years (Enumerator to calculate the number of years)

14) Did you have prior knowledge of dairy farming? ☐ Yes (1) ☐ No (2)

15) If yes, from where?

16) How did you start dairy farming?

- a) Encouraged by parents/relatives/friends (1)
- b) Introduced by Govt./NGO/Donors (2), please specify.....
- c) Self-motivated (3)
- d) Inherited (4)
- e) Other (5), please specify).....

17) Why did you start dairy farming? (choose up to 2 options)

- a) To increase income (1)
- b) To increase food security (2)
- c) To diversify sources of income (3)
- d) Other (4), please specify.....

Section B 2. Dairy farm structure, facilities and management

18) Number of dairy cattle kept on farm

18a. Type of animals	18b. Local breed	18c. Crossbreed	18d. Pure breed
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	Number of animals	Number of animals	Number of animals
1.Lactating (milking) cows			
2. Dry cows (pregnant)			
3. Dry cows (not pregnant)			
4. Heifers (more than 1 year old)			
5. Female calves (less than 1 year old)			
6. Bull (more than 2 years old)			

19) Number of other livestock kept on farm

Type of animals	Number of animals
1.Ox	
2. Donkey	
3. Mule / Horse	
4. Goat	
5.Sheep	
6. Pig	
7.Other, please specify.....	

20) How did you get the (dairy) animals when you first set up your dairy farm?

☐ Loan from government (1) ☐ Pass on credit by NGO (2)

☐ Purchased myself (3) ☐ Inherited (given by) from relatives (4)

☐ Donated (5)

☐ Other (6), please specify.....

21) Who owns the (dairy) animals/farm? (multiple choices possible)

Husband (1) ☐ Wife (2) ☐ Both husband and wife (3) ☐ Relative (4)

Other (5), please specify).....

22) Who manages the (dairy) animals/farm? (multiple choices possible)

Husband (1) ☐ Wife (2) ☐ Both husband and wife (3)

Relative (4) ☐ Farm labourer (5)

Other (6), please specify).....

=

23) Herd dynamics

23a. Type of animals	23b.Total number	23c. Number born (in the last 12 months)	23d. Number dead (in the last 12 months)			23e. Cause of death, please specify (in the last 12 months)	23f. Number of stillbirth s	23g. Number of new-born deaths (in the last 12 months)	23h. Culling (in the last 12 months)		
			No	Sex of the animal	Age when died				No	Sex of the animal	Age culled
Local breed											
Cross breed											
Pure											

breed										
	23i. Slaughtering for home consumption (in the last 12 months)			23j. Number of animals sold (in the last 12 months)	23k. Number of animals transferred (in the last 12 months)	23l. Number of animals received as gifts (in the last 12 months)	23m. Number of animals given as gifts (in the last 12 months)	23n. Number of (dairy) animals stolen from the farm (in the last 12 months)		
	No	Sex of the animal	Age slaughtered							

						when fully grown	Not in Mil k	(dd/mm /yy)		days	–	60 da ys	60 da ys			ated before getting pregna nt?		
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		

10																		
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Section B 3. Labour use in dairy farming

25) How many workers do you have at the (dairy) farm, i.e. contributing to the dairy enterprise?

25a.Type of employment	25b. Male (No. of persons)	25c. Female (No. of persons)	25d.Total
Self-employed or unpaid workers (family member, i.e. husband, wife, son, daughter or relatives)			
Paid workers			
How much is a worker paid in a month? (US\$/ person)			

26) Who regularly performs the following activities on your dairy farm?

Activity	Person responsible (multiple choices possible)
Feeding	
Fetching water (for drinking, cleaning, etc)	
Milking	
Cleaning	
Dipping	

Marketing	
General maintenance	

Codes for the responses: ☐ Farm Manager (1) ☐ Husband (2) ☐ Wife (3) ☐ Workers (4)

☐ Children (5) ☐ Farm labourer(6)

☐

Section B 4. Feeding

27) Which type of grazing do you practice (for your dairy animals), and for how many months a year?

☐ Free grazing (in pasture) (1); *Months of grazing in this category each year.....months*

☐ Free grazing in communal land (2); *Months of grazing in this category each*

year.....months

☐ Semi-zero grazing (3); *Months of grazing in this*

category each year.....months

☐ Zero grazing (4); *Months in this category each*

year.....months

☐ Other (5), please

specify.....

Months of grazing in this category each year.....months

28) Do you practice fertilisation of grazing land?

☐ Yes (1) ☐ No (0)

29) If yes, please specify the amount and type of fertilizer applied (multiple choices possible)

Type of fertiliser	Amount, kg/ha
Synthetic (1)	
209	

Manure (2)

Compost (3)

Legumes (4)

30) If you use community land for grazing, how much of total feed quantity does this provide?
.....% (Enumerator to calculate % if necessary)

31) Have you undertaken any land improvement and conservation measures during the last 2 years?

☐ Yes (1) ☐ No (0)

32) If Yes, please indicate the type of conservation you have undertaken (choose as many as apply)

- ☐ Soil or stone bunds (1);ha
- ☐ Terraces (2);ha
- ☐ Drainage ditches (3);.....ha
- ☐ Fences (4);ha
- ☐ Planting trees (5);Number
- ☐ Other (6), please specify.....;ha

33) Which grass do you grow on the farm?

Name	Grass yield ³	
	kg of dry matter per ha	kg of fresh weight per ha
Ruzi grass (1)		
Panicum grass (2)		
Guinea grass (3)		
Napier grass (4)		
Rhodes grass (5)		
Centrocema (6)		
Thatch grass (7)		
Star grass (8)		
Plicatulum grass (9)		
Other (10), please specify.....		

34) Feed / Fodder (roughage) (multiple choice possible)

³ Enumerator to use either dry matter per ha or fresh weight per ha as specified by the farmer.

34a.Type of feed	Yes (1) or No (0)	34b.Source (1) Plant yourself or (2) Natural pasture or (3) Purchase	34c.Feeding practice 1) Grazing 2) Stall-feed 3) Both	34d. How many times do you feed your cows per day?	34e.How much do you feed (per cow per day)? <i>Unit Code:</i> _____		34f.If you purchase please in average p US\$ per unit (plea specify u
					Unit and wt (kg)	Quan- tity ~ no of units	
Concentrate feed (1) (e.g. dairy mash)							
Grass (grazing) (2)							
Grass (cut and carry) (3)							
Hay (4)							
Maize bran (5)							
Groundnut haulms (6)							
Feed supplements (7)							

Do you produce Silage (8)							
Forage (9) – Legumes							
Fodder ² (10)							
Other (11) a).....							
b).....							
c).....							

2 e.g. from agroforestry

Note: Unit Code: Kilogram = 1; Basket of ____ kg = 2; Pale/Bucket of 20 liters=3; Bag of ____ kg=4; Other = 5, please specify

35) Purchase crop by-products during the year?

☐ Yes (1) ☐ No (0)

36) If you purchase crop by-products, which crop by-products did you purchase for the farm over the last 12 months?

36a.Type of crop by-product	36b.Price per kg	36c. Quantity purchased				36d. Which month
		36c1.Unit of 213	36c2. Number of	36c3. Weight per	36c4.Tota l kg	

measure units unit, kg

Ground nut haulms

Maize stalks

Soybean haulms

Banana stems

Wheat straws

Sorghum stover

Other, please
specify.....

Note: Unit Code: Kilogram = 1; Basket of ____kg = 2; bales/bundles/stacks of _
kgs=3; Bag of ____ kg=4; Other = 5, please specify.....

37) Do you have enough fodder for your animals for the whole year?

☐ Yes (1) ☐ No (0)

38) Do you regularly experience a shortage of feed?

☐ Yes (1) ☐ No (0)

39) If yes, which season / month do you experience the most severe

shortage.....

40) How do you obtain feed when experiencing a shortage of feed, please

explain.....

41) Do you make conserved feeds (e.g. hay)

☐ Yes(1)

☐ No(0)

42) If yes, how much hay do you make?(specify quantity
and units)

43) Have you experienced differences in feed availability over the past ten (10) years?

☐ Yes(1)

☐ No(0)

44)a) Do you have enough water for your animals throughout the day?

☐ Yes (1) ☐ No (0)

b) Amount of water consumed.....litres (convert if buckets)

c) Total monthly cost of water.....US\$

45. What is the source of water for the animals (choose up to 2)? Indicate the distance for each source indicated (multiple responses are possible)

☐ On-farm well (1) Dist. _ m

☐ Piped public water supply (2) Dist _ _ m

☐ Water storage tank/pond (3) Dist _____ m

☐ River / stream (4) Dist _____ m Other (5), please specify..... Dist _____ m

Section B 5. Milk production and milking practice

45) How many times a day do you milk your cows?

☐ Once (1) ☐ 2 times (2) ☐ 3 times (3)

46) Average milk per day in the high season..... kg or litre, from

(number of milking) cows

47) Average milk per day in the low season.....kg or litre, from

(number of milking) cows

48) Do you mix evening and morning milk before you send it to the MCC every morning?

☐ Yes (1)

☐ No (0)

50) Do you plan to increase the amount of milk you produce? ☐ Yes (1) ☐ No (0)

51) If yes, how do you plan to increase your milk production? (choose up to 3)

- ☐ Increase the number of dairy cows (1)
- ☐ Improve the grade of animals (2)
- ☐ Produce more feed (3)
- ☐ Buy more feed (4)
- ☐ Spend more on controlling animal disease (5)
- ☐ Depends on extension advice (6)
- ☐ Change farm management practices (e.g.feed) (7)
- ☐ Don't know (8)
- ☐ Other (9) (please explain).....

52) Do you think there are any significant constraints to the (dairy) production of the farm?

☐ Yes (1) ☐ No (0)

53) If answered yes, which are the three main constraints you are facing with your dairy farm (choose 3 and rank from 1 to 3 in the order of importance, with 1 being the most important)?

- ☐ Lack of fodder or roughage (1), ranking.....
- ☐ Low quality of fodder or roughage (2), ranking.....
- ☐ Low quality of concentrate feed (3), ranking.....
- ☐ High cost of concentrate feed (4), ranking.....
- ☐ Lack of credit to buy new animals (5), ranking.....
- ☐ Lack of farm labourer/s (6), ranking.....
- ☐ Low quality of milk (7), ranking.....
- ☐ Low milk yield (8), ranking.....
- ☐ Low market price of milk (9), ranking.....
- ☐ High price of cattle feed (concentrate feed) (10), ranking.....
- ☐ Infertility (11), ranking.....
- ☐ Animal disease (12), ranking.....
- ☐ Good quality semen and genetics (13), ranking.....
- ☐ Other (14), please specify,
a)ranking.....
b)ranking.....
c).....ranking.....

Section B 6. Manure management

54) How much time a day do the cows spend grazing?

Type of an animal	Hours per day
Calves	
Gestating cows	
Lactating cows	

Bulls	
-------	--

55) How much time a day do the cows spend housed?

Type of an animal	Hours per day
Calves	

Gestating cows

Lactating cows

Bulls

56) When not grazing, how is the manure stored?

.....

57) When not grazing, how is the manure removed?.....

58) How long is the manure stored before using?.....

59) Is the stored solid (if any) manure covered by, kept with or mixed with any material?

- a) Covered by other material ☐ Yes (1) ☐ No (0)
- b) Kept with other material (but not mixed) ☐ Yes (1) ☐ No (0)
- c) Mixed with other material ☐ Yes (1) ☐ No (0)

60) Common manure storage system

- ☐ Lagoon (1) ☐ Solid storage facility (2)
- ☐ Dry lot (heap) (3) ☐ Pit storage (4) ☐ Daily spread (5)
- ☐ Other (6), please specify.....

61) Common manure storage system (multiple choices possible)	
Manure Management During Housed Period (adult females only)	% of Manure Stored in this System (Enumerator to calculate if necessary)
Liquid / slurry (with crust) (1)	
Liquid / slurry (without crust) (2)	
Lagoon (3)	
Solid manure (4)	

Drylot (5)

Daily spread (6)

Burned (7)

Anaerobic digestion (8)

Other (9) (please
specify).....

62) Do you use manure or cattle slurry? ☐ Yes (1) ☐ No (0)

63) If yes, for what? (multiple choices possible)

☐ In pasture (grass) field (1) ☐ In other crop field (2) ☐ Fuel (3)

☐ Biogas (4) ☐ Other (5), please specify.....

64) What proportion of manure produced when the cattle are housed is applied on your fields?.....

65) What proportion of manure you produce is used as fuel?.....

69) Do you sell manure? ☐ Yes (1) ☐ No (0)

66) If yes, what proportion of manure is sold?.....

67) What is the price per unit (e.g., bag, ox-cart, etc)? US\$ _____ / _____ (indicate unit)

68) If you don't use and don't sell manure, what is done with manure?

Please explain.....

- 69) Do you produce biogas on your farm?
- ☐ Yes (1) ☐ No (0)
- ☐ No, but intend to (2)
- ☐ Other (3), please explain.....

Section C: Dairy Marketing Chain and Market Access

Section C 1. Marketing

70) Disaggregated milk quantities

Category	Average litres per day	
	High season	Low season
Total production		
Home consumption		
Milk wastage		
Milk given to calves		
Milk sold through the MCC		
Milk sold locally		
Milk sold through the dairy cooperative (other than MCC)		
Other, please specify.....		

71) Selling price in the MCC, per kg or litre.....US\$

72) If the selling price in the MCC is different in low season, please

indicate.....US\$

73) Selling price locally, per kg, litre or local unit(if in local units, please indicate the number of litres or kg per unit)

74) How far do you live from the MCC/collecting centre or market? kilometres, or hours walking

75) What mode of transport do you normally use to get to the MCC?

- a) Go by foot (1)
- b) Bicycle (2)
- c) Ox-cart (3)
- d) Own vehicle (4)
- e) Hired vehicle (5)
- f) Other (6), please

specify.....

76) Do you ever have difficulties selling your milk? ☐ Yes (1) ☐ No (0)

77) If yes, what are the difficulties?

- a) Poor quality of milk/sour milk (1)
- b) No market (2)
- c) Low price (3)
- d) Lack of transportation (4)
- e) Other (5), please specify.....

78) What is the (average) quantity of your milk rejected by MCC in the last month?

.....litres

79) Do you ever have a delay in getting paid for milk sold?

Yes (1) ☐ No (0)

80) If you do have delays, how many days on average per month (in the last 6 months)?

.....days

81) Does your MCC or dairy cooperative have an incentive system (additional payment) paid to farmers who have better quality of milk?

Yes (1) ☐ No (0)

82) If yes, how much do they pay for the:

Standard (normal) milk.....US\$/litre

Better quality of milk.....US\$/litre

83) What do you do to increase the quality of milk you sell?

.....

Section C 2. Milk collection centres and dairy co-operatives

84) Are you (or any members of your family) a member of a dairy co-operative (other than MCC)?

☐ Yes (1) ☐ No (0)

85) If no, why (please explain).....

86) What services of the MCC or dairy co-op do you use (choose all that apply)?

Services	Yes (1) or No (0)
Milk collection	
Veterinary services and livestock extension	
Feed	

Veterinary drugs

Artificial insemination

Other farming inputs

Credit

Other (please

specify).....

Section C 3. Access to credit/finance

87) Do you have (or have you had in the past 12 months) access to credit to support your dairy farm?

☐ Yes (1) ☐ No (0)

88) If yes, where did you get the credit from?

- a) Regional/international NGO (1)
- b) AgriBank (2)
- c) Zimbabwean government (3)
- d) Formal lending agencies (4)
- e) Credit union (5)
- f) Friends/relatives/neighbours (6)
- g) Other (7), please

specify.....

89) If no, would you consider borrowing to invest in your (dairy) farm?

☐ Yes (1) ☐ No (0)

90) If no, why (please

explain).....

91) Did you try to access credit in the past but did not obtain it?

☐ Yes (1) ☐ No (0)

92) Can you identify any constraints when trying to get credit (choose up to 3)?

High interest rate (1)

No formal documentation for the land (2)

☐ Credit organizations not willing to lend to smallholders (3)

☐ Other (4), please specify.....

Section C 4. Theft and security

93) If you have had any dairy animals stolen in the last 12 months, what impact did it have on you as a dairy farmer? (choose up to 3)

☐ No impact (1)

☐	Less willing to invest money in dairy farming (2)				
	☐ Moved / will move to practicing other agricultural activities (3)				
	☐ Labour constraints (if animals were used for traction) (4)				
	☐ Increased food insecurity (5)				
	☐ Other (6), please specify a) b) c)				

94) How do you plan to tackle theft in the future, please explain?

.....

Section D: Access to Animal Health and Livestock Extension Service

Section D 1. General

95) Support for the dairy farm over the last 12 months

	From the Government	From your MCC	From NGOs	From Development agencies	From other organizations, please specify.....
Do you receive support for your dairy farm,					

Yes (1)

or No (0)

Are you

satisfied

with the

level of
support
you
receive,

Yes (1)

or No (0)

96) Who provides dairy extension services in your village/Area?

☐ Government (1)

☐ NGO (2)

☐ Both (3)

☐ No extension services available (4)

☐ Other (5), please specify.....

97) Is there an extension worker at your local MCC? ☐ Yes (1) ☐ No (0)

98) If yes, how often did you have contact with them in the last 12 months?

☐ Once (1) ☐ Twice (2) ☐ More than twice (3)

☐ Never (4)

☐ Other (5), please specify.....

Section D 2. Animal health service

99) Do you vaccinate your animals? ☐ Yes (1)

☐ No (0)

100) If yes, against which diseases?

☐ Anthrax (1)

☐ Foot and mouth disease (2)

☐ Other (3), please specify

a)

b).....

c).....

101) Who vaccinates your animals?

☐ Yourself (1)

☐ Relatives/neighbours (2)

- ☐ MCC/extension support veterinarian (3)
- ☐ Private veterinarian (4)
- ☐ Community Animal Health Worker (5)
- ☐ Other (6), please specify.....
- 102) Do you pay for vaccination? ☐ Yes (1) ☐ No (0)
- 103) If you do pay for vaccination, how much do you pay?US\$
- 104) Do you de-worm your animals each year? ☐ Yes (1) ☐ No (0)
- 105) If yes, how much does it cost (per annum)?.....US\$
- 106) During last 12 months, did you see any diseased animal on your farm?
- ☐ Yes (1) ☐ No (0)
- 107) If yes, what kind of disease was it?

- ☐ East Coast Fever (1)
- ☐ Foot and Mouth Disease (2)
- ☐ Haemorrhagic Septicaemia (3)
- ☐ Black leg or Black quarter (4)
- ☐ Anthrax (5)
- ☐ Tuberculosis (6)
- ☐ Brucellosis (7)
- ☐ Not sure (8)
- ☐ Other (9), please specify.....

108) Who provides treatment to your animals in case of sickness?

- ☐ Yourself (1)
- ☐ Relatives/neighbours (2)
- ☐ MCC/extension support veterinarian (3)
- ☐ Private veterinarian (4)
- ☐ Community Animal Health Worker (5)
- ☐ Other (6), please specify.....

109) During the last year, has there been any death of the cattle on your farm?

☐ Yes (1) ☐ No (0)

110) If yes, list the details as per Table below

Cattle ID	Sex	Cause of death	How did you dispose?	Value if it were to be sold,

					US\$
		Disease ~ list	Parasites ~ list	Other ~ list	1 = burnt ; 2 = buried; 3 = sold; 4 = eaten

111) Where are some veterinary services available?

☐ In local MCC (1)

☐ Government district veterinary offices (2)

☐ Dip Tanks (3)

☐ Other (4), please specify.....

112) Are you satisfied with veterinary services you use? ☐ Yes (1) ☐ No (0)

113) Do you have any suggestions on how to increase the effectiveness of the services you use, please explain?

.....

Section D 3. Reproduction and breeding service

Have you been trained on heat detection? ☐ Yes (1) ☐ No (0)

114

) Do you use artificial insemination (AI)? ☐ Yes (1) ☐ No (0)

115

) Do you pay for AI service? ☐ Yes (1) ☐ No (0)

116) If yes, how much do you pay for each service?.....US\$

117) Do you use a bull for the whole herd? ☐ Yes (1) ☐ No (0)

118) Who is inseminating the cows?

☐ Government inseminator (1) ☐ Private inseminator (2)

☐ Farmer AI Technician (3)

☐ Veterinarian (4)

☐ Other (5), please specify.....

119) How many times do you observe your animals per day to see if a cow is on heat?

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ More than 4

120) How many times did you inseminate your cows when they became on heat?

☐ 1 time ☐ 2 times

121) Average number of services per conception?

122) Are you satisfied with the AI / breeding services you use?

123) Do you have any suggestions on how to increase the effectiveness of the services you use, please explain?

.....

Section D 4. Record keeping and level of knowledge

124) Do you practice record keeping on your farm? ☐ Yes (1) ☐ No (0)

125) If yes, select the type of information you record in Table below

Type of record	Code
Individual cow records (1)	
Breeding/fertility/reproduction records (2)	
Milk production records (3)	

Milk sales records (4)

Costs (5)

Other (6), please

specify.....

126) From whom did you (the farmer) get most of his/her knowledge on dairy farming

- ☐ Other dairy farmers (1)
- ☐ Government official (2)
- ☐ Cooperative extension (3)
- ☐ Local/International NGO (4)
- ☐ Other (5), please specify.....

127) Please rank your knowledge on dairy feed and feeding

- ☐ Very good (1) ☐ Good (2) ☐ Fair (3) ☐ Needs to be improved (4)

128) What kind of knowledge/information would you like to receive more via training? (multiple choices possible)

- ☐ General farm management (1)
- ☐ Feed and feeding (2)
- ☐ Animal disease (3)
- ☐ Udder management (4)
- ☐ Mastitis (5)
- ☐ Marketing (6)
- ☐ Artificial insemination (7)
- ☐ Farm accounts/record keeping (8)
- ☐ Quality of milk (9)
- ☐ Breeding (10)
- ☐ Other (11), please specify.....

Section E: Food Security and Climate Change

Section E 1. Food security

129) During the last 7 days how many meals did the household take per day?

- ☐ 1 (1)
- ☐ 2 (2)
- ☐ 3 (3)
- ☐ More than 3 (4)
- ☐ Other (5), please specify.....

130) How many meals a day do you have during the lean periods (on average)

- ☐ 1 (1)
- ☐ 2 (2)
- ☐ 3 (3)
- ☐ More than 3 (4)
- ☐ Other (5), please specify.....

131) Describe the food security level in your household

- ☐ Food secure throughout the year (1)
- ☐ Secure for most of the year / seasonal food security (2)
- ☐ Food insecure for most of the year (depend on the outside aid) (3)

132) Months of food inadequacy⁴ per year (on average)?..... months

133) Did your household have to undertake any of these strategies in the last 12 months (choose up to 3):

- ☐ Storing food from the harvest season (1)
- ☐ Reducing the consumption of food/consuming green maize (2)
- ☐ Food aid from relatives (3)
- ☐ Dependent on food aid from the Government (4)
- ☐ Dependent on food aid from NGOs (5)
- ☐ Reducing number of meals per day (6)
- ☐ Cutting of trees and sale for firewood (7)
- ☐ Working for other people in exchange for food (8)
- ☐ Other (9), please specify.....

134) In the past 7 days, what were the sources of food for the household?

- ☐ Own produce (1)
- ☐ Purchase from market (2)
- ☐ Casual labour paid in food (3)
- ☐ Wild food (4)
- ☐ Gift (5)
- ☐ Food for work (6)
- ☐ Free food (7)
- ☐ Winter/irrigated own food (8)
- ☐ Barter of household assets (9)
- ☐ Barter of livestock (10)

⁴ i.e. not having enough food to satisfy daily needs

☐ Other (11), please specify.....

135) In the past 7 days, what income sources did the household use to provide for the food consumed?

- ☐ Sale of own staple food crop (1)
- ☐ Sale of own other food crops (2)
- ☐ Sale of own cash crops (3)
- ☐ Sale of own livestock / milk (4)
- ☐ Sale of firewood (5)
- ☐ Brick moulding for sale (6)
- ☐ Income from business work (7)
- ☐ Income from paid job (8)
- ☐ Remittances (9)
- ☐ Sale of household assets (10)
- ☐ Other (11), please specify.....

136) Please indicate the types of food eaten over the last 7 days (choose as many as applicable):

Item	Code
Cereals, Grains and Cereal Products (1)	
Roots, Tubers and Plantains (2)	
Legumes / Vegetables (3)	
Nuts and Pulses (4)	
Meat, Fish and Animal Products (5)	
Milk and Milk Products (6)	
Fruit (7)	

Fats / Oil (8)			
Sugar / Sugar products (9)			

Spices / Condiments (10)

Wild foods (11)

Other (12), please specify

Section E 2. Climate change

137) Have you heard about climate change? ☐ Yes (1) ☐ No (0)

138) Describe features that, in your opinion, indicate climate change

.....

139) Do you think climate change is affecting Zimbabwe ?

☐ Yes (1) ☐ No (0)

140) If yes, in what way (please explain)?.....

141) Did you notice any change in the regular weather patterns in the last 5 years (choose all that apply)?

- ☐ More frequent droughts (1)
- ☐ Flooding (2)
- ☐ Erratic rainfall (3)
- ☐ Changes in crop yields (4)
- ☐ Changes in disease outbreaks (5)
- ☐ Did not notice any change (6)
- ☐ Other (7), please specify.....

142) Do you think the events identified in the question above have had an impact on your dairy farm?

☐ Yes (1) ☐ No (0)

143) If yes, how (please explain)?

.....

144) Do you think these events (identified in the question 141 above) affected any of the following?

a.	Factor	Effect ~ 1 = Increase;	If yes, how	How does
----	--------	------------------------	-------------	----------

	2 = decline ; 3 = no change; 4 = do not know	do you cope?	the change affect you and your household?
b. Feed availability			
i. Grass			
ii. Legumes			
iii. Crop residues			
iv. Concentrate			
v) Cattle diseases			
vi) Milk yield			
vii) Milk quality			
Viii) Herd size			
ix) Water availability			
x) Profit from dairy			

145) As a dairy farmer, are you aware that your activities can contribute to climate change or reduce the impacts of climate change?

☐ Yes (1)

☐ No (0)

146) Have you taken any measures in your dairy farming practices with a clear intention to reduce the impacts of climate change?

☐ Yes (1) ☐ No (0)

147) If yes, how (please explain)?

.....

148) Do you use renewable energy sources such as solar/wind?

149) If yes, please choose from below, level of usage

- a) Operations always powered by solar/other renewable energy source (1)
- b) Only use when the utility power supply is interrupted (2)
- c) Only use it to power a certain section of operations (3)

150) Are you involved in any community tree planting activities ?

☐ Yes (1) ☐ No (0)

151) How many trees do you have on your farm?

a) Local trees (number).....Please specify names:

- a.
- b.
- c.

b) Exotic trees (number).....Please specify names

- a.
- b.
- c.

152) Are you involved in any agro-forestry work?

☐ Yes (1) ☐ No (0)

153) If yes, what system of agro-forestry (and mention species used)?

Agroforestry system	Species used	Amount of land under this system, ha	Years practicing this system

154) If no, why are you not involved in any agro-forestry activities?

.....

.....

Before the enumerator leaves the farmer, he/she must rank the general condition and cleanliness of the kraal with respect to

Condition	Ranks range between 1 and 3:
	1=Poor 2=Fair 3=Good

Condition of the animal (degree of thinness, fatness)

Condition of the pens (size, ventilation, strength of

structure, etc)

Condition of the roof (iron sheets, grass thatched with plastic paper, leakage, exposure to direct sunshine, etc)

Condition of the floor (whether concrete or mud floor or bedding)

General cleanliness (presence of dung, feed, urine)

THANK YOU VERY MUCH FOR YOUR TIME AND ANSWERS

Appendix 2: Participant Information Sheet

Ethics clearance reference number: **2021/CAES_HREC/078**

Research permission reference number: **N/A**

Date: **22 March 2022**

Title: **Adoption of climate-smart agriculture practices by smallholder dairy farmers in Chipinge and Mutasa districts of Manicaland province, Zimbabwe.**

Dear Prospective Participant

My name is Mr Tinashe Chavhunduka and I am doing research with Professor Khanyisile R. Mbatha, a Professor in the Department of Agriculture and Animal Health towards a PhD in Agriculture degree at the University of South Africa. We have funding from (Not applicable). We are inviting you to participate in a study entitled Adoption of climate-smart agriculture practices by smallholder dairy farmers in Chipinge and Mutasa districts of Manicaland province, Zimbabwe.

WHAT IS THE PURPOSE OF THE STUDY?

This study is expected to collect important information that could lead to the redesigning of strategies meant for the development of the smallholder dairy farming in the country. Any gaps identified could be turned into opportunities for tailor-making sustainable smallholder dairy development strategies that directly deal with the challenges at hand.

WHY AM I BEING INVITED TO PARTICIPATE?

I work for the Southern African Confederation of Agricultural Unions (SACAU), a regional farmers' organization in southern Africa. I am responsible for coordination activities for a regional dairy platform formed by the dairy associations from southern Africa. It is in this platform that I work with the Zimbabwe Association of Dairy Farmers (ZADF). It is from discussions with ZADF that I got an idea of the concentration of smallholder dairy farmers in this area and decided that we could carry out this study in your area. Further discussions with ZADF in how the study could be done therefore led me to obtaining your contact details from their membership database. I am therefore contacting you to ask if you will be interested in participating in the study. The total number of participants from both Chipinge and Mutasa districts will be 149 all drawn from ZADF members in the districts mentioned above.

WHAT IS THE NATURE OF MY PARTICIPATION IN THIS STUDY?

Describe the participant's actual role in the study.

The study involves answering questions from a questionnaire and as you respond to the questions, the questionnaire will be filled in. The questionnaire has different sections with questions asked on 1. Basic household information 2. Dairy farm management and milk production 3. Dairy marketing chain and market access 4. Access to animal health and livestock extension services 5. Food security and climate change. The questionnaire will take approximately up to two (2) hours to complete and that is the time that will be asked of you on the day of the interview.

CAN I WITHDRAW FROM THIS STUDY EVEN AFTER HAVING AGREED TO PARTICIPATE?

Statement that participation is voluntary and that there is no penalty or loss of benefit for non-participation.

Participating in this study is voluntary and there is no penalty or loss of benefit for non-participation. You are therefore under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent form. You are free to withdraw at any time and without giving a reason. The questionnaire will clearly indicate your identity, the researcher will however take responsibility to anonymise your personal data.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

There are no material benefits for participating in the study. However, the study results may be used by policy makers, donors and other role-players in redefining smallholder dairy development agenda in the country. Some of the modifications to the sector's development may directly address some of the challenges you are currently experiencing as smallholder dairy farmers.

ARE THERE ANY NEGATIVE CONSEQUENCES FOR ME IF I PARTICIPATE IN THE RESEARCH PROJECT?

The study is generally low risk because it involves oral interaction between the participant and the interviewer. The foreseeable risks are: 1. Discomfort caused by having to endure the two hours of interview answering questions. The process requires concentration, and this may cause discomfort to some participants. 2. Opportunity cost of time, the two hours spent answering questions could have been spent on productive time on the dairy business. The loss of productive time on the dairy business can also be said an inconvenience to the participant. Short breaks can be taken during the interview to break monotony, this can mitigate the risk of fatigue. As for the risk of lost time, prior arrangements will assist the participant to put time aside for the interview. The participant will voluntarily offer their time if they feel that the study has been fully explained to them.

WILL THE INFORMATION THAT I CONVEY TO THE RESEARCHER AND MY IDENTITY BE KEPT CONFIDENTIAL?

You have the right to insist that your name will not be recorded anywhere and that no one, apart from the researcher and identified members of the research team, will know about your involvement in this research [*this measure refers to confidentiality*] OR your name will not be recorded anywhere and no one will be able to connect you to the answers you give [*this measure refers to anonymity*]. Your answers will be given a code number, or a pseudonym and you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings [*this measure refers to confidentiality*].

If relevant, identify who will have access to the data [*transcriber/external coder*] and how these individuals will maintain confidentiality [*e.g. by signing a confidentiality agreement. Please note that confidentiality agreements should be submitted to the Research Ethics Review Committee for consideration*]. Your answers may be reviewed by people responsible for making sure that research is done properly, including the transcriber, external coder, and members of the Research Ethics Review Committee. Otherwise, records that identify you will be available only to people working on the study, unless you give permission for other people to see the records.

The participant should also be aware that his/her anonymous data may be used for other purposes, such as a research report, journal articles and/or conference proceedings. A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report

HOW WILL THE RESEARCHER(S) PROTECT THE SECURITY OF DATA?

Hard copies of your answers will be stored by the researcher for a period of five years in a locked cupboard/filing cabinet at UNISA in South Africa for future research or academic purposes; electronic information will be stored on a password protected computer. Future use of the stored data will be subject to further Research Ethics Review and approval if applicable. Hard copies will be shredded and/or electronic copies will be permanently deleted from the hard drive of the computer through the use of a relevant software programme.

WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICIPATING IN THIS STUDY?

Participant are advised that there will be no payment or reward offered, financial or otherwise. The Researcher values the time spent by the participants answering questions during the interview and will duly acknowledge their participation in the thesis and any publications coming out the study.

HAS THE STUDY RECEIVED ETHICS APPROVAL

This study has received written approval from the Health Research Ethics Committee of the College of Agriculture and Environmental Sciences, Unisa. A copy of the approval letter can be obtained from the researcher if you so wish.

HOW WILL I BE INFORMED OF THE FINDINGS/RESULTS OF THE RESEARCH?

If you would like to be informed of the final research findings, please contact Tinashe Chavhunduka on +27730036895 or email him on chavhundukati@yahoo.com or 62025694@mylife.unisa.ac.za. The findings are accessible for a period of five years after the study.

Should you require any further information or want to contact the researcher about any aspect of this study, please contact Mr Tinashe Chavhunduka on +27730036895 or email him on chavhundukati@yahoo.com.

Should you have concerns about the way in which the research has been conducted, you may contact Professor Khanyisile Mbatha on +27826121931 or email on mbathkr@unisa.ac.za Contact the research ethics chairperson of the CAES Health Research Ethics Committee, Prof MA Antwi on 011-670-9391 or antwima@unisa.ac.za if you have any ethical concerns.

Thank you for taking time to read this information sheet and for participating in this study.

Thank

you.



Tinashe Chavhunduka

Appendix 3: Consent to participate in this study

I, _____ (participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable).

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.

I agree to the recording of the <insert specific data collection method>.

I have received a signed copy of the informed consent agreement.

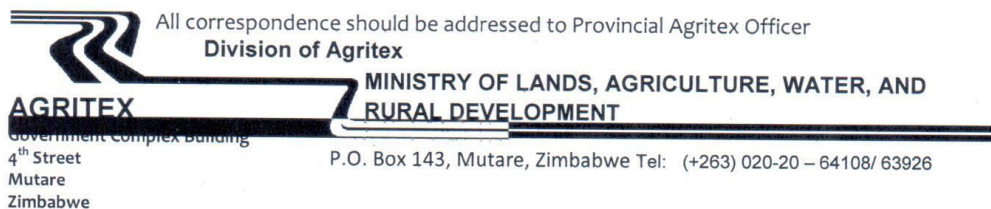
Participant Name & Surname..... (please print)

Participant Signature.....Date.....

Researcher's Name & Surname..... (please print)

Researcher's signature.....Date.....

Appendix 4: Letter of permission – Ministry of Lands, Agriculture, , Water and Rural Development



24 March 2022

TO WHOM IT MAY CONCERN

RE: APPROVAL TO CARRY OUT A RESEARCH STUDY AND DATA COLLECTION IN CHIPINGE AND MUTASA DISTRICT

This letter serves to confirm that **Tinashe Chavhunduka, student number 62025694** is a PhD student at the University of South Africa (UNISA) has been granted approval to carry out a research study and data collection in Mutasa and Chipinge districts, Zimbabwe.

The focus of his research is based on the adoption of climate agricultural practises by small holder dairy farmers in Manicaland Province on behalf of the Zimbabwe Association of Dairy Farmers (ZADF).

It is expected that the researcher is going to adhere to confidentiality on data which is going to be collected and respect of people's traditional values and local leaders.

May you please kindly assist him with the necessary information as per his research requirements.



PP *Khoza*

P. Rwambiwa
A/Director - Provincial Agricultural and Rural Development Services
MANICALAND

Appendix 4: Letter of permission – Ministry of Local Government and Public Works

Ministry of Local Government, & Public Works

*Correspondence should not
be addressed to individuals*

Telephone: 028-2561/2228
Telefax: 028-2228



ZIMBABWE

Office of the District Development Coordinator
(Mutasa)
P Bag J7113
Mutare

22 March 2022

To whom it may concern.

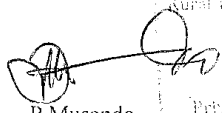
**PERMISSION TO CARRYOUT A RESEARCH IN MUTASA
DISTRICT:CHAVHUNDUKA TINASHE, ID 27-104650A27 STUDENT NUMBER
62025694 UNIVESITY OF SOUTH AFRICA.**

The subject matter above refers.

The above named is a student at University of South Africa who is pursuing his studies in PhD .
He is required is to carryout a research in Adoption of climate –smart agriculture practices by
smallholder dairy farmers in Chipinge and Mutasa districts of Manicaland.

May you render him necessary support. This office granted him the permission to carryout his
research.

Your cooperation is highly appreciated.


P Musendo
22/3/22
MUTASA
Private Bag 17113, Mutasa

FOR ACTING DISTRICT DEVELOPMENT COORDINATOR-MUTASA