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COLLEGEOFDEVELOPMENTALSTUDIES

CENTREFORFOODSECURITYSTUDIES

METEOROLOGICAL HAZARDS: CAUSES AND IMPACTS ON FOOD SECURITY AND DISASTER RISK MANAGEMENT STRATEGY IN BORENA PASTORALISTS, ETHIOPIA

By

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AddisAbaba, Ethiopia

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Athesis submittedin fulfillment ofthe requirements ofthe degreeofDoctor ofPhilosophyinFoodSecurityandDevelopment

Center for Food Security StudiesCollege of Development StudiesAddisAbaba University

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1.

DEDICATION

To my incredible father and mother, with love and gratitude.

Your constant encouragement and support have been the cornerstones of my path. Your faith in me has helped me through every setback and victory, shining a kind and wise light on my road.

Father, I've learned the value of tenacity from your determination and strength. You've taught me the value of perseverance and the significance of honesty. I have always been inspired by your quiet courage and unwavering determination.

Mother, my heart has been built by your unending love and caring nature. I now have the courage to follow my aspirations and the self-assurance to dream big thanks to you. I now understand the value of empathy and compassion because of your generosity and kindness.

You two have demonstrated to me what true love and support look like. This work is an expression of your love and the lessons you have taught. I dedicate this to you with sincere gratitude and admiration because without your leadership, none of this would have been possible.

DECLARATION

I, Fikru Tarekegn Dayo,declarethat; thisdissertationreport,exceptwereindicated otherwise,ismyoriginalresearch,

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Name:Fikru Tarekegn Dayo

Signature:____

Date:____

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DISSERTATIONAPPROVAL

This is to certify that the thesis prepared by Fikru Tarekegn Dayo entitled "Meteorological Hazards: Causes and Impacts on Food Security and Disaster Risk Management Strategy in Borena Pastoralists, Ethiopia" and submitted to the Center for Food Security Studies in fulfillment of the requirements for the Degree of Doctor of Philosophy in Food Security and Development complies with the regulations of Addis Ababa University and meets the accepted standards with respect to originality and quality.

ApprovedbyBoardofExaminers

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ACRONYMSAND ABBREVIATIONS

AAU	Addis AbabaUniversity
ATE	AverageTreatmentEffect
ATT	Average Treatment Effect of the Treated
ATU	AverageTreatmentEffectoftheUntreated
CDD	Continuous Dry Days
CSA	Central Statistics Authority
CV	CoefficientofVariation
CWD	Continuous Wet Day
DMI	Dipole Mode index
DRV	Drought-Resistant Varieties
DT	DroughtTolerant
ENSO	El Niño–Southern Oscillation
ESR	EndogenousSwitchingRegression
FANTA	FoodAndNutritionalTechnicalAssistance
FAO	FoodandAgriculturalOrganization
FCS	Food Consumption Score
FDRE	Federal Democratic Republic of Ethiopia
FGD	FocusGroupDiscussion
GDP	Gross Domestic Product
GHI	Global Hunger Index
HDDS	HouseholdDietaryDiversityScore
HFIAS	HouseholdFood InsecurityAccessScale
ID	Internally Displaced People
IEC	Information, Education, and Communication
IFPRI	International Food Policy Research Institute
IPCC	InternationalPanelonClimateChange
KII	KeyInformant Interview
MK	MannKendall
MVN	Multivariate Normal

MVP	Multivariate Probit Model
NAO	North Atlantic Oscillation
NGO	Non-Governmental Organization
NMA	National Meteorological Agency
NOAA	National Oceanic and Atmospheric Administration
NPI	North Pacific Index
OLS	OrdinaryLeastSquaresRegression
PDO	Pacific Decadal Oscillation
SLP	Sea Level Pressure
SSA	Sub-SaharanAfrica
SST	Sea Surface Temperature
SWC	Soil and Water Conservation
TPI	Trans-Polar index
UNDP	UnitedNationsDevelopment Program
UNFCCC	UnitedNationsFrameworkConventiononClimateChange

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Contents

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Publication Status of Relevant Articles:

1. Manuscript 1: Determinants and perceived climate variability adaptation successfulness of pastoral and agropastoral households in Borena Zone, Southern Ethiopia" has been published in the Journal of Sustainable Development in Africa (Volume 26, No.1, 2024) with ISSN 1520-5509. Affiliated with Pennsylvania Western University, Clarion, Pennsylvania.

2. Manuscript 2: Effect of Perceived Climate Variability on Household Food Security and Coping response in Borena Zone Southern, Ethiopia" has been accepted for publication in the Ethiopian Journal of Development Research at the College of Development Studies, Addis Ababa University.

3. Manuscript 3: Climate Variability Perceptions and Adaptation response to Ensure Household Food Security in Borena Zone, Ethiopia" is currently under review at the International Journal of Climate Change Strategies and Management (IJCCSM). Passed the technical assessment and under review, presently being given full consideration for publication, with manuscript ID IJCCSM-03-2024-0032.

4. Manuscript 4: Spatio-temporal Rainfall Variability in Borena Zone Southern Ethiopia and Its Linkage with Global Large Scale Climate Oscillations: Implications to Pastoral Household Food security " is ready for submission.

5. Manuscript 5: Climate Change Uncertainty and Household Food Security Among Pastoralists in Ethiopia: Review, ready and will be submitted to a Journal of BMC Nutrition.

EXECUTIVESUMMARY

The heavy dependence on rainfed agriculture as the primary livelihood strategy raises concerns about the impact of climate variability on Ethiopian pastoralists and agro-pastoralists. Regions characterized by arid and semi-arid conditions, such as the Borena Zone, are particularly vulnerable to meteorological hazards like droughts and floods, which are influenced by changing weather patterns. These hazards directly affect food security and worsen vulnerability due to socio-economic and environmental factors. The lack of effective adaptation strategies further compounds the challenges faced by these communities, leading to high poverty levels and increased susceptibility to livestock losses during extreme weather events. Therefore, it is crucial to comprehend meteorological hazards to develop mitigation strategies, strengthen resilience, and guide targeted adaptation efforts.

This study aims to investigate the impacts of meteorological hazards on food security and the responses to adaptation among Borena Pastoralists in Ethiopia. A mixed research approach was employed, utilizing data from 20 key informants, 12 focus groups, and 417 sample households selected through a multistage sampling technique. Additionally, daily rainfall and temperature data from the National Meteorological Agency covering the period from 1981 to 2020 were used to examine the variability of climate extreme indices. The Mann-Kendal and Sen's slope estimator was employed to analyze the standardized anomalies of temperature and rainfall variability, as well as to assess the occurrence of dry and wet periods. Descriptive statistics, including mean, median, and percentages, were employed to summarize demographic, socioeconomic, and institutional characteristics, as well as the food security status and climate change adaptation strategies. Furthermore, a multivariate probit model was utilized to identify the determinants of climate variability adaptation strategies, while a multiple linear regression model was applied to ascertain the factors influencing household food security within the Borena Zone. A probit model was also adopted to analyze household perceptions of climate variability about their adaptation responses. Moreover, the impact of climate variability adaptation responses on food security among agro-pastoralists and pastoralists was analyzed using an endogenous switching regression model.

The analysis of climate extreme indices in the Borena area revealed increasing trends in both maximum and minimum temperatures, along with shifts in various extreme temperature and rainfall patterns. These changes have significant implications for evaporation rates and rainfed agriculture, which are key factors affecting food security. Furthermore, the findings obtained from the Household Food Insecurity Access Scale (HFIAS) indicated that a majority (95%) of households experienced food insecurity. Among them, 36%, 36%, and 24% had experienced severe, moderate, or mild food insecurity respectively. The results from the multivariate probit model demonstrated that perceptions of temperature increase, and decreased rainfall significantly influence the coping strategies adopted by pastoralists and agro-pastoralists. A perception of temperature increases leads to an increased adoption of land contracting, borrowing from credit unions, selling fuelwood, and engaging in daily labor, while reducing the adoption of selling charcoal, seeking free support, and reducing expenses. Additionally, the multiple linear regression model highlighted that borrowing from friends or family (2.58),

expense reduction (1.87), age (0.047), family size (0.37), and access to extension services (0.02) significantly reduce food insecurity among pastoralist and agro-pastoral households.

Regarding climate adaptation responses, a high percentage of pastoralist and agro-pastoralist households perceive temperature increases (94.7%), decreases in rainfall (87.8%), and increases in drought (83.9%). Livestock adaptation strategies include practices such as feed storage (61.9%), destocking (39.6%), and rainwater harvesting (67.4%). The endogenous switching regression model was revealed that a significant average treatment effect (ATT) on household food security for various climate adaptation responses. Growing livestock feed (ATT = 15.6), feed storage (ATT = 14.1), soil and water conservation (ATT = 14.2), saving crop seed or money (ATT = 14.6), receiving free support (ATT = 14.7), and accessing mass media (ATT = 12.8) all demonstrate reductions in food insecurity among pastoralist and agro-pastoralist households. The survey was indicated high success rates for most adaptation strategies among pastoralist and agro-pastoralist households, particularly in terms of veterinary services (55.0%), modern forecast information precision (73.0%), and extended search for feed (81.0%). However, the destocking strategy showeda lower success rate (27.0%), suggesting room for improvement in this specific strategy.

The multivariate Probit modelrevealed that asignificant correlation between climate change adaptation strategies and various factors such as household size, membership in credit associations, education level, monthly income, and access to extension services. These factors significantly influenced the perceived success of strategies such as veterinary services, water harvesting, feed conservation, seasonal migration, modern forecast information precision, extended search for feed, destocking, and receiving government aid.

The findings underscore the complex factors shaping adaptation strategies within pastoralist communities in the Borena Zone. These context-specific adaptation strategies, their efficacy in enhancing food security, and the factors influencing their adoption can inform the design of more targeted, locally appropriate interventions for policy makers and stakeholders.

They stress the pressing need for integrated adaptation strategies, focusing on increased soil conservation, livestock management, and improved weather information availability. These recommendations are essential for developing focused interventions meant to lessen the effects of climate change and guarantee food security in susceptible areas, such as the Borena Zone. To reduce food insecurity among Ethiopian pastoralists and agro-pastoralists and increase resilience to extreme weather events, it is imperative to prioritize livestock management programs, support sustainable agriculture, and improve early warning and preparedness.

CHAPTER 1: GENERAL INTRODUCTION

1.1. Background and justification

Extreme meteorological and climatic phenomena, such as floods, droughts, storms, tornadoes, and landslides, generate hydro-meteorological hazards (Amin et al., 2022). They make up most natural hazards and occur in all parts of the globe, though the frequency and severity of specific hazards, as well as societal vulnerability, vary by area. Strong floods, droughts, and other climate extremes cause significant infrastructure damage and kill hundreds of thousands of people every year throughout the globe (Wu et al., 2016).

Natural hazards such as floods, droughts, and heatwaves endanger social-ecological systems across the world. Floods and droughts are typically caused by a combination of naturally occurring extreme weather events and anthropogenic activity (Harris et al, 2020, Sayers et al., 2013; van Dijk et al., 2013; Schubert et al., 2004). Agricultural production and commercial activities are leading to the deterioration of natural ecosystems' regulating capabilities, which typically serve to sustain hydrological processes (MA, 2005; De Groot et al., 2002), resulting in higher flooding and other consequences (Sayers et al., 2013; Steiger et al., 1998). Global climate change is also exacerbating the severity of hydro-meteorological hazards, pushing them to extremes that have the potential to profoundly alter natural ecosystems (Guleria and Gupta, 2024; IPCC, 2014).

Natural hazards do not create disasters; catastrophes come from the interaction of an exposed, vulnerable, and poorly prepared population or community with a hazard event (Goniewicz et al., 2023). Climate change will thus affect disaster risks in two ways: first, by increasing the likelihood of increased weather and climate hazards, and second, by increasing community vulnerability to natural hazards, particularly through ecosystem degradation, reduced water and food availability, and changes in livelihoods. Climate change will add to the stresses of environmental degradation, diminishing communities' ability to deal with even the current levels of weather threats (UNDRR, 2008). Disaster affects all components of food security. It threatens all economic sectors, particularly agriculture (Abid et al., 2015), which employs over 1.3

billion global population (22% of the worldwide population) (Allahyari et al., 2016) . It is a major issue in Africa, particularly in countries like Ethiopia. Ethiopia, with an approximate population 126.5 million in 2023, is Africa's second most populous country (World Bank, 2023). Although climate variability and change have made it difficult for rural people to ensure sustainable agricultural production and food security, farming remains a vital part of rural life. Climate-related risks usually affect the poor directly by decreasing crop yields or damaging dwellings, as well as indirectly by boosting food costs and food insecurity (IPCC, 2014).

The frequency and intensity of extreme weather events like droughts, floods, and landslides have increased, causing significant loss of life and economic damage (Gebrehiwot & van der Veen, 2017). Rural communities dependent on climate-sensitive livelihoods are disproportionately impacted by these disasters (FDRE, 2020). Climate change is exacerbating existing vulnerabilities and undermining disaster risk reduction efforts (Teklu et al., 2023). Droughts, floods, and other climate-related disasters are driving internal displacement and migration within Ethiopia (Leal Filho et al., 2023).

Rising temperatures and decreasing precipitation in Ethiopia have contributed to the country's history of drought (NMA, 2007). A lengthy history of droughts, particularly in the lowlands, has made Ethiopia more vulnerable to the effects of climate change (Lautze et al., 2003). Since 1876, Ethiopia has had 22 droughts, with an average cycle of 6 years, although now just 2 to 3 years. Droughts in Ethiopia have been more frequent and severe over time (Eshetu et al., 2010). Moreover, the annual lowest temperature has climbed, and the rainfall data mean has lately shown a significant degree of variability (NMA, 2007).

People around the world and the pastoral community are affected by climate change (Seid et al., 2016). Climate change is incredibly hazardous for pastoralists and agro pastoral. Climate change could lead to an increase in livestock mortality and a reduction in herd size. The fall in animal populations affects food security, pastoralists' reliance on livestock and their products, and the other contributions they make (Herrero et al., 2016). Reduced livestock and inadequate government intervention pushed herders to abandon pastoralist livelihoods and look for other options such as charcoal manufacturing, crop farming, and other economic pursuits (Beyene and

Korf, 2008). Afar, Oromia, Somali, and the SNNP are the four lowland regions in Ethiopia where pastoralists live. The Borena plateau, where pastoralists live, has the greatest rate of poverty and the fewest facilities (Oxfam, 2010).

Adaptation is a major policy response to climate change. ‘‘... the process of adjusting to existing or predicted climate and its effects to mitigate harm or exploit good opportunities," (IPCC, 2014). Pastoralists' climate-change adaptation strategies focus on livestock and pasture management. Grassland tenure, financing, and access to agricultural markets were also identified as hurdles by pastoralists. Household livelihood capital and geography were also revealed to be important elements influencing the choice of adaptation strategies (Zhang et al., 2019).The adaptation strategies for climate change in pastoral communities of Ethiopia include maintaining or improving animal health, managing livestock feed and water, diversifying livelihoods, using energy sources other than wood and charcoal, improving human health (sanitation) and clean water supply, market, and infrastructure (Chinasho, 2017).

Furthermore, disaster risk management plays a critical role in reducing the natural disaster risk impact and building resilience to food security, making food available to affected people. Disaster risk management is the systematic process of using administrative directives, organizational and operational skills, and capacities to implement strategies, policies, and improved coping capacities to lessen the adverse impacts of hazards and the possibility of disaster (UNISDR, 2009). Most natural disasters cannot be avoided, even with preventive measures, and the risk cannot be reduced to zero (World Bank, 2014). Hence, it is important to maintain definitive risk management strategies to mitigate natural disasters where risk cannot be avoided. Disaster management is typically dependent on information sources, monitoring, and early warning (Riaz, McAfee & Gharbia, 2023). Improving the monitoring components enables us to evaluate the situation and plan accordingly. Preparation based on monitoring, evaluation, and early warning will mitigate the effects of extreme natural disasters and save lives. Along with weather monitoring, it is critical to monitor food reserves and be prepared for disasters. Evaluating the potential impacts on crops, livestock, and fisheries is critical for better disaster risk reduction and climate risk management. Food security management measurements include livestock shelters, animal fodder reserves, bags for smallholder farmers to store seeds, improved seed storage facilities, raised seedbeds, and strategic animal fodder reserves.

Adaptation to climate change and disaster risk management both seek to reduce risk factors and modify environmental and human contexts that contribute to climate-related risk, thus supporting and promoting sustainability in social and economic development (IPCC, 2014). Adaptation strategies to implement disaster risk reduction should be established based on the evaluation and prioritization of the risks that people faceand their ability to adapt to and resist the effects of those risks. An increase in disaster preparedness to manage risk also ensures climate change resilience (Reddy et al., 2019).

The current Ethiopian pastoral development policy and strategy focus on realizing improved and sustainable livelihoods for people in pastoral areas through integrated development that is centered on animal resources, local knowledge, and other reliable endowments. The policy is aiming at responding to the demands of pastoralists for growth and development in a holistic manner by taking their livelihood system as the basis; guiding sectorial policies and strategies that have been developed in a segmented fashion, based on the constitution, national policies, and strategies, and regional conventions, to be revised in light of the livelihood basis and ecology of pastoralists, and coordinate such policies and strategies so that they will be implemented in cooperation; coordinating government and non-government pastoral development actors so that they will work together and exchange experiences for a common goal; coordinating efforts to make pastoral areas sustainably food secure, peaceful; and where democracy and good governance are enshrined; and narrowing down the gaps in development and capability indicators between pastoral areas and relatively developed neighboring regions and the national average (FDRE, 2020).

Understanding the causes of drought, flood, and other climate extremes and their impact on climate-sensitive sectors' livelihoods, agricultural production, and food security is of utmost importance. Accordingly, this research is designed to understand rainfall and temperature variables' linkage with sea surface temperature and its impact on pastoralists' household food security and their coping responses, which in turn determine their adaptive capacity and disaster risk management strategies.

1.2. Statement of the Problem

Climate change is one of the most pressing environmental issues of our day (UNFCCC, 2007). Ethiopia is one of the most vulnerable countries to climate change in Africa, with the least capacity to respond (Thornton et al., 2006). In Ethiopia, the 2015/16 El Niño event caused a decline in agriculture and cattle production and left more than 10 million people in food aid and acute food insecurity. Droughts, floods, heavy rains, high winds, and heat waves are common in Ethiopia (Abebe, 2007). In addition, Ethiopia is more dependent on climate-sensitive economic sectors, including subsistence crop cultivation and animal production (Gemeda et al., 2023; Sector, 2014).

Pastoralists herd their animals in the arid and semi-arid lowlands that make up around 61% of Ethiopia's land mass (MARD, 2008). Droughts and flash floods are common in these locations. Droughts have occurred in southern Ethiopia more regularly and for extended durations than previously recorded. Because of the shifting environment, the region's livestock, as well as nomadic pastoralists such as the Borena, have been badly impacted (Gatew and Guyo, 2024; Hurst et al. 2012). Livestock provides food, income, manure, and draught power for pastoralists, as well as a social status symbol. Gifts, exchanges, and fines are employed to assist and socialize with other people (Watson and Cutley, 2008). Many pastoralists' credit access is based on their livestock assets. Thus, the sector is considered pastoralists' economic and social insurance (Vandamme et al., 2010). In general, the present climate variability and extreme weather events negatively impact the livestock and agricultural sectors, increasing disease prevalence, reducing production, and decreasing profitability (Delandmeter et al., 2024; Thornton and Gerber, 2010).Furthermore, they favor parasites and pathogens, reducing reproduction and raising mortality (Nkedianye et al., 2011; Huho et al., 2011).

The Borena plateau's grazing systems have become unsustainable in recent decades (Degen, 2024; Coppock et al., 2008; Wassie et al., 2007; Getachew et al., 2006). The area has been hit by cyclical and prolonged droughts that have decimated livestock, increasing poverty (Coppock et al., 2008) and food insecurity (Ayal et al., 2017). Poor infrastructure, decades of neglect, unsuitable development intervention, and economic and political marginalization will boost pastoralists' vulnerability (Busby et al., 2012; Thornton and Gerber, 2010). The Borena pastoralists' livestock system is highly vulnerable to climate variability and extremes (Ayal et al., 2017). The Borena pastoralists are becoming more sensitive to climate extremes due to a decline in classical forecasting of the weather and an absence of climate variability adaptation management (Ayal et al., 2015). The combined impact of these issues weakens adaptation and coping strategies and exacerbates already insecure food security in the region.

Every household responds differently to a food crisis. Their coping strategies change based on the severity of the crisis and the resources available to them. Some sell their possessions, seek part-time employment, turn to their social network, participate in income-generating activities, or get food assistance from NGOs and the government (Chlembo, 2004). Another study revealed that the most common coping practices that are sequentially used during a food crisis consist of reducing the number and size of meals, selling small ruminants and draft oxen, consuming wild food, and borrowing cash and/or food from better-off neighbors and/or relatives. Other less frequently used strategies were postponing weddings and other ceremonies, selling firewood, drawing children from school, and eating toxic taboo foods (Eshetu, 2000).

The most important coping strategies used by pastoral and agro-pastoral communities in drought are mobility, raiding (aggressive taking away of animals), species diversification, and herbs; mortgaging and selling assets; distress migration; borrowing food or money to buy food; and clan interdependence (members of the same clan share food among themselves). Other coping methods include giving part of their cattle to relatives who live in non-drought regions, seeking paid work from sedentary agricultural families, and relying on remittances. Some coping methods are small trading, charcoal sales, and eating wild fruits and leaves (Belay et al., 2005). Other coping strategies include harvesting immature food crops, selling cattle, searching for alternative water sources, and using alternative, non-production-based means to access food (Mayanja et al., 2020).

The effectiveness of their coping and adaptation techniques is affected by climatic extremes and associated dangers (Hurst et al., 2012; Aklilu et al., 2009). There is a need for a fresh and deeper understanding of the impact of climate extremes in pastoralist areas for an appropriate understanding of their environmental and socio-economic trajectories. To precisely assess pastoralist regions' ecological and socio-economic trends, a deep intellectual comprehension of climate extremes is required. Despite widespread agreement on the degree of climate variability at the global and national levels and its unfavorable influence on livestock and agricultural productivity, the issues in Borena still must be addressed. As a result, it is critical to investigate the present state of climate variability in the study area and its implications on food security. It is crucial to comprehend pastoralists' perceptions of climate variability, its underlying causes, and destructive effects on food security to successfully utilize the knowledge and establish logical and practical adaptation and coping strategies to climate extremes (Tolera and Senbeta, 2020; Thomas et al., 2007).

Food security in the face of natural disasters and climate change requires the design of adaptation strategies that can reduce vulnerability and increase resilience. Adaptation approaches must incorporate actions targeted at climate change resilience and disaster risk reduction, as well as addressing the underlying causes of vulnerability. Disaster risk reduction protects development investments in the agriculture, livestock, fisheries/aquaculture, and forestry sectors, helping the world's most vulnerable people become food secure. Disaster risk reduction is vital for ensuring one of the most basic human rights, the right to food and freedom from hunger. Furthermore, disaster risk reduction creates a multiplier effect that accelerates the achievement of the eradication of extreme poverty and hunger. An integrated approach to adaptation involves disaster preparedness and relief and resilient infrastructure to face disaster and climate change risks. Integrated adaptive strategies for natural disaster risk reduction and climate change adaptation secure food in vulnerable communities (Reddy et al., 2019; Amaral et al., 2012).

Research on climate variability, the perceived impact of climate change on food security, and adaptation responses is crucial for addressing the challenges posed by the changing climate. It provides the knowledge and evidence needed to develop effective strategies, policies, and interventions to safeguard global food security, promote sustainable agriculture, and build resilience in the face of climate change. Thus, this study explored the degree and causes of climate variability, its impact on food security, climate change adaptation and coping strategies, and pastoralists' climate change perceptions in the Borena zone of southern Ethiopia.

1.3. Objectives

1.3.1. General objective

This study investigated the causes and impacts of meteorological hazards on food security andadaptation strategies among Borena Pastoralists, in Ethiopia.

1.3.2. Specific objectives

The specific objectives of the study are to:

1. Examine the trend and variability of temperature and rainfall (1981-2020).
2. Identify the causes of climate extremes mainly rainfall.
3. Assess the effect of climate variability on household food security status and their food coping responses.
4. Examine pastoral household's climate variability perceptions and adaptation response to ensure their food security.
5. Identify climate change adaptation response determinants and examine perceived adaptation successfulness among pastoral households.

1.4. Theoretical Foundation of the Study

Psychological dimensions of climate change and sustainable livelihood approaches are adopted as the main theoretical frameworks for the study. Below are the salient features of each of the theories that guided the research.

1.4.1. Psychological dimensions of climate change

Figure 1.1 illustrates the well-known theoretical framework in the field of environmental psychology for addressing the human dimensions of climate change: Stern's model of the "psychological dimensions of climate change" (Stern, 1992). The framework discusses the idea that human activity, like as burning fossil fuels and clearing forests, directly affects the climate. These acts are the result of many different cultural, economic, political, and social settings and processes, collectively referred to as "human systems," in addition to psychological elements like human understanding of climate change, affective responses to climate change, and psychological motivations.

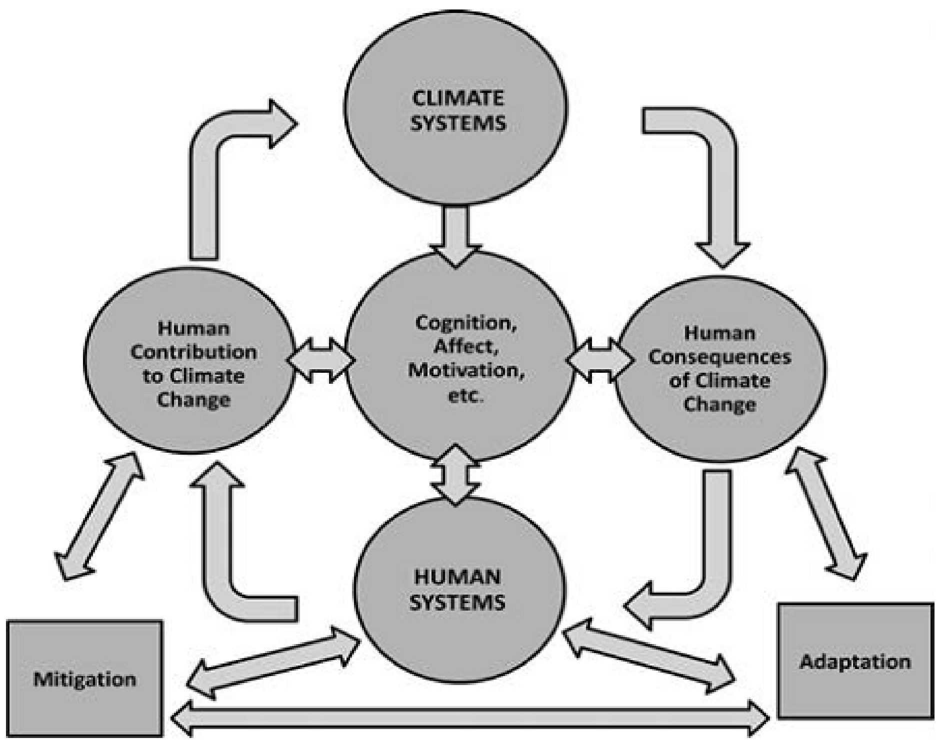

Figure 1.1:The Psychological Dimensions of Climate Change (adapted from Stern, 1992: pp. 273)

Climate change adaptation includes addressing the psychological and social implications of the threat as well as the emerging consequences of climate change. The psychological aspects of climate change are intrinsically psychological, as evidenced by the direct and indirect effects of psychological processes on many of the elements. Psychology can also offer concepts and knowledge to help explain human understanding of the causes and effects of climate variability, as well as guide and enhance response (Swim et al., 2011).

By altering hazard frequency, intensity, vulnerability, and exposure patterns, climate change has the potential to increase the risk of disasters. The frequency and severity of many weather-related risks are already shifting due to climate change, and exposed communities that depend on arable land, water availability, and steady mean temperatures and rainfall are losing ground. The likelihood of weather-related disasters, climate-related hazards, and the effects of sea level rise are all increased by climate change. In addition, communities are more vulnerable to natural hazards because of ecosystem degradation, decreased water and food availability, and altered livelihoods. As a result of environmental degradation, climate change, and rapid, unplanned urban growth, communities will not be able to handle even the current level of weather risks. Even while the precise effects of climate change are unknown and may not affect every place equally, it is anticipated that these effects will raise the likelihood of disaster. The rise in unofficial settlements in vulnerable places, a lack of funding for drainage infrastructure, and inadequate urban and municipal governance are other risk patterns associated with climate change. By addressing these, climate change resilience can be increased (IPCC, 2014). The psychological aspects of the climate change theoretical framework wasapplied in this study to better understand how humans relate to the causes and effects of climate variability as well as to guide and enhance existing responses.

1.4.2. Sustainable livelihoods theoretical framework

The Sustainable Livelihoods theoretical framework was used in this study to investigate how individuals might adapt to natural disasters. Four strategies were employed by Kelman and Mather (2008) to apply the Sustainable Livelihoods theoretical framework for disaster risk reduction:

- Understanding, communicating, and managing vulnerability and risk and local perceptions of vulnerability and risk beyond immediate threats to life
- Maximizing the benefits to communities of their disaster environment, especially during quiescent periods, without increasing vulnerability
- Managing crises
- Managing reconstruction and resettlement after a crisis.

According to Chambers and Conway (1992), the livelihood concept is predicated on the idea that a rural household possesses or has access to a set of resource bases, such as capital or assets, which can be used to create a variety of livelihood strategies, such as crop farming, livestock rearing, off-farm employment, etc., to enhance household welfare. According to Ellis (2000) and Chambers and Conway (1992), a household can be considered sustainable if it can effectively manage and recover from climate-related shocks and stresses, while also maintaining or enhancing its current and future capacities and assets, all without endangering the natural resource base. Using the sustainable livelihoods concept, the complex relationships between climate change and the vulnerability environment of pastoralist households, their asset base, intervening institutions, and livelihood strategies are emphasized.Using a holistic approach, the researcher suggests applying a sustainable livelihood modeling approach to investigate the possible effects of climate variability, pastoralist views, and adaptation strategies on food security. The objective is to gain knowledge of the several factors that influence food security in connection to climate change, their interactions, and the best ways to encourage more sustainable living (Chambers and Conway, 1992).

Using a holistic approach, the researcher applied a sustainable livelihood modeling approach to investigate the possible effects of climate variability, pastoralist views, and adaptation strategies on food security. The objective is to gain knowledge of the several factors that influence food security in connection to climate change, their interactions, and the best ways to encourage more sustainable living (Chambers and Conway, 1992).

According to the framework, people's asset status is directly impacted by the vulnerability context, which creates their external environment and gives them significance (Devereux, 2001).

The variously shaped asset pentagons demonstrate the community's ability to accomplish its goals for a living by showcasing its financial, physical, social, natural, and human capital.

Transforming Structures and Processes is a representation of the institutions, groups, laws, and policies that influence livelihoods. They are essential because they function at all levels and efficiently set terms of exchange and access for all kinds of transactions (Shankland, 2000). The several decisions and actions people take to reach their livelihood objectives are referred to as livelihood strategies. Increased income, improved well-being, decreased susceptibility to climate change, and more sustainable use of natural resources are among the livelihood outcomes listed in the last section of the box (Figure 1.2).

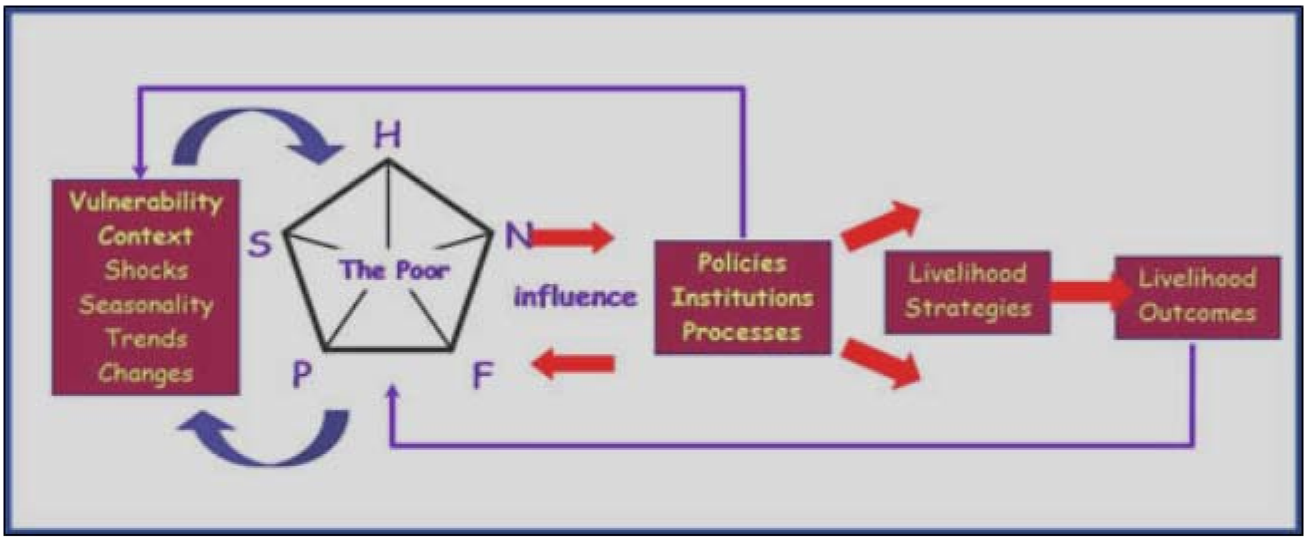

Figure 1.2: Sustainable Livelihoods Framework. Source: Chambers, R., and Convey, G., 1992

1.5. Description of the study area

The study was conducted in the Borena Zone, in the southern part of the Oromia regional state, Ethiopia. The zone shares boundaries with the Guji zone in the east, the Somali regional state in the southeast, the Southern Nations in the west, and Kenya in the south. The zone is situated at 4 º N to 6 º N and 36 º E to 42 º E (see Fig. 1). The Borena Zone is characterized by a semi-arid to arid climate, with an average annual rainfall ranging from 300 to 700 millimeters (Desta & Coppock, 2004). The region is dominated by a plateaued landscape, with elevations ranging from 1,000 to 1,500 meters above sea level (Coppock, 1994). This topography features a mix of grasslands, shrublands, and scattered acacia trees, which provide important grazing resources for the region's pastoralist communities (Desta & Coppock, 2002).The Borena Zone comprises 13 districts. It covers an area of approximately 45,000 square kilometers and shares borders with Kenya to the south and the Somali Regional State to the east (ONRS, 2022).The zone is named after the Borena people, who are the predominant ethnic group in the area.The Borena Zone is characterized by diverse landscapes, including vast grasslands, savannas, and scattered hills. It is situated within the Great Rift Valley, which runs through Ethiopia.

The climate of the Borena Zone is predominantly semi-arid, with a mix of dry and wet seasons. The majority of the Borena Zone's annual precipitation occurs during the July-September Ganna rains, which are crucial for replenishing water sources and providing forage for the region's pastoralist communities and livestock (Desta & Coppock, 2004).The March-May Hagaya rains provide additional rainfall that helps sustain vegetation and water resources during the drier months (Desta & Coppock, 2002).Droughts have had a significant impact on the lowland areas of Borena, and the region experiences fluctuating rainfall patterns. Pasture availability in the area is limited and highly variable due to the fluctuating rainfall patterns (NAPA, 2007). In the study site, pastoralism is a predominant livelihood. Climate variability is posing different challenges to household food security.

The Borena Zone is known for its pastoralist communities, which practice traditional livestock herding as their primary means of subsistence. The local economy revolves around the rearing of cattle, goats, and sheep, and the Borena people have developed sophisticated systems for managing their herds and adapting to the challenges of the semi-arid environment.In addition to pastoralism, the Borena Zone also supports some agricultural activities, mainly focused on rain-fed crops such as maize, sorghum, and beans. The area is rich in natural resources, including minerals, wildlife, and diverse flora.

Major towns in the Borena Zone include Yabelo, Mega, Moyale, and Dillo, which serve as administrative and commercial centres for the surrounding rural areas. Overall, the Borena Zone is characterized by its unique cultural heritage, traditional livelihood practices, and the striking natural beauty of its landscapes. Arero, Dhas, Dillo, Dirre, Dubluk, Eelwoye, Gomole, Guchi, Miyo, Moyale, Taltale, Yaballo, and Wachile are among the thirteen-pastoralist rural woreda in the zone. Within the zone, there are eleven town kebeles and 134 rural kebeles (Peasant Associations). Due to their extreme remoteness, most of the Borena Zone's districts lack access to essential amenities like banking, water, and phone service. The Central Statistics Agency's 2009 prediction states that there are 503,877 people residing in the zone, with a male-to-female ratio of 1:1. Additionally, 89% of people live in rural areas, which are sparsely populated with an average of 23 people per km; however, settlement patterns vary from district to district. Yabello Town serves as the zone's capital and is situated 570 kilometres away from Addis Ababa, the nation's capital. The zone is home to Burji, Konso, and several other ethnicities, although the main ethnic groups residing there are the Borena Oromo, Guji, and Gabra.

One of the most significant natural resources that the Borena zone is provided with is wildlife. The zone's varied topography and climate have produced a range of natural habitats that are home to a rich array of flora and fauna. The park is home to about 300 species of birds and about 30 species of mammals. Being home to 64% of the Somali-Masai bird biome ensemble and providing habitat for highly endangered bird and mammal species, Borena National Park is an intriguing ornithological location. Ethiopian Bush Crow, White-tailed Swallow, Ostrich, Archer's Grey-wing, little spotted woodpecker, Grey-headed Silver-bill, little tawny Pipit, Somali Sparrow, Star-spotted Nightjar, and other bird species are among those found in Borena National Park. Some of the remarkable mammal species found in the park include Gravy’s Zebra, Grant’s Gazelle, Gerenuk, Oryx, Greater Kudu, Lesser Kudu, Cheetah, Leopard, Lion, and others.

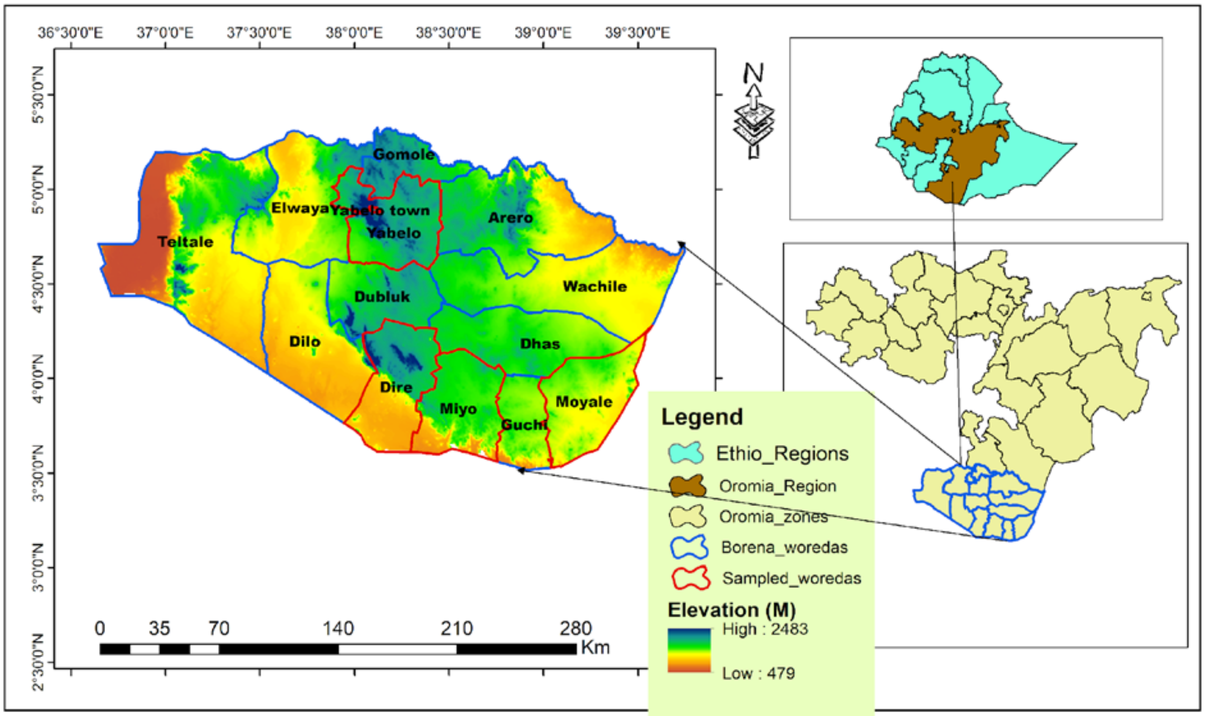

Figure 1.3: Map of the study area

Source: Own GIS construction (2023)

1.6. Research Methodology

1.6.1. Research Philosophy

According to Bonache (2020), research philosophy refers to a collection of beliefs about the nature of reality that is being studied. The sort of research philosophy that is employed in each field of study depends on the knowledge base being studied. The research philosophy underlying this study is rooted in a combination of positivism and constructivism, recognizing the importance of both objective data collection and subjective understanding of the lived experiences of the Borena pastoralists.

The positivist approach guided the quantitative aspects of this research. It emphasized the collection of empirical data through systematic observations and measurements. By employing data-driven methodologies, such as surveys, meteorological data analysis, and econometric analysis, the study will aim to identify the causes and patterns of meteorological hazards, their impact on food security, and the relationship between these hazards and disaster risk. The constructivist perspective informed the qualitative aspects of the research. It recognizes the social and cultural contexts in which meteorological hazards occur and the subjective experiences and interpretations of the Borena pastoralists. Constructivists or interpretivists are those who believe there is no reality other than what individuals create in their minds (Matta, 2022).

The research philosophy for this study combined positivism and constructivism to provide a comprehensive understanding of meteorological hazards, their impact on food security, and disaster risk management strategies in the context of Borena pastoralists, Ethiopia. By integrating quantitative and qualitative approaches, the study generated knowledge that can inform policies, programs, and interventions aimed at building resilience and improving the well-being of the Borena pastoralist community in the face of meteorological hazards.

1.6.2. Research Design

A quantitative analysis of meteorological data from 1981 to 2020 was conducted to assess temperature and rainfall trends for Borena pastoralists. Ethiopia's climate has undergone significant changes due to climate change, as indicated by studies like Hagos et al. (2019), Conway and Schipper (2011), and Funk et al. (2019). This study extends previous research by examining a wider range of climate extremes and their impacts on food security and disaster risk management, considering factors like natural variability and human-induced climate change, as discussed in studies by IPCC (2012), Deressa et al. (2011), and Hassen et al. (2018).

This study adopted an integrated approach combining quantitative and qualitative methods to evaluate the impact of climate variability on household food security and pastoralists' adaptation responses. Previous research by Gebrehiwot et al. (2018) and Lemma et al. (2020) has emphasized the significant influence of climate variability on food security in Ethiopian pastoralist communities. By conducting household surveys and interviews, the study aimed to explore the specific mechanisms through which climate variability affects food security and the coping strategies used by Borena pastoralists. Pastoral communities often rely on traditional knowledge and adaptive strategies to deal with climate variability, as noted in studies by Tessema et al. (2017), Catley et al. (2013), and Galvin et al. (2020). Additionally, identifying the determinants of climate change adaptation responses among pastoral households required a mixed-methods approach, considering insights from previous studies by Adger et al. (2009) and O'Brien et al. (2018) on factors influencing adaptation decision-making and the effectiveness of adaptation strategies.

1.6.3. Methods of data collection

Meteorological data spanning from 1981 to 2020, essential for analyzing temperature and rainfall trends and variability, was acquired from meteorological stations located within or near the Borena region. This historical meteorological data, including daily precipitation and temperature records, was sourced from national meteorological agencies, particularly the National Meteorological Agency (NMA). The data collection process entails accessing existing meteorological records and potentially conducting supplementary data quality assessments. Literature, such as studies by Funk et al. (2019) and Hagos et al. (2019), offers valuable insights into the availability and reliability of meteorological data in Ethiopia.

Climate extremes, including floods, droughts, and other events, necessitate a blend of meteorological data, remote sensing imagery, and socio-economic indicators. Meteorological data on extreme weather events was sourced from national meteorological agencies, while socio-economic data on the impacts of climate extremes was gathered through household surveys and interviews. Literature by Deressa et al. (2011) and Hassen et al. (2018) discusses the utilization of integrated approaches to assess the causes and impacts of climate extremes in Ethiopia.

Assessing the impact of climate variability on household food security status and coping responses necessitated household-level data on food consumption, income sources, and coping strategies. Household surveys and interviews served as the primary data collection methods to gather this information, with survey questions designed to capture household perceptions of climate variability, experiences with food insecurity, and the efficacy of coping mechanisms.

Relevant literature by Gebrehiwot et al. (2018) and Lemma et al. (2020) provides examples of survey instruments used to assess food security and coping responses in pastoralist communities of Ethiopia.

To explore pastoral households' perceptions of climate variability and their adaptation responses, both qualitative and quantitative data collection methods were employed, including focus group discussions and semi-structured interviews. These methods allowed researchers to delve into the nuanced perspectives and experiences of pastoral communities regarding climate change and adaptation. Literature by Tessema et al. (2017) underscores the importance of incorporating local knowledge and perceptions into climate adaptation research in pastoralist areas.Identifying the determinants of climate change adaptation responses and assessing their effectiveness among pastoral households necessitated a mixed-methods approach combining quantitative surveys with qualitative interviews and focus group discussions. Quantitative surveys captured demographic characteristics, socio-economic status, and access to resources, while qualitative methods explored contextual factors influencing adaptation decision-making and perceived effectiveness. Literature by Adger et al. (2009) and O'Brien et al. (2018) highlights the importance of interdisciplinary approaches to understanding adaptation processes and outcomes in diverse socio-ecological contexts.

1.6.4. Sampling technique and sample size determination

To examine the trends and variability of temperature and rainfall, a systematic sampling approach was utilized to select meteorological stations within or near the Borena region. The sample size depended on the availability of meteorological stations with complete data records spanning from 1981 to 2020. To ensure spatial representativeness, different meteorological stations were chosen, guided by insights from literature by Hagos et al. (2019) and Funk et al. (2019) regarding station distribution and suitability for trend analysis in Ethiopia.

To assess the impact of climate variability on household food security, understand pastoral households' perceptions and adaptation responses to climate variability, and identify determinants of climate change adaptation responses and their effectiveness, a multi-stage sampling technique was employed. This technique involved selecting households from agro-pastoralist and pastoralist communities within the Borena region. Stratification was based on geographical location, household size, and socio-economic status to ensure diversity and representation. The sample size was determined using the Cochran formula for estimating proportions with a confidence level of 95% and a margin of error of 5%, guided by literature by Gebrehiwot et al. (2018) and Lemma et al. (2020) on sample size determination for assessing food security in pastoralist communities.

1.6.5. Data analysis method

A descriptive analysis was conducted to examine the trend and variability of temperature and rainfall over the study period from 1981 to 2020. The trend of temperature and precipitation extreme indices was evaluated using the Mann-Kendall test. Time series plots and Sen's slope estimator were utilized to visualize and quantify the trends in temperature and rainfall. Additionally, indices such as frequency, duration, and severity were analysed to assess the impacts of climate extremes, including floods, droughts, and other extreme events.

To understand the effect of climate variability on household food security and coping responses, descriptive analysis was employed. Indicators of food security, such as food consumption scores, household food insecurity access scale, and dietary diversity scores, were calculated to examine how households managed during periods of climate variability. Inferential analysis, including regression analysis using multivariate probit models, probit models, and multiple linear regression models, was conducted to determine the relationship between climate variability and food security outcomes while controlling for relevant socio-economic variables. Previous studies by Gebrehiwot et al. (2018) and Lemma et al. (2020) have utilized econometric models to analyse food security in pastoralist communities.

Qualitative analysis was employed to explore pastoral households' perceptions of climate variability and their adaptation responses. Descriptive statistics, such as frequencies and percentages, were used to summarize qualitative data. A multivariate probit (MVP) model was applied to identify the adaptation responses adopted based on the perceived climate variability.

The study also used an endogenous switching regression (ESR) model to analyze the impact of climate variability adaptation responses on the food security of agro-pastoralists and pastoralists. Previous research by Tessema et al. (2017) has employed econometric models to analyze adaptation responses in pastoralist communities.

A mixed-methods analysis was conducted to identify the determinants of climate change adaptation responses and assess their effectiveness among pastoral households. Qualitative analysis involves thematic analysis of qualitative data to identify key determinants and factors influencing adaptation decisions and outcomes. Descriptive statistics were used to summarize quantitative survey data on household characteristics and adaptation responses. A multivariate probit model was employed to analyse the causal relationships between determinants and adaptation outcomes. Previous studies by Adger et al. (2009) and O'Brien et al. (2018) have employed econometric models to analyse adaptation processes and outcomes in various socio-ecological contexts.

1.7. Significance of the study

The study research on meteorological hazards in Borena pastoralists, Ethiopia, holds significant implications for both academia and policymaking. Firstly, understanding the trend and variability of temperature and rainfall from 1981 to 2020 is crucial for assessing the impact of climate change on pastoralist communities in the region. By examining long-term climate data, the study contributes to the scientific understanding of climate dynamics in this area, whichinforms future climate projections and adaptation strategies. Moreover, identifying the causes of climate extremes, such as floods, droughts, and other extremes, hasshed light on the specific environmental factors driving these hazards, allowing for targeted mitigation and disaster risk management efforts.

Secondly, the research was intended to determine the effect of climate variability on household food security status and coping responses among pastoralist communities. Given the vulnerability of these communities to climate-related shocks, understanding the linkages between climate variability and food security is paramount for designing effective interventions to enhance resilience and livelihood sustainability. Additionally, examining pastoral households' perceptions of climate variability and their adaptation responses provides valuable insights into local knowledge systems and traditional coping mechanisms. This understanding informs the development of contextually appropriate adaptation strategies that are aligned with the needs and priorities of pastoralist communities. Ultimately, by identifying climate change adaptation response determinants and examining perceived adaptation successfulness among pastoral households, the study is expected to contribute to evidence-based policymaking and community-centered approaches to disaster risk management and food security in Borena and similar pastoralist regions.

1.8. Limitation and scope of the study

This study, conducted in Borena, Ethiopia, has the wide-ranging objective of comprehensively exploring the intricate interactions among climate variability, food security, and disaster risk management strategies within pastoralist communities. However, it is important to acknowledge certain inherent limitations. Methodologically, challenges related to the availability and quality of data, particularly historical meteorological records and household-level socio-economic data, may arise. The accessibility of reliable and detailed data on climate variables, food security indicators, and adaptation responses may vary across different regions, potentially limiting the generalizability of findings. Moreover, conducting surveys and interviews in remote pastoralist communities had logistical difficulties and took more budget than anticipated.

Theoretical limitations could arise from the complexity of the relationships between climate variability, food security, and adaptation responses, which may possibly not be fully captured by existing frameworks. Accounting for diverse socio-cultural contexts and adaptive capacities within pastoralist communities could be challenging, affecting perceptions and adaptation strategies. Subjectivity in assessing variables such as food security status and adaptation success also limit the reliability of measurements. Additionally, constraints in sample size and study scope limit the depth and breadth of the analysis, thus hindering a comprehensive understanding of the dynamics between climate, food security, and adaptation within Borena pastoralist communities.

Despite these limitations, the study aimed to provide valuable insights into enhancing food security and disaster risk management in Ethiopia's pastoralist regions facing meteorological hazards.

1.9.Operational definitions of terminologies

Climate Change: Climate change refers to long-term shifts in temperature, precipitation patterns, and other climate variables over decades to centuries, resulting from natural processes and human activities such as greenhouse gas emissions and land-use changes. In this study, climate change is operationally defined as the observed and projected alterations in climatic conditions, including changes in temperature and rainfall patterns, occurring over the period from 1981 to 2020 and beyond in the Borena pastoralist region of Ethiopia. Literature by IPCC (2014) and Hulme (2009) provides comprehensive discussions on the definition and drivers of climate change.

Food Security: Food security encompasses the availability, accessibility, utilization, and stability of food resources necessary for maintaining a healthy and active life. In the context of this study, food security is operationally defined as the ability of pastoralist households in the Borena region to consistently access and afford sufficient, safe, and nutritious food to meet their dietary needs, even in the face of climate variability and extreme weather events. Literature by FAO (2008) and Maxwell & Smith (1992) offers foundational definitions and frameworks for understanding food security.

Vulnerability: Vulnerability refers to the degree to which individuals, communities, or systems are susceptible to harm or adverse impacts from climate variability, climate change, or other stressors. In this study, vulnerability is operationally defined as the predisposition of pastoralist households in the Borena region to experience food insecurity and other negative consequences due to their exposure, sensitivity, and adaptive capacity to meteorological hazards. Literature by Adger (2006) and Brooks et al. (2005) provides conceptual frameworks for understanding vulnerability in the context of climate change.

Meteorological Hazard:A meteorological hazard is an extreme or hazardous weather event, such as floods, droughts, storms, or heatwaves, resulting from atmospheric processes and posing risks to human life, property, and livelihoods. In this study, meteorological hazards are operationally defined as weather-related events, primarily rainfall extremes, that have the potential to impact food security and livelihoods in the Borena pastoralist region. Literature by Smith et al. (2009) and IPCC (2012) discusses the classification and impacts of meteorological hazards.

Coping Mechanism: Coping mechanisms are adaptive strategies employed by individuals or communities to manage and mitigate the adverse impacts of stressors or shocks, such as climate variability or food insecurity. In the context of this study, coping mechanisms are operationally defined as the actions and behaviors adopted by pastoralist households in response to meteorological hazards and food insecurity, including temporary measures to maintain food access and livelihoods. Literature by Ellis (2000) and Scoones (1998) provides insights into coping strategies in agrarian and pastoralist contexts.

Pastoralism Climate Adaptation Strategies: Pastoralism climate adaptation strategies refer to the specific actions and practices implemented by pastoralist communities to cope with and adapt to climate variability and change while maintaining their traditional livelihoods and cultural practices. In this study, pastoralism climate adaptation strategies are operationally defined as the diverse range of measures employed by Borena pastoralists to mitigate the impacts of meteorological hazards on their food security and resilience. Literature by Galvin et al. (2004) and Behnke et al. (1993) offers examples of adaptation strategies in pastoralist systems.

Climate Extremes: Climate extremes are unusual or extreme weather events that deviate significantly from the average or expected climatic conditions, resulting in severe impacts on ecosystems, livelihoods, and infrastructure. In this study, climate extremes are operationally defined as extreme variations in rainfall, including floods, droughts, and other extreme weather phenomena, that have the potential to disrupt food production systems and livelihoods in the Borena pastoralist region. Literature by Seneviratne et al. (2012) and Coumou&Rahmstorf (2012) discusses the characteristics and drivers of climate extremes.

Adaptation: Adaptation refers to the process of adjusting to changes in the environment or society in response to actual or expected climatic stimuli or their effects. It involves implementing measures to reduce vulnerability to climate change impacts and exploit new opportunities. In the context of this study, adaptation is operationally defined as the strategies and actions undertaken by pastoralist households in the Borena region to cope with and mitigate the impacts of climate variability and extremes on their food security and livelihoods. Literature by Smit et al. (2000) and Brooks et al. (2005) offers conceptual frameworks and typologies of adaptation strategies in the context of climate change.

1.10. Organization of the dissertation

The dissertation was organized into six chapters and followed the format for article-based manuscript reporting. The executive summary, objectives, background, problem statement, theoretical underpinning, study area description, methodology, significance, and operational definitions are all included in the first general introduction chapter. The distinct manuscripts prepared following the paper's stated aims are presented in Chapters 2 through 5. The conclusion, synthesis, and suggestion section are covered in Chapter 6.

1.11. Ethical considerations

In conducting research involving human participants, particularly in vulnerable communities like the Borena pastoralists in Ethiopia, ethical considerations are of utmost importance. This study prioritized upholding the dignity, autonomy, and rights of all participants throughout the research process. Informed consent was diligently obtained from each participant, ensuring they fully comprehend the purpose, procedures, and potential risks and benefits of their involvement. Stricter measures were implemented to maintain confidentiality and anonymity, safeguarding the privacy of participants and their sensitive information. Adhering to ethical principles is crucial as it upholds the rights of study subjects, including their environment and community (Hay, 2012). Ethical conduct serves as a social code, reflecting moral integrity and consistent values (Partington, 2003). Therefore, all researchers are bound by ethical principles regardless of their research methods. Moreover, the research demonstrated cultural sensitivity and respect for local customs and traditions by involving community leaders and stakeholders in the research design and implementation, ensuring their perspectives are adequately represented and respected.

Approval for the study was obtained from the Center of Food Security Studies at Addis Ababa University's College of Development Studies through the thesis examining/advisory committee. Additionally, the advisory group ensured that all citations and significant contributions from published or unpublished works used in this study were properly attributed, referenced, and fully supported. This study's content has not been published elsewhere in any format. Furthermore, the survey and interview data were collected and managed to protect the privacy of the study participants and any personally identifiable information.

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CHAPTER 2:SPATIO-TEMPORAL RAINFALL VARIABILITY OSCILLATIONS IN BORENA ZONE SOUTHERN ETHIOPIA AND ITS LINKAGE WITH LARGE SCALE CLIMATE OSCILLATION: IMPLICATIONS TO PASTORAL HOUSEHOLD FOOD SECURITY

2.1. Abstract

The focus of this study is on daily extreme climate indices and causes for such extremes rather than traditional average climate investigation. The aim is to properly strategize the adaptation measures for the climate extremes and ensure food security. The research was conducted in the Borena zone, an area that has witnessed recurrent extreme weather events, particularly droughts, over the past decades. Utilizing daily rainfall and temperature data sourced from the National Meteorological Agency (NMA) spanning from 1981 to 2020, the study examines the variability of climate extreme indices within the Borena zone. In addition to mean maximum and mean minimum temperatures, six extreme temperature indices and five extreme rainfall indices were employed for comprehensive analysis. The result obtained from temporal analysis depicts Max. T_{max} (TXx), Max. T_{min}(TNx), Min. T_{max}(TXn), and Max. T_{min} (TNn) showed significantly increasing trend ranges from(0.016-0.0530c/year), as well as the other extreme temperature indices cool day(TX10) and cool night (TN10p) showed decreasing trend that ranges (0.058-0.406%/year).The spatial analysis of extreme indices also revealed the increasing temperature all over the zone, which confirms a higher warming trend in the area. Among the extreme rainfall indices, PRCPTOT of the area alone showed a very significant (P=0006) increasing trend with (3.65mm/year). The very heavy rainfall days (R20mm) and the very wet days (R95p) observed a significant increasing trend with a range of 0.05-2.044mm/year. The continuous wet day (CWD) showed a decreasing trend, and the value of continuous dry days (CDD) also showed an increasing trend. The spatial analysis of rainfall indices supports the findings from the temporal analysis. Correlation analysis of daily rainfall with global indices such as Sea Surface Temperature (SST) and Sea Level Pressure (SLP) reveals a significant positive correlation with consecutive dry days (CDD) and a negative correlation with consecutive wet days (CWD). This study's results indicate warming trends in the area, accompanied by erratic rainfall patterns that significantly affect evaporation rates and various key sectors, notably rainfed agriculture, leading to drought conditions.

Keywords: *- Climate indices, extremes, drought, temporal, spatial, Borena, Ethiopia*

2.2. Introduction

Since the beginning of the Industrial Revolution, climate extremes have affected many parts of the world (Fagan, 2008). Global warming and other human-caused climate extremes have had a harmful effect on the environment and human well-being to differing degrees(Shivanna, 2022). Tropical regions are more vulnerable due to their location and the absence of advanced technology to control hydro-meteorological hazards(Sahani et al., 2019). Particularly, developing countries like Ethiopia have experienced a rise in the index of climate risk due to exceptional catastrophes and low adaptive capacity. Due to its extreme reliance on rain-fed agriculture and natural resources, Ethiopia is one of the nation's most sensitive to climatic unpredictability and change. Future projections also indicate that hydro-meteorological hazards and temperature extremes will occur more frequently and with greater intensity (Wang et al., 2008; Tierney et al., 2013; Zandonadi et al., 2016; Kenawy et al., 2019). Rising temperatures, both now and in the future, are attributed to excessive emissions of greenhouse gases from many sources. For example, the global average surface temperature is predictable to rise by 2.6 to 4.8°C by the end of the 21st century after increasing at a rate of 0.3 to 0.6°C in the 20th century (IPCC, 2007). In general, extreme weather and climate events have a negative impact on livelihoods and the overall decline of ecosystems. The largest extremes in surface temperature shifts are expected to occur in Africa (IPCC, 2013). The sub-Saharan region experienced 40 to 50 heat wave occurrences between 1989 and 2009. The hydrological cycle, which includes the processes of evapotranspiration and precipitation, may be altered by increases in surface temperature (Santos et al., 2012; Hartmann et al., 2013; Adhikari et al., 2015; Muluneh et al., 2017).

The hydro-meteorological risk in the Horn of Africa is associated with the El Niño Southern Oscillation (Liebmann et al., 2014; Nicholson, 2017). Climate extreme events like drought and floods, and their consequences impacts such as landslides, erosion, and a reduction of agricultural yields, water resources, etc.In Ethiopia, the most crucial economic systems are becoming increasingly susceptible due to climate variability and extreme occurrences (such as large floods and droughts) that are seriously harming people's lives, property, and natural resources. Significant portions of the nation, especially the semi-arid and desert regions, are vulnerable to high levels of climatic fluctuation and periodic droughts. The recent data indicated Borena zone is one of the drought-prone areas in Ethiopia (Ambelu et al., 2017; Bogale and Erena, 2022).

While assessing the variation and trend of temperature and rainfall extremes, it is essential to know the relationships of rainfall variation to global-scale climate indices (Sillmann et al., 2017), which are the main driving forces for regional climate variability. For example, whenever the global climate indices (El Niño or La Niña) develop, an atmospheric-oceanic anomaly in the tropical Pacific could affect the patterns of various climate parameters, mainly rainfall pattern worldwide (Unal et al., 2012). In addition to the complex geographical features, the rainfall variations of Ethiopia are mainly controlled by the seasonal migration of the ITCZ and the global climate system (Camberlin, 2009; Fazzini et al., 2015; Gleixner et al., 2017; Korecha and Barnston, 2007). Other previous studies (e.g., Alhamshry et al., 2020; Diro et al., 2011; Segele et al., 2009) also reported the association between SST and Ethiopian rainfall, but they had limited and temporal coverage. Moreover, these researchers did not consider the rainfall variation in southern Ethiopia mainly the rainfall extreme indices. To cover this gap, this study aimed to investigate the association of different global climate indices on the variation of daily extreme rainfall indices of Borena zone which found in southern part of Ethiopia that experiences several extreme events, prolonged drought.

Several climate researchers attentively applied annual and monthly mean average data that masks a lot of significant variables, including those that describe the behavior of extreme indices that typically cause extreme events. Hence, extreme indices formed from daily climate data purpose to unbiasedly gather information from weather observations to understand inquiries about extremes that have a great impact on numerous ecosystems. Therefore, unlike the previous works, this study gives new insight into the trend of daily extreme temperature and rainfall indices for the study area. It applied more than the climate normal data set from 1981 to 2020. Accordingly, the main objective of this study is to evaluate the recent changes in the temporal variation and trends of daily temperature and rainfall extremes and the impacts of extreme climate change in the area. In addition, it explores the teleconnection of the rainfall of the area with global indices. The results could contribute to basic scientific information on historical climate change, which is useful for water resources and the hydrological system management for the area.

2.3. Materials and Methods

2.3.1. Data Source and Quality Control

This study made use of gridded daily precipitation maximum and lowest temperature data from the National Meteorological Agency (NMA) within a period of the years 1981 to 2020. This gridded dataset combines locally calibrated satellite-derived data with integrated quality-controlled station data from the National Observation Network. This combined dataset employed the combined product shows improved quality over regions of the country where stations are sparsely distributed (Dinku et al., 2014; Esayas et al., 2018). Because it resolves a significant discontinuity seen in station data during a brief period, this data is recommended for use.

In this study data quality control process of each time series was tested using RClimDex 1.1(Zhang and Yang, 2004). The quality control involves checking errors such as (i) days with negative or greater than 500mm rainfall amount, (ii) minimum temperature equal to or greater than maximum temperature, and outliers, which are values plus or minus four times standard deviation. Accordingly, a station with the best value data quality is considered in the study. After the quality control, the data was used for extreme analysis.

2.3.2. Trend Analysis of Rainfall and Temperature

The Mann-Kendal test was used to evaluate the trend of temperature and precipitation extremes indices. Mann Kendal (Mann, 1945; Kendall, 1975) is the most robust tool for detecting trends because the method is less sensitive to outliers and skewed distributions within time series data (Wang and Swail, 2001). In this study, the Mann-Kendal test was applied for temperature and precipitation data which are not always normally distributed (Yue and Wang, 2004). The trend was tested by computing p-value at a 95% confidence level. The slope of temperature and rainfall extremes were determined using the non-parametric Sen's slope estimator (Sen, 1968). It uses the median slope to assess the trend over time. Sen's slope estimator is widely applied to quantify the slope of rainfall and temperature time series data. Both the Mann-Kendall test and

Sen's slope estimator were used to compute trends in hydro-meteorological series. Detailed descriptions of Mann–Kendall and Sen's slope estimation can be found in the related studies (Li et al., 2018; Worku et al., 2019).

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} sgn(x_j - x_i) \quad 1$$

Where N is the number of data points. Assuming $(x_j - x_i) = \theta$, the value of $sgn(\theta)$ is computed as follows:

$$sgn(\theta) = \begin{Bmatrix} 1\ if\ (x_j - x_i) > 0 \\ 0\ if\ (x_j - x_i) = 0 \\ -1\ if\ (x_j - x_i) < 0 \end{Bmatrix} 2$$

Where: -Seasonal and annual values in years j and $i, j > i$, respectively. $(x_j - x_i)$ is the signum function. The test statistic (S) has been assumed to be asymptotically normal, $E(S) = 0$. The equation indicates the increasing and decreasing trend of the data(M.G. Kendall, 1975).

The variance statistic is also calculated as follows: -

$$V(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{k=1}^{g} t_k(t_k - 1)(2t_k + 5)\right] 3$$

where n is the number of data points, g is the number of tied groups (a tied group is a set of data having the same value), and t_k is the number of data points in the k^{th} group. The standard test statistics Z is calculated as follows.

$$Z_s = \begin{cases} \frac{S-1}{\sqrt{Var\ (S)}}, S > 0 \\ 0, \quad S = 0 \quad 4 \\ \frac{S+1}{\sqrt{Var\ (S)}}\ , S < 0 \end{cases}$$

The Z_s Value is used to evaluate the significance of the trend variation in terms of decreasing and increasing trends. In the two-sided test under a significant α level, if $|Z_s| < Z_{\left(1-\frac{\alpha}{2}\right)}$, the hypothesis that the sequence X_i has no trend is accepted, but if $|Z_s| > Z_{\left(1-\frac{\alpha}{2}\right)}$, the hypothesis is rejected and the sequence has either an increasing or decreasing monotonic trend. $Z_{\left(1-\frac{\alpha}{2}\right)}$ is the standard normal distribution value when the probability exceeds $1 - \frac{\alpha}{2}$. In this study, a significance level of $\alpha = 0.05$ was adopted; thus, $Z_{\left(1-\frac{\alpha}{2}\right)} = 1.96$.

2.3.3. Sen's slope estimator

Sen's slope estimator the direction and its magnitude (Kocsis et al., 2017) in meteorological time series (Chattopadhyay and Vennila,2015;Pal et al., 2017). It is the non-parametric method that can calculate the change per unit time. This method is used to determine the linear trend of the time series (Pal et al., 2017b). In this method, the slopesT_i of all data pairs are calculated as flows:

$$T_i = \frac{x_j - x_i}{j - i} \quad 5$$

For i =1, 2, N

Where $x_j\, and\, x_i$ are data values at a time j and $i(j > i)$, respectively. If there are n valuesx_j in the time series and obtained N=n(n-1)/2 slope estimates S_i.The median of these N values of T_i is Sen's estimator of slope, which is calculated as

$$T_{Med} = \begin{cases} T_{\frac{N+1}{2}} & N\ is\ odd \\ \frac{1}{2}\left(\frac{T_N}{2} + \frac{T_{N+2}}{2}\right) & N\ is\ even \end{cases} \quad 6$$

A positive value of Ti indicates the isan increasing and a negative value of Ti gives a decreasing trend in the time series (Mondal et al., 2012).

2.3.4. Evaluation of Extreme Indices

A statistical examination of variations in the dependent climatological characteristics, including time series analysis and comparison, extremes, and trends, is made possible by extreme climate indices. The RClimDex 1.1 software package was utilized to assess the extreme indices of daily rainfall and temperature time series, focusing on their trend and variance. The Expert Team on Climate Change Detection Monitoring Indices (ETCCDMI), among other worldwide research organizations, created the analysis package for trend and variability evaluation of time series temperature and rainfall data (WMO, 2009). You can get RClimDex, an easily navigable R-based program, from http://etccdi.pacificclimate.org/. Shanghai et al. (2011). Out of the 27 core indices that RClimDex computes daily, the most pertinent 10 temperature indices and 10 precipitation indices for this study.

Table 0.1: List of temperature and rainfall indices

	Index	Indicator name	Definition of the Index	Units
Rainfall extremes indices	R20mm	The Number of very heavy rainfall days	Annual count of days when PRCP≥ 20 mm	Days
	CDD	Consecutive dry days	Maximum number of consecutive days with RR < 1 mm	Days
	CWD	Consecutive wet days	Maximum number of consecutive days with RR≥1 mm	Days
	R95p	Very wet days	Annual total PRCP when RR > 95^{th} percentile	mm
	PRCPTOT	Total wet-day rainfall	Annual total PRCP in wet days (RR ≥ 1 mm)	mm
Temperature extremes	TXx	Max. T_{max}	Annual maximum value of daily maximum temperature	^{0}C
	TNx	Max. T_{min}	Annual maximum value of daily minimum temperature	^{0}C
	TXn	Min. T_{max}	Annual minimum value of daily maximum temperature	^{0}C
	TNn	Min. T_{min}	Annual minimum value of daily minimum temperature	^{0}C
	TN10p	Cool nights	Percentage of days when TN <10^{th} percentile	%
	TX10p	Cool days	Percentage of days when TX < 10^{th} percentile	%

Max. = maximum, Min. = minimum, T_{max} = maximum temperature, T_{min} = minimum temperature, PRCP = precipitation, and RR=daily precipitation.

2.3.5. Global-climate indices

Several large-scale ocean-atmospheric indices have been identified to have teleconnections with the variability of rainfall in Ethiopia (Degefu and Bewket, 2017; Zeleke and Damtie, 2016). Among these climate indices, Sea level pressure (SLP) is increasing/ decreasing in atmospheric pressure at sea level, which can disclose useful information on atmospheric circulation, bringing about wetter and drier conditions. Changes in Sea Surface Temperature (SST) can also generate a difference in the heat-flux field, bringing about anomalies in atmospheric circulation and rainfall patterns (Copsey et al., 2006). This study selected the most important global climate indices to estimate their association with local precipitation indices. These are: -

a) The global SST anomalies, including the Dipole mode index (DMI), the anomalies of SST between the Western (10°S-10°N and 50°-70°E) and the Southeastern (10°S-0° and 90°-110°E) the equatorial Indian Ocean. The Pacific Decadal Oscillation (PDO) index is the leading principal component of Northern Pacific monthly SST variability (poleward of 20°N in the Pacific Basin), El Niño–Southern Oscillation (ENSO) represented by averaged Niño SST indices, Niño 1+2, Niño 3 (90–150°W and 5° N–5° S), Niño 3.4, and Niño 4 (150°W– 160°E and 5° N–5° S), and

b) Atmospheric pressure at sea level or sea level pressure (SLP), including the Southern Oscillation Index (SOI), and the North Pacific Index (NPI), are the area-weighted SLP over the region 30–65° N, 160° E–140° W, the Trans-Polar index (TPI), and the North Atlantic Oscillation (NAO).
The data were obtained from the National Oceanic and Atmospheric Administration (NOAA) http://www.cgd.usar.edu.cas/catalog/climate/TNI_ N 34 index .html.

2.3.6. Correlation of daily extreme indices with global atmospheric circulation

In this study, the Pearson Correlation Coefficient (r) was used to evaluate the link of daily rainfall extreme with global atmospheric indices at a 95% confidence level. Pearson correlation was used to evaluate linear association between two variablesx_i and y_i.The Pearson correlation (r) is given by:To prove the formula for the correlation coefficient, we start with its definition and derive it accordingly,

$$\mathrm{Cov(X,Y)} = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y}) \text{--}7$$

$$\mathrm{Var(X)} = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})\,2 \text{--}8$$

$$\mathrm{Var(Y)} = \frac{1}{n}\sum_{i=1}^{n}(y_i - \bar{y})2 \text{---}9$$

$$r = \frac{\{\text{Cov}\}(X,Y}{\sqrt{Var\ (X).Var\ (Y)}}\text{--}10$$

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 (y_i - \bar{y})^2}}\text{--}11$$

Where n is the number of observations, x_i, and y_i the variable and $\bar{x}$ and $\bar{y}$ are their mean, respectively.

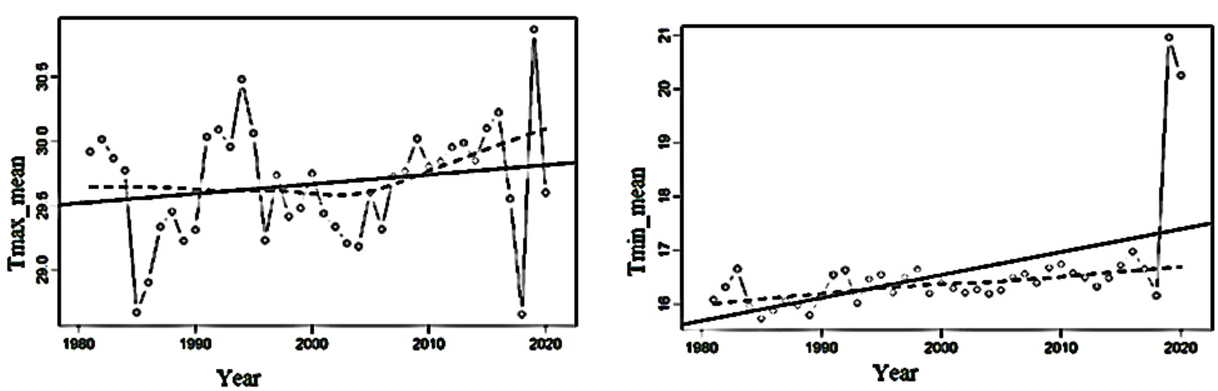
- If X and Y are perfectly positively correlated, r = 1
- If there is absolutely no association, r = 0
- If X and Y are perfectly negatively correlated, r = -1
- Thus $-1 \leq r \leq 1$.
- The closer r is to +1 or -1, the greater is the strength of the association (Freedman, et al., 2007).

2.4.Result and Discussion

2.4.1. Temporal and Spatial Trends of Daily Extreme Temperature and Rainfall Indices

2.4.1.1.Temporal Trend of Daily Extremes Temperature Indices

Fig.2.1 depicts, the Borena Zone underscores the complex of maximum and minimum temperatures, the dynamics, and their increase of them.



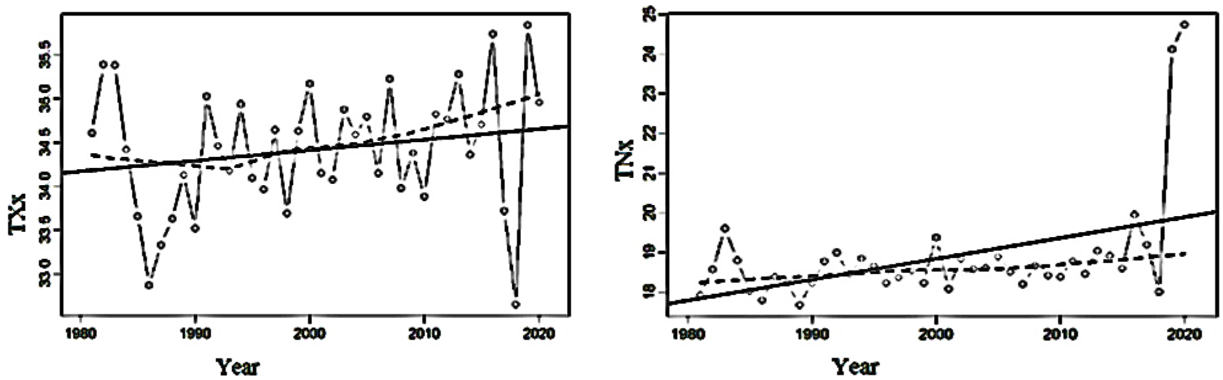


Figure 2.1: Extreme temperature indices of (T-max mean and T-min mean)

The straight solid line in the figure is the linear trend for each variable for the basin, whereas the dashed line is the moving average. The mean maximum temperature of the area observed an increasing trend with a positive slope, and the annual TMAX-mean increased by 0.057^0C/year. The moving average also depicts the higher variation or anomalies of the maximum temperature in the area from 1981 to 2020. The mean minimum temperature of Borena in this study period also shows a significant increasing trend, and it was very exaggerated from 2010 to the last study period. The result observed the annual mean increased by 0.043^0C/year throughout the study period. This annual result is more analysis taken from daily extreme values. Accordingly, the daily maximum temperature (TXX) of Borena shows an increasing trend. The moving average also shows an increasing anomaly except for 1986 and 2018 year. The daily minimum temperature (TNX) trend of the area showed that increasing trend and the anomaly also observed an extreme increase, particularly in 2018. In agreement with this study's results' researchers (Asfaw et al., 2018; Belay et al., 2021; Mengistu and Haji, 2015) done on the area reported the highest increase of both maximum and minimum temperatures. The studies confirmed the existing and future temperatures in the area were observed to be warming trends.

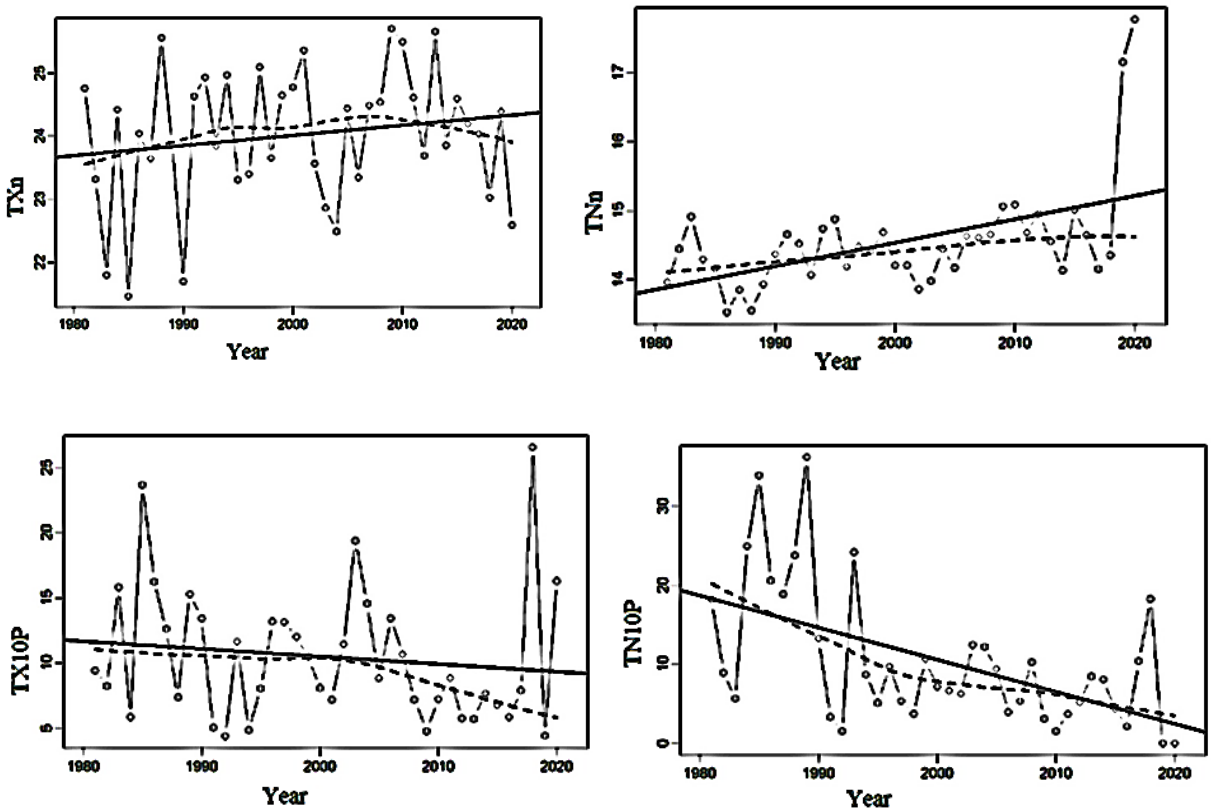


Figure 2.2:Extreme temperature indices of (TXn, TNn, TN10p and TX10p)

The straight solid line in the figure is the linear trend for each variable for the basin, whereas the dashed line is the moving average. The Monthly minimum value of the daily maximum temperature (TXn) observed an increasing tendency, and the moving average shows a decreasing trend. Thus, the TXn or the coldest day significant variation has been observed or considerable anomalies recorded in the study area (Fig.2.2). Similarly, research done by (Mekasha et al., 2014) noted a similar trend as both increasing and decreasing trends have been recorded. The coldest night (TNn) showed a very significant increasing trend, and the anomalies of the moving average observed a significant increasing trend, particularly in the 2019 year. Esayas et al. (2018) reported a similar result that shows an increase in the coldest day (TNn) in southern Ethiopia. Both cool day (TX10P) and Cool night (TN10P) depicted a very decreasing trend that agreed on the increment of warm night and warm day. In agreement with these results, the study done by Damtew et al., (2022) stated the decline of cold extreme temperature indices in cool days (TN10p) and cool nights (TX10p). These extreme climate events make people suffer from continuous drought (Dejene et al., 2023).

2.4.1.2.Spatial Trend of Daily Extremes Temperature Indices

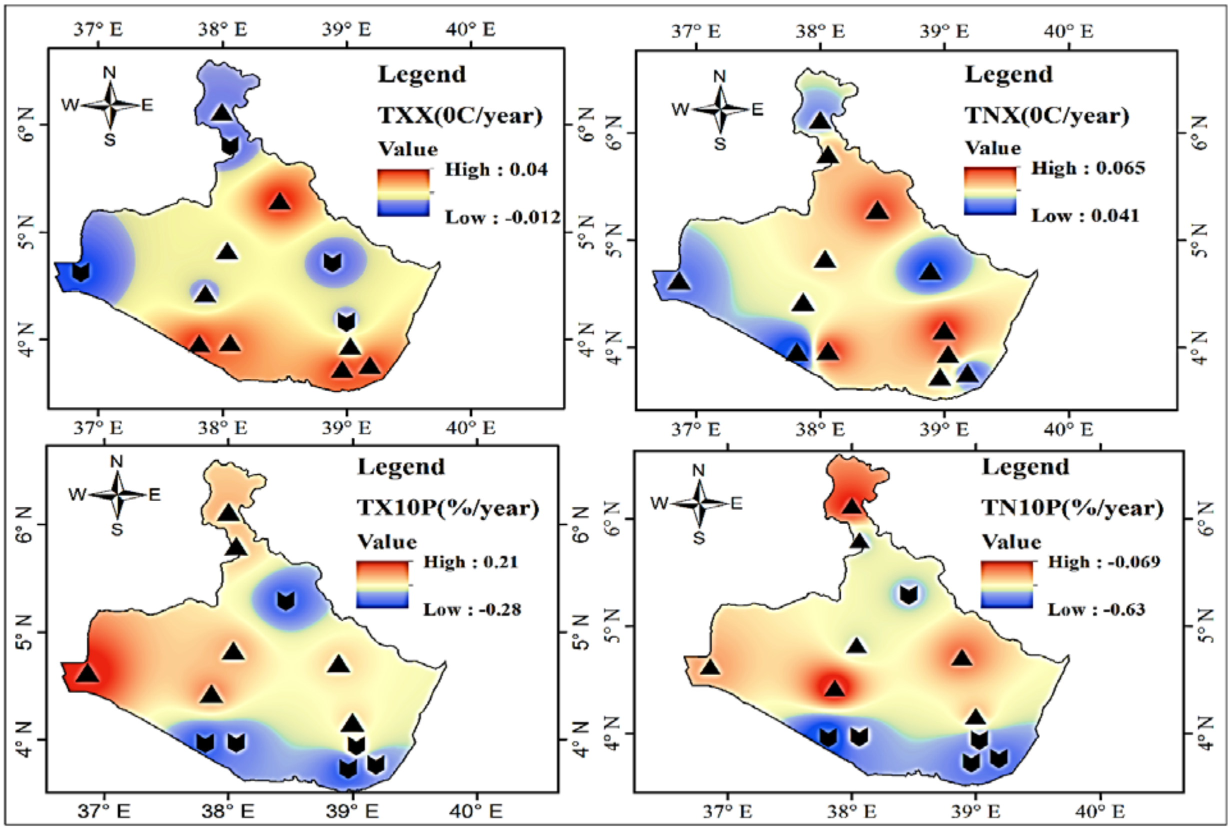


Figure 2.3: Spatial variations of extreme temperature indices of TXx, TXn, TNx, and TNn trends in °C/year of Borena for the years 1981-2020.

The triangles and the down-arrow in the pictures indicate significant increasing and decreasing trends at the 5% level, respectively.In the northern humid and central moist part of the zone, the maximum value of the maximum temperature (TXx) shows a decreasing trend with 0.0120c/year. In the central, the west semi-arid, and the east arid regions TXx trend value increased significantly ($p<0.05$) with 0.04^{0}C/year. The trend TNx in the study period showed an increasing trend all over the study area from 0.041-0.065^{0}C/year.The regional trends of the two indices, TXx and TNx, show stout increases trend. The percentages of cool days (TX10p) and cool nights (TN10p) showed strong variability that depicts the increasing and decreasing trend; however, both showed decreasing in the southern area in common (Fig.2.3). Studies (Esayas et al., 2018; Mekasha et al., 2014; Mohammed et al., 2022) done on temperature extreme indices in the area confirmed the result obtained in this research. Increasing trend of warm extreme indicesand decreasing trend of cold extreme indices (TN10p and TX10p) were observed. Trend on mean annual maximum and minimum temperature and most extreme temperature indices confirm higher warming trend in the area. In general, the daily extreme temperature trends in the eco-environments under the study area experienced the rising of warm extremes and falling cold extremes.

2.4.1.3.Temporal Trend of Daily Extremes Rainfall Indices

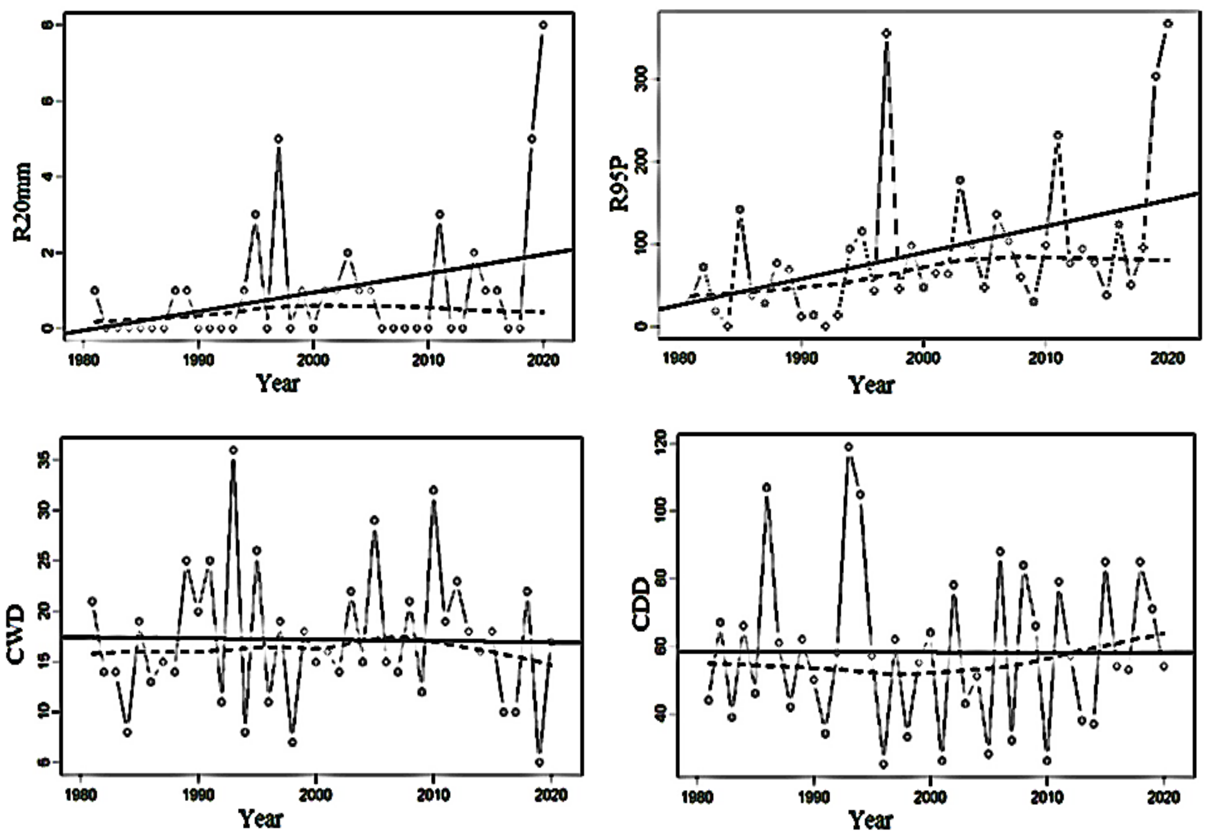


Figure 2.4: Extreme rainfall indices of (R20mm and R95p, CWD, CDD)

The straight solid line in the figure is the linear trend for each variable for the basin, whereas the dashed line is the moving average.The number of very heavy rainfall days (R20mm) observed an increasing with a slope of 0.05mm/year. However, the moving average showed the highest fluctuation of anomaly and almost below-average value except the the higher increase shown in 2018. The very wet day (R95p) observed a significant increasing trend of 2.044mm/year. The moving average depicted the strongest variation anomalies, and mainly in 1998 and 2018, it showed the highest value above the average. Continuous wet day (CWD) value in the study period never showed an increasing or decreasing slope; however, the moving average showed a variation and a decreasing trend since 2010. On the contrary, the value of continuous wet days observed a decreasing trend of 0.013 mm/year. The value of continuous dry days (CDD) also showed an increasing trend with considerable anomalies, particularly since 2016, it was above the average (Fig.2.4). Similar to these results, the study done by Dendir and Birhanu (2022); Kiros et al.(2017); Mohammed et al.(2022) in the same agroecological zone found the increment of R20mm, R95p, and the decreasing of CWD as well as the increment of CCD in the southern Ethiopia These studies made emphasis on the recent increasing of CDD and the decreasing of CWD are responsible for the occurrence of drought in the area.

2.4.1.4.Spatial Trend of Daily Extremes Rainfall Indices

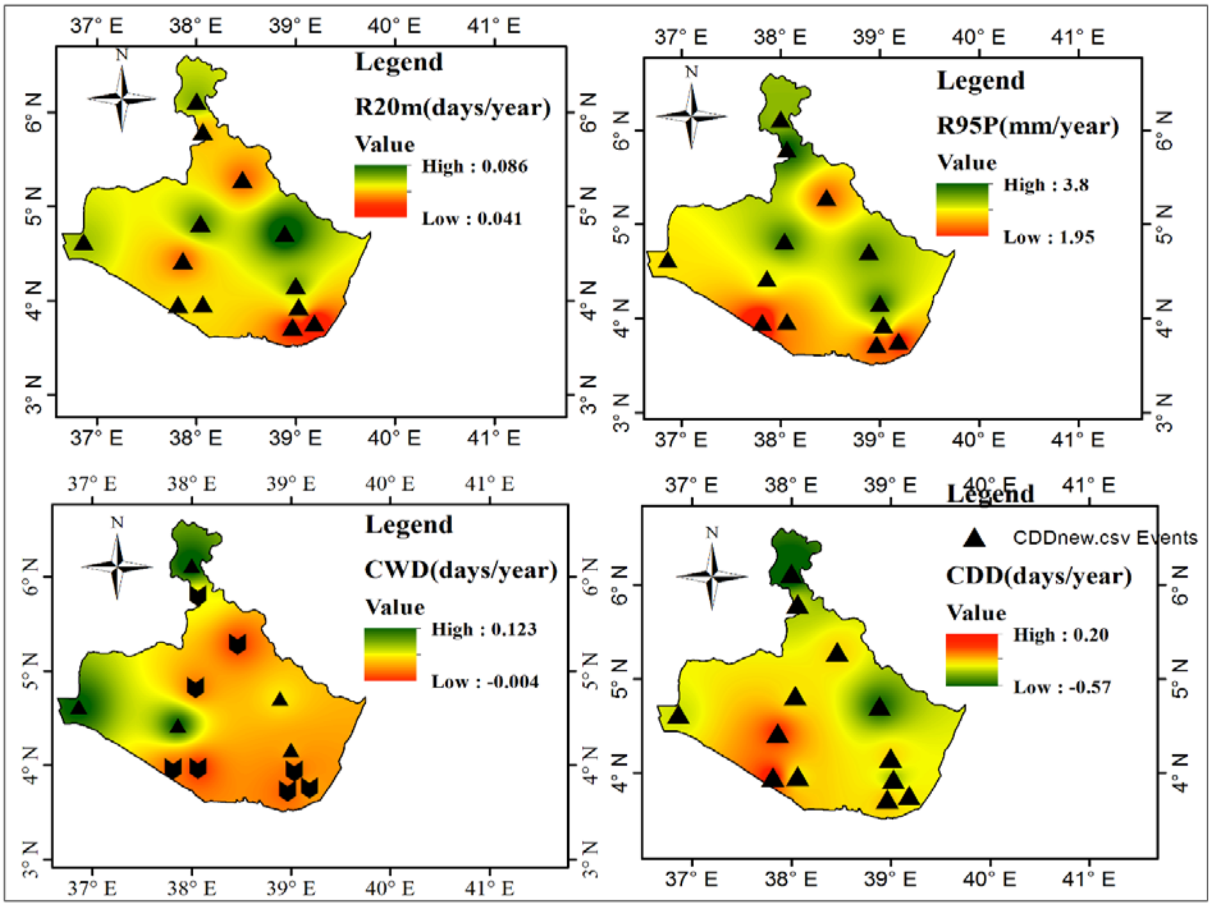


Figure 2.5: Spatial variations of rainfall extreme indices trends of R20mm (days/year), R95P(mm/year) both in mm/year, trends in CWD (Days/year), and trends in d CDD (days/year) of Borena for the duration of 1981-2020.

The triangles and the down-arrow in the pictures indicate significant increasing and decreasing trends at the 5% level, respectively.The spatial trend of R20mm, R95p, CWD, and CDD in Fig.2.5 showed very different values in humid, moist, semi-arid, and arid regions of the Borena Zone. Accordingly, the R20mm value showed a significant (p=0.03) increasing trend in most parts of the study area with 0.05mm/year. It also has an insignificant decreasing trend in the southeast (arid) part of the zone. The value of R90p showed a significant (P=0.006) increasing trend (3.183mm/year) throughout the zone. The number of continuous wet-day CWD showed a decreasing trend with (0.013 day/year) except for the western semi-arid and the northernmost zone. Continuous dry days (CDD) showed an increasing trend except for the central moist regions. In line with this result, studies done by (Adem and Amsalu, 2021; Amsalu and Adem, 2009; Gemeda et al., 2022) found the erratic rainfall and the increment warming conditions of the area caused extreme drought and other climate hazards.

2.4.2. Correlation of daily extreme indices with global atmospheric circulation

Regional climate change, particularly the variation and change of daily extreme rainfall highly affected by global atmospheric climate indices like SST and SLP (Kebede and Bewket, 2009).

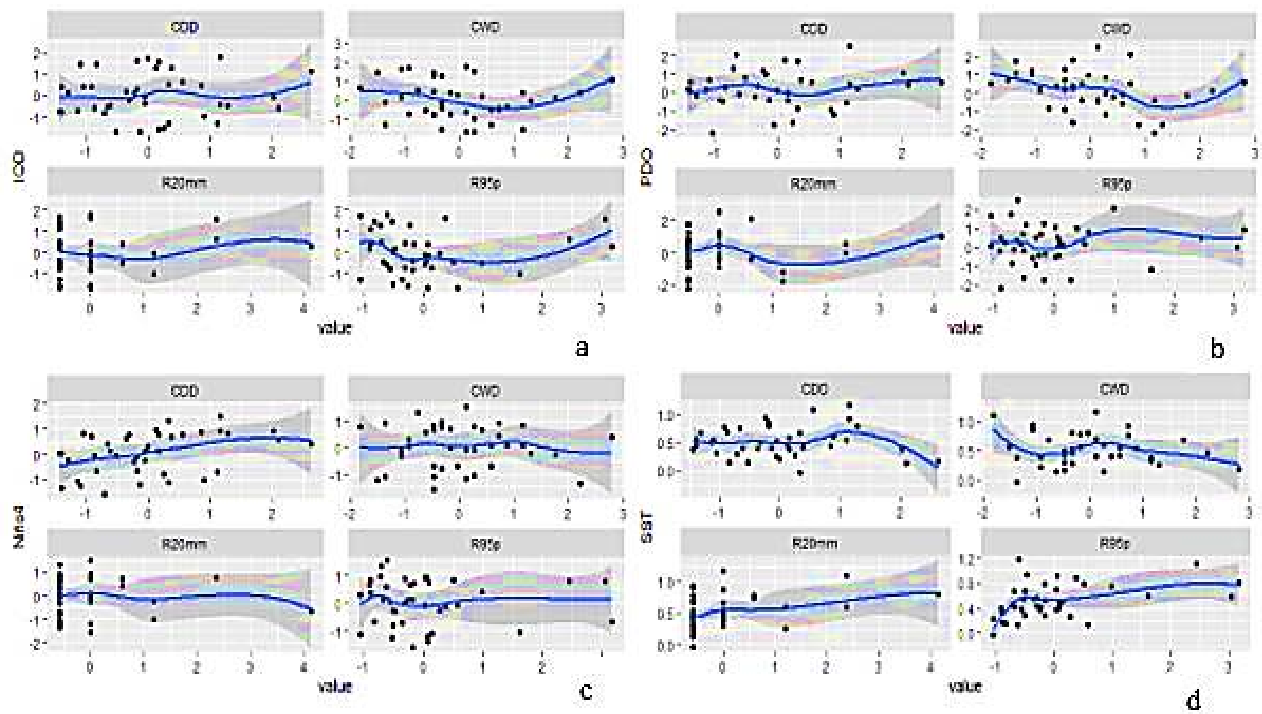


Figure 2.6: The correlation of global indices (IOD, PDO, NINO 4, and Global SST) with daily extreme rainfall CDD, CWD, R20mm, and R95sp) of the Borena zone in the period of 1981 to 2020.

Fig.2.7 shows the correlation between SST groups, which include IOD, PDO, NINO 4, and Global SST itself. Hence, Nino 4 and global SST had a negative correlation with CWD and showed a significant positive correlation with CDD (r=0.36 and 0.41) with a 95% confidence level. The remaining large-scale climate indices, IOD and PDO, showed almost the same pattern: There was a negative correlation with CWD and a negative correlation with extreme daily rainfall indices. This result exhibits a negative correlation with wet days, suggesting the decreasing extreme rainfall in the area. The positive correlation between CDD and the negative correlation with CWD showed the warmed or drought tendency of the study area. This pattern observed a tendency towards warming or drought events. This analysis of SST groups depicts the connotation between rainfall extreme indices and global climatic factors in the Borena zone showed different patterns. It observed a warming tendency as NINO 4 and global SST clearly correlate with more dry spells and fewer wet days. Furthermore, highlighting the trend toward warmer or drier conditions in the study area, IOD and PDO also contribute to this pattern by demonstrating negative associations with CWD and daily rainfall extremes. In agreement with these findings, studies done by Beyene et al.(2022), Degefu et al.(2017), and Tashebo et al.(2021) stated that the recent global SST variation has led to a severe extreme impact in lowland pastoralist areas, including the Borena zone.

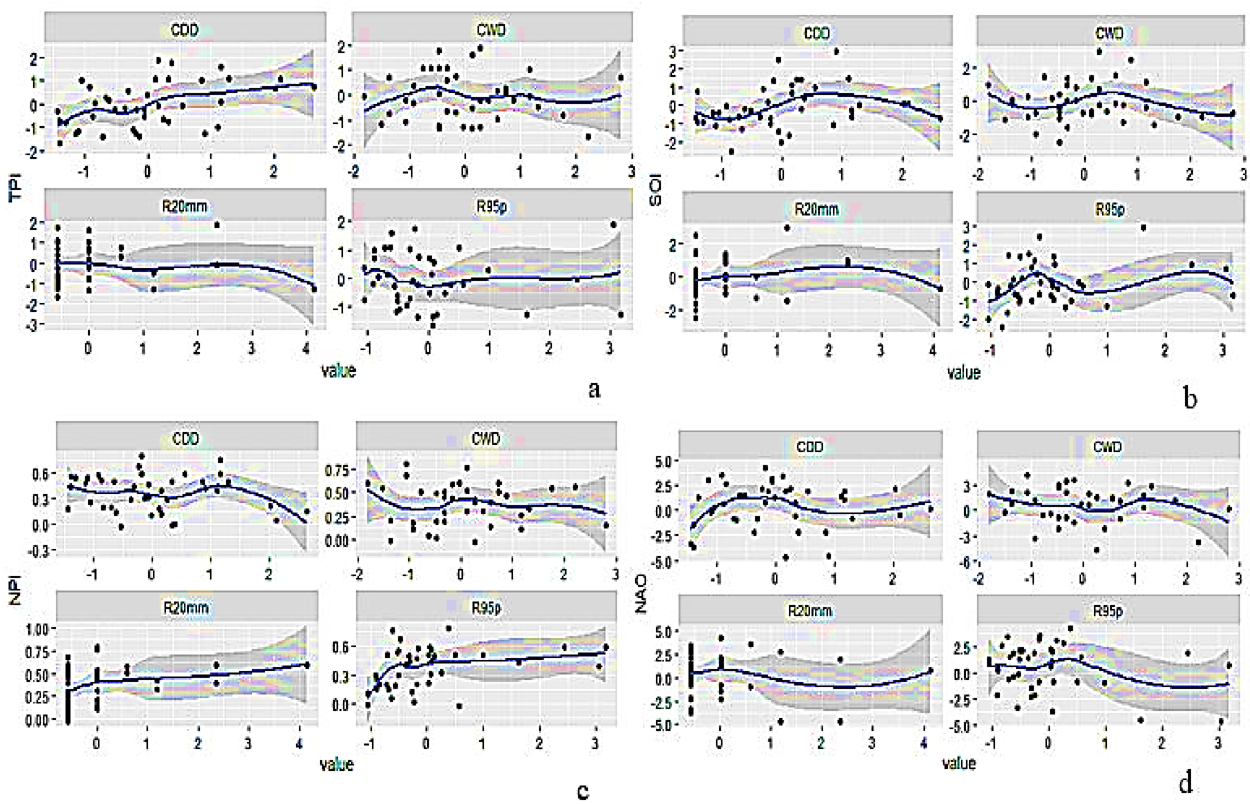


Figure 2.7: The correlation of global indices (TPI, SOI, NPI, and NAO) with daily extreme rainfall CDD, CWD, R20mm, and R95sp) of the Borena zone in the period of 1981 to 2020.

Figure 2.8 shows the correlation of sea level pressure (SLP), including TPI, SOI, NPI, and NAO. Accordingly, TPI had a negative correlation with R20mm and R95p and made a positive significant correlation with CDD (r=0.435), which is responsible for the drying of the area. The SOI has a negative correlation with CWD and made positive correlation with CDD, R20mm, and R95p. The NPI had a negative correlation with CWD and made a positive correlation of R20mm and R95p. The NAO had a positive correlation with CDD and made a negative correlation with other daily extreme rainfall indices. This finding observed SOI, TPI, and NAO correlation values with daily rainfall indices of the area associated with prolonged dry spells, leading to warming (drought). It confirms the complex correlation between global climate indices and extreme daily rainfall indices that affect the wet and dry spells in the area.The correlation analysis of sea level pressure (SLP) indicators, including TPI, SOI, NPI, and NAO, with daily rainfall indices provides useful insights into their influence on precipitation extremes in the research area. The negative correlations of TPI, SOI, and NPI with cumulative wet days (CWD) imply a decline in wet day occurrences during periods of high index values, indicating a drying trend. On the other hand, these indicators' positive correlations with the heavy rainfall and consecutive dry days (CDD) indices (R20mm and R95p) point to a higher chance of extended dry spells and severe rainfall events during those times. Anose et al.(2022) and Hou et al.(2023) all stated in line with this study that SlP anomalies have a great association with the southern part of climate conditions, related to prolonged dry spells and fewer occurrences of heavy rainfall.

2.5.Conclusion

Evaluating temperature and precipitation extremes' temporal and spatial trends at fine resolution can provide valuable information for the management of and decision-making in different productive sectors, such as water resource managers and agriculture. This study examined the temporal and spatial difference of daily extreme indices in Borena zone from 1981 to 2020. The result obtained indicates the temporal and spatial extreme temperature increased significantly except for the cool day (TX10p) and the cool night (TN10p), which also aggravated the warming situation of the area. Conferring to the result obtained from the spatial and temporal trend of extreme indices showed a very slight increment, particularly the value of continuous dry day decreasing as well as the increase of continuous dry day (CDD) in a zone. The result obtained from the evaluation of the association between daily extreme rainfall and the global indices evaluating climatic variability revealed that the large-scale climate indices have possible effects on regional climates. This study also found the significant positive correlation of SST and SLP groups with CDD informs an increase in extended dry spells, and the negative correlations with CWD depicted a drop in wet day occurrences, suggesting dry tendencies. The findings also highlight how essential it is to understand the associations between regional climate variables and large-scale climate indices. All these climatic phenomena have a great impact on water resource scarcity and prolonged drought. The observed results of extreme indices investigation in this study area, with existing literature on the area, documented the erratic rainfall and extreme rising of temperature. This climatic condition poses a challenge to infrastructure, agricultural yield reduction, scarcity of water resources, and risk of adaptation strategies. Further study is needed to understand the magnitude of the extreme events in terms of the climate variations and changes in the area.

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CHAPTER 3: EFFECT OF PERCEIVED CLIMATE VARIABILITY ON HOUSEHOLD FOOD SECURITY AND COPING RESPONSE IN BORENA ZONE, SOUTHERN ETHIOPIA

3.1. Abstract

This paper aimed to assess the effect of climate variability on household food security status and coping mechanisms used by respondents in the selected districts of Borana. In this research a mixed explanatory research design was applied to understand the effect of climate variability and extreme events on household food security. Accordingly, data were collected from 417 sample households selected using multistage sampling methods, key informants and focus group discussion participants. Data were analysed using descriptive statistics (e.g. mean, percentage) and econometric models (e.g. multivariate probit and multiple linear regression models to evaluate the effect of climate variability on household food security status). The results revealed that 77% of the households perceived an increase in temperature and 89% perceived decrease in rainfall in recent years. The Household Food Insecurity Access Scale (HFIAS) result showed that about 95% of respondents s experienced food insecurity. The most common coping mechanisms employed by respondents include selling charcoal and fuel wood, borrowing money from friends or family, migration, humanitarian relief, and daily labour. It appears that climate induced food insecurity is pervasive and serious problem in the study area. Perception of the effect of temperature increase on crop and livestock has significantly increased the adoption of land contracting /leasing, adoption of selling fuel wood and daily labour increased as a coping response to climate variability among pastoralists and agropastoral. The perception of the impact of decrease in annual rainfall on crop and livestock has significantly increased the adoption of borrowing from friends or families and free support of resources among pastoralists and agropastoral. Business-as-usual perception increases the adoption of borrowing from credit union, free support of resources, and migration. Regarding perceived effect of food insecurity, borrowing from credit union, borrowing from friends or families, and reduction of expenses has reduced the food insecurity among pastoralists and agropastoral households.

Hence, it is highly recommended to implement integrated interventions that address both household food insecurity and viable adaptation responses. These interventions should aim to *mitigate the need for coping strategies and prevent maladaptation measures that lead to the depletion of assets.*

***Keywords**: food security, coping response, Borena, pastoralists, agropastoral, climate variability, perceptions, Ethiopia*

3.2. Introduction

Climate change and extreme events have recently become a global phenomenon with far-reaching implications, particularly for vulnerable communities in sub-Saharan Africa (Trisos et al., 2022). These events have exacerbated the severity of hydro-meteorological hazards, which have the potential to significantly alter natural ecosystems and hence induce food insecurity (Birkmann *et al.,* 2022; IPCC, 2007). Climate change and extreme events could trigger disaster risks in two ways: firstly, by increasing the likelihood of more frequent and intense weather and climate hazards, and secondly, by amplifying community vulnerability to these hazards (Bouroncle et al., 2016). This vulnerability is primarily driven by ecosystem degradation, reduced water, and pasture availability, and further affect livelihoods and food security (UNDRR, 2008; Birkmann *et al.,* 2022).

Sub-Saharan African countries are more vulnerable to climate change due to high dependency on natural resources and weak adaptive capacity (Omotoso, and Omotayo, 2024; Allahyari et al., 2016; Abid et al., 2015). For instance, subsistent agricultural production can be affected by change in temperature and precipitation patterns (Tetteh, et al., 2022). Empirical evidence confirmed that the yields of most crops have been affected negatively by climate changes over recent decades (Lee et al., 2024; Change, 2019).

Ethiopia is one of the most vulnerable countries to climate change in Africa, with the least capacity to respond (Solomon et al., 2021). Vulnerability of rural communities to climate variability and change poses significant challenges for ensuring sustainable agricultural production (Seid et al., 2015; IPCC, 2014). Droughts, floods, heavy rains, high winds, and heat waves are the common phenomenon that affected and remains to affect production and productivity of agricultural sector in Ethiopia (Abebe, 2007). For example, the 2015/16 El Niño event caused a decline in agriculture and cattle production and left more than 10 million people to food aid and acute food insecurity in the country (Holleman et al., 2020). Furthermore, the national and agricultural GDP was reduced by 1.6%, and 3.6% respectively, and increased the number of people below the poverty line from 30% to 31.2% (IFPRI and UNDP, 2019). The country heavily depends on climate-sensitive economic sectors such as subsistence crop cultivation and animal husbandry (Sector, 2014). As a result, Ethiopia ranked among the most food-insecure countries in the world (Solomon et al., 2021; Mohamed, 2017).

Pastoralist communities, such as the Borena, rely heavily on livestock rearing as their primary livelihood strategy (Tofu et al., 2023). Livestock provides food, income, manure, and draught power for pastoralists, as well as a social status symbol (Benti et al., 2022). Thus, the sector is considered pastoralists' economic and social insurance (Benti et al., 2022). However, climate change has significantly affected the sector and their traditional way of life, threatening their food security, income stability, and overall well-being (Tofu, 2023).

The Borena plateau's grazing systems have become unsustainable in recent times (Degen, 2024; Coppock et al., 2008). The area has been hit by cyclical and prolonged droughts that have decimated livestock, increased poverty (Coppock et al., 2008), and food insecurity (Ayal et al., 2017). Poor infrastructure, decades of neglect by government, unsuitable development intervention, and economic and political marginalization have all contributed to pastoralists' vulnerability to climate change (Busby et al., 2012). The Borena pastoralists have recently vulnerable to climate extremes due to lack of climate adaptive capacity andtechniques (Ayal et al., 2015).

The Borena community was particularly vulnerable to the effects of climate change because of the government's plans to sedentarism the pastoralists and turn the rangeland into farmland, as well as a history of devastating droughts, loss of grazing pastures, interethnic conflicts, and degradation of rangelands. In 2023, over 2.3 million cattle died because of the major issue, and 67,000 households were forced to relocate (Degen et al., 2024). This fact makes the Borena one of the most drought affected areas in Ethiopia and the need to conduct research in the location.
Understanding the specific effect of climate change and extremes on pastoralist households in the Borena Zone and their coping responses is crucial for feasible policy formulation and targeted interventions. By examining the local context, traditional knowledge, and the effectiveness of existing coping strategies, the study aimed to contribute to the development of evidence-based

approaches that enhance the resilience of pastoralist households and ensure their food security in the face of climate change and extremes. Most of the research done so far in Borena area focused on measurable climate data and misses the necessity of incorporating local adaptation and coping strategies into climate change risk studies (Shibru et al., 2023). These studies have not fully explored the connection between climate change perception, coping strategies and food insecurity among pastoral and agropastoral households. Therefore, this study intended to fill these gaps and answers two questions: How pastoralists perceive climate change/variability and its effects on crop and livestock productivity among households in Borana? What are the factors influencing food security among pastoral and agropastoral households in the study area?

3.3.Materials and Methods

3.3.1. Study Design and Methods

The study employed a mixed explanatory research design to gain a deeper understanding of the perceived effects of climate variability on pastoral and agropastoral households, their coping strategies, and the factors influencing household food security status. A mixed- approach allows us to collect both quantitative and qualitative data from different sources. The quantitative data focused on the perceived effects of climate variability, coping strategies, and food security determinants, while the focus group discussions and key informant interviews were held to collect qualitative data which helps to gain deeper insights about the effect of climate variability on pastoral and agropastoral households.

3.3.2. Sampling design and sample size determination

The study used a multi-stage sampling technique to select the study sites and sample respondents. The target population for this study were the pastoral and agro-pastoral households in the Borena zone, Ethiopia.The sample frame was the list of all households in the Borena zone. At the first stage, the Borana Zone and four districts namely Moyale, Yabello, Dire, and Miyo were selected purposively due to high vulnerability to climate variability and high food insecurity level. The Southern and southeastern pastoral areas of the country are among the areas of highest concern in relation to emergency and crisis (FEWS NET, 2022). At the second stage, sample kebeles namely Darito, Bokola, Dida Yabelo, Dibandiba, Silala, Bede, Medacho, and Dida megawere selected using simple random sampling method from four woredas (Yabello, Dire, Miyo, and Moyale). At the third stage, representative sample households were selected randomly from each kebele proportionally. The sample size was determined using Cochran's (1977) formula, which is widely used when there is a large population and when the study requires accurate variability and heterogeneity of the population.

$$n_o = \frac{Z^2 q(1-q)}{e^2} \text{---(1)}$$

n_o = required sample size

Z = standard normal value which is 1.96 for 95% confidence interval (5% significance level)

p = estimated proportion of population (maximum variability) (0.5)

q = (1-p) or estimated proportion of failure

e = the desired level of precision (0.05)

Accordingly, the sample size estimated was 384 households. However, the sample size increased to 422 with the addition of a non-response rate of 10%. As expected, 5 households had zero response rate. Therefore, the final sample size 417 households.

3.3.3. Data collection

Primary data was collected using household survey from pastoral and agro-pastoral households using structured questionnaires. In addition, secondary data were collected from reports of the Borena Zone office, farmers' cooperative, Ethiopian Statistical Service-ESS, and published documents. Finally, experienced enumerators were recruited and trained to collect data from the sample households. Focus group discussions and key informant interviews were also conducted.

3.3.4. Methods of data analysis

Descriptive statistics and econometrics analysis were used to analyze quantitative data.

For the quantitative data, the household food insecurity access scale (HFIAS), food consumption score (FCS), and household dietary diversity score (HDDS) were used to measure the food security status of households in the study area.

Household food insecurity access scale: Household food insecurity access scale (HFIAS) consists of two types of related questions. The first question type is called anoccurrence question. There are nine occurrence questions that ask whether a specific conditionassociated with the experience of food insecurity ever occurred during the previous four weeks(30 days). Each severity question is followed by a frequency-of-occurrence question, which askshow often a reported condition occurred during the previous four weeks. The HFIAS score is a continuous measure of the degree of food insecurity (access) in thehousehold in the past four weeks (30 days) (Coates et al., 2006). First, a HFIAS score variableis calculated for eachhousehold by summing the codes for each frequency-of-occurrence question. The higher the score, the more food insecurity (access) thehousehold experienced. The lower the score, the less food insecurity (access) a household hadexperienced. The HFIAS indicator categorizes households into four levels of household food insecurity(access): food secure, and mild, moderately, and severely food insecure. Households arecategorized as increasingly food insecure as they respond affirmatively to more severe conditionsand/or experience those conditions more frequently (Coates et al., 2007).

Household dietary diversity: According to FAO (2010) household dietary diversity score is an indication of household economic access to food. It was calculated by summing the number of food groups consumed in the household respondentover the 24-hour recall period. Respondents were asked whether they consumed the 12 food groupsand their “yes” responses were coded as 1 and the negative response “no" coded as 0 (INDEX Project, 2021). The nextstep is summing the dietary diversity variable values of all new food groups and, the potentialscore ranges from 0 to 12 for HDDS. The higher score indicated that households consumed morediversified food groups. The HDDS of ≤ 3, 4 -5, and ≥ 6 imply low, medium, and high dietary diversity, respectively (Data4diets, 2023).

Food consumption score: According to FAO (2008) cited in Marivoet and Becquey (2019) food consumption score is a composite score based on dietary diversity, food frequency, and relative nutritional importance of different food groups and it can be calculated using the frequency of consumption of different food groups consumed by a household during the 7 days before the survey (Hoddinott, 2002). The following four procedure are important to calculate the FCS,: (i) group all the food items (the 16 food items) into specific food groups (12 food groups), (ii) sum all the consumption frequencies of food items of the same group, and recode the value of each group above 7 as 7, (iii) multiply the value obtained for each food group by its weight (the standard weights for main staples 2, pulses 3, vegetables 1, fruit 1, meat and fish 4, milk 4, sugar 0.5, oil 0.5, condiments 0) and create new weighted food group scores and, (iv) sum the weighed food group scores, thus creating the food consumption score (FCS). FCS of 0-21, 21.5-35, and >35 indicated poor, borderline, and acceptable household consumption respectively. For this study, both HFIAS, HDDS and FCS were calculated at the household level.

Econometrics analysis

In this study econometric analysis method is applied to examine the determinants of perceived effects of climate variability against coping responses. The dependent variable of this study is a binary variable indicating whether or not the household has perceived the specified climate variability effect. The variable takes a value of 1 if the household has perceived the effect of temperature increase, rainfall decrease, and business as usual otherwise 0. To identify the determinants of climate variability adaptation strategies (land contracting, borrowing from friends or families, selling wood tree, selling charcoal, free support of resources, migration, reduction of expenses, daily labor, sell assets), a multivariate probit model was applied.

The multivariate probit model is a statistical model that is used to estimate several correlated binary outcomes jointly (Greene, 2012). The multivariate probit model was justified for examining the effect of perceived climate variability on selection of coping strategies among pastoral and agro-pastoral householdsdue to its ability to analyze multiple correlated dependent variables simultaneously. This model allows for the examination of the complex relationships between various aspects of climate variability, coping strategies, and providing a more comprehensive understanding of the interplay between these factors. Compared to other possible models, the multivariate probit model offers the advantage of capturing the joint distribution of the effectstemperature increment, and rainfall decrease on crop and livestock productivity, which is essential for studying the interconnected nature of climate variability, and coping strategies. However, a weakness of this model was the potential complexity of interpreting the results and the need for robust coping methods to address any weaknesses in the model's assumptions and potential biases in the estimation process. To cope up with this weakness, the study used various methods such as maximum likelihood estimation to estimate the parameters of the model with careful consideration and validation of the model's assumptions. The likelihood function for the multivariate probit model does not have a closed-form solution, so numerical methods are used to estimate the parameters (Heckman, 1979).

The MVP econometric model is characterized by a set of binary dependent variables (Y_{ij}), such that:

$Y_{ij}^{*} = \beta_i{}' X_{ij} + \varepsilon_{ij}$, --(2)

And

$Y_{ij} = \{1,\ if Y_{ij}^{*} > 0 0,\ otherwise$ ---(3)

Where i=1,2,3 denotes perceived effects of climate variability such as 1= temperature increment effect on crop and livestock productivity 2=effects of rainfall decrease on crop and livestock productivity, 3= business as usual; and j=1, ..., n and n denote the sample size. The Eq. (2) assumption is that a rational j^{th} household has a latent variable, Y*ij, which captures the unobserved preferences derived from the i-th perceived effects of climate variability. This latent variable is assumed to be a linear combination of copying responses of climate variability (Xij), as well as unobserved characteristics captured by the stochastic error term εij. The vector of parameters to be estimated is denoted by βi. Given the latent nature of Y*ij, the estimations are based on observable binary discrete variables Yij, which indicate whether pastoral and agro pastoral households have the i-th perceived effects of climate variability. If the specific climate variability copying responses is independent of another climate variability responses, then Eqs. (2) and (3) specify univariate probit models where information on pastoral and agro pastoral household climate variability effects does not alter the prediction of the probability that they have another perceived effect of climate variability. Since we assumed that a pastoral and agro pastoral household have multiple climate variability effects, the error terms in Eq. (2) jointly follow a multivariate normal (MVN) distribution, with 0 conditional mean and variance normalized to 1. Where ($\rho 1$,$\rho 2$,$\rho 3$) distributed MVN (0,Ω″) and the symmetric variance - covariance matrix ″ is given by:

$$\Omega = [1\rho_{12}\rho_{13}\rho_{21}\,1\rho_{23}\rho_{31}\rho_{32}\,1]\text{-----}(4)$$

where (ρ_{im}) denotes the pairwise correlation coefficient of the error terms corresponding to any two perceived effects climate variability equations to be estimated in the model.

The off-diagonal elements in the covariance matrix, ρ_{im} which represent the unobserved correlation between the stochastic component of the i^{th} and m^{th} perceived effects climate variability, are important. This assumption means that Eq. (3) tests whether an MVP model was appropriate for the analysis or the univariate probit model suffices for the analysis.

To determine the effect of independent variables on perceived effects of climate variability against copying responses, the final analysis contains marginal effect analysis results based on Eq (5) (Greene, 2012). Therefore, the marginal effect of copying responses (X_{ij}) was calculated because marginal effects measure the effects that a specific copying response has on the perceived effects of climate variability of pastoral and agro pastoral households while all other variables are held constant.

Marginal Effect of X_{ij} = Pr (Y_i = 1|X, X_{ij} = 1) – Pr (Y_i=1|X, X_{ij} = 0) ------------------------------- (5)

The study's second objective involved applying a multiple linear regression model to identify factors influencing food insecurity among pastoral and agropastoral households in the Borena Zone, Oromia region, Ethiopia. This approach was chosen to understand the complex interplay of coping responses and adaptation factors on household food security in the area. While multiple linear regression allows for the identification and quantification of specific relationships between variables, it assumes linearity, which may not always hold true in real-world scenarios. To address this, the researchers used coping mechanisms such as standardizing independent variables, including interaction terms, and employing robust regression techniques account for outliers and other non-normal data distributions and to provide a more nuanced and accurate understanding of the factors influencing food security in the study area (Wooldridge, 2012).

Assuming that the research was indeed about factors affecting food security status, the multiple linear regression model was specified as follows eq. (6):

Dependent variable: Food security status (Y), independent variables: Factors affecting food security (X_1, X_2, X_3, ... X_n), therefore, the model was represented as:

$Y = \beta_0 + \beta_1 X1 + \beta_2 X_2 + \beta_3 X_3 + ... + \beta_n X_n + \varepsilon$---(6)

Where: Y is the food security status, β_0 is the intercept, β_1, β_2, β_3, ... βn are the coefficients for the factors affecting food security, X_1, X_2, X_3, ... X_n are the independent variables representing the factors affecting food security ε is the error term. This model estimates the effects of various factors on food security status in the Borena Zone, Oromia region, Ethiopia using multiple linear regression analysis.

The study utilized marginal effects of the model to understand how changes in the independent variables affect food security status. This involved interpreting the effect of a one-unit increase in an independent variable on the dependent variable, while holding all other independent variables constant. Mathematically, this was expressed as:

$\frac{\partial Xi}{\partial Yi} = \beta i$--(7)

Where Y is the dependent variable, Xi is the i-th independent variable, and βi is the coefficient of the i-th independent variable in the multiple linear regression model.
All data were analysed using STATA 17.

3.4.Results and Discussions

3.4.1. Descriptive analysis

3.4.1.1.Description of demographic characteristics of pastoral and agropastoral households

Table 3.1 shows that the survey participants have a relatively mature age profile, with an average age of 44.4 years. Most of the survey participants (77%) lacks basic literacy skills, while only 37% are considered literate**.** Thus, the sample participants demographic characteristics could provide perspective about the study area community climate change's perceived effect on food security and their response.

Table 2.1: Socio-demographic characteristics of pastoral and agropastoral households (N=417)

Continuous variables	**Description**	**Min**	**Max**	**SD**	**Mean**	**Percent**
Age of head	Continuous	18	96	14.99	44.40	-
Sex of head	Male	-	-	-	-	51.80
	Female	-	-	-	-	48.20
Education	No formal education	-	-	-	-	77.22
	Primary education	-	-	-	-	18.94
	High school/preparatory					2.88
	Above diploma					0.96

Source: Author computation (2023)

About 76.50% of the households perceive the effect of temperature increase on crops and livestock. Around 89.21% of the respondents are aware of the decreasing trend of annual rainfall effect on crop and livestock production and productivity. About 76.02% of the households follow business as usual approach even if they perceived and encountered the effect of climate change and extremes. Previous research reports in the study sites reported that the extent of temperature increase and rainfall decrease is higher than the national average (Ayal et al., 2018). This finding is also consistent with a study conducted by Mekuyie and Mulu (2021) who reported that 98 % of their respondents perceived that the rainfall has declined and 95 % of households perceived in temperature increase.

The explanatory variables are coping responses adopted to reduce the effect of climate variability and food insecurity. Pastoralists and agro pastoralists adopted different coping responses to reduce climate variability and food security. These include humanitarian aid from government or

NGOs (100%), migration (86.81%), borrowing from friends or families (82.7%), reduce expenses (79.1%), daily labor (77.0%), free support of resources (62.8%), sell of charcoal (51.80%), sell of fuel wood (50.4%), borrowing from credit unions (36.5%), land contracting (5.8%), and sell assets (2.6%).

Table 2.2: Description of dependent and explanatory variables

Variables	Description of variables	Percent	
Dependent variables			
Effect of temperature increase on crop, and livestock	Dummy = 1 if household Perceived the effect of temperature increase on crop and livestock productivity, 0 otherwise	Perceived	76.50
		Not perceived	23.50
Effect of decrease in annual rainfall on crop and livestock productivity	Dummy = 1 if household Rainfall affects agriculture, 0 otherwise	Perceived	89.21
		Not perceived	10.79
Business as usual approach	Dummy = 1 if household Business as usual 0 otherwise	Perceived	76.02
		Not perceived	23.98
Explanatory variables			
Land contracting	Dummy = 1 if household adopt Land contracting, 0 otherwise	Yes	5.76
		No	94.24
Borrowing from credit union	Dummy = 1 if household adopt Borrowing from credit union, 0 otherwise	Yes	36.45
		No	63.55
Borrowing from friends or families	Dummy = 1 if household adopt rain Borrowing from friends or families, 0 otherwise	Yes	82.73
		No	17.27
Selling wood tree	Dummy = 1 if household Selling wood tree, 0 otherwise	Yes	50.36
		No	49.64
Selling charcoal	Dummy = 1 if household adopt Selling charcoal, 0 otherwise	Yes	51.80
		No	48.20
Free support of resources	Dummy = 1 if household adopt Free support money, 0 otherwise	Yes	62.83
		No	37.17
Migration	Dummy = 1 if household adopt Migration,	Yes	86.81

	0 otherwise	No	13.19
Aid from government or non-governmental organization	Dummy = 1 if household adopt non-governmental organization, 0 otherwise	Yes	100.00
		No	0.00
Reductio of expenses	Dummy = 1 if household adopt Reductio of expenses, 0 otherwise	Yes	79.14
		No	20.86
Looking for daily labor	Dummy = 1 if household adopt Looking for daily labor, 0 otherwise	Yes	76.98
		No	23.02
Sell assets	Dummy = 1 if household adopt Sell assets, 0 otherwise	Yes	2.64
		No	97.36

Sources: Researcher's own construction (2023)

3.4.2. Food security status of pastoralist and agropastoral households

The food consumption score shows that about 23.02% of participants were at an acceptable food consumption level that met the minimum criteria for an adequate and balanced diet, indicating relatively better access to a variety of food groups and nutritional requirements, whereas 31.18% fell under the borderline food consumption level (Table 3.3). These households face some challenges in accessing a diverse range of food items or may have inconsistent access to nutritious foods. While their food consumption might not be classified as poor, it is still below the optimal level. About 45.80% of participant households have poor food consumption scores. Accordingly, a significant number of participants were experiencing challenges in accessing an adequate and diverse range of food items. These households are likely to face higher risks of food insecurity, malnutrition, and nutrient deficiencies.

Table 2.3: Status of food consumption score, Borena Zone, N= (417)

Food consumption score	Categorization rule	Frequency	Percent
Poor	0-21	191	45.80
Borderline	21.5-35	130	31.18
Acceptable	>35	96	23.02

Sources: Researcher's own construction (2023)

Table 3.4 presents the status of the household dietary diversity score of the participanthouseholds. Accordingly, 23.98% of the participant households had high dietary diversity scorethat consume a wide range of food groups, including items from various food categories such as grains, vegetables, fruits, dairy, protein sources, and oils/fats, 30.94% of the households had medium dietary diversity scorewho consume a moderate variety of food groups but might have limited access to certain food categories or have relatively fewer options within each category, and 45.08% of the households had low dietary diversity score with limited diversity in their food consumption and might rely heavily on a few food groups or have restricted access to a diverse range of food sources.

Table 2.4: Status of household dietary diversity score, Borena Zone, N= (417)

Household Dietary Diversity Score	Categorization rule (0-12)	Frequency	Percent
Low	HDDS≤3	188	45.08
Medium	4≤HDDS ≥6	129	30.94
High	HDDS>6	100	23.98

Sources: Researcher’s own construction (2023)

3.4.3. Household Food Insecurity Access Scale of participant Households

Table 3.5 depicts that about 95% of the participant households were food insecure. Whereas only around 5% of the sampled households were food secure. More explicitly 24.0%, 36.0%, and 35.5% of the households were classified as mildly, moderately, or severely food insecure, respectively.

The three most ranked coping responses were receiving humanitarian aid from government or non-governmental organizations, migration, and borrowing from friends or family. These coping responses demonstrate the desperate measures taken by participant householdsto obtain the necessary food for their survival.

In addition to the incidence, sample households were asked about the frequency with which the circumstance occurred, i.e., whether it occurred rarely (once or twice in 30 days), sometimes (3–10 days in the previous 30 days), or often (once or twice in 30 days) (if it had happened more than ten times in the past 30 days). Table 5 illustrates that 32%, 7% and 25.2% of the households had worried about food in the last 30 days sometimes and often, respectively. The data reveals that a significant percentage of households faced challenges in accessing their preferred food and had limited food variety. Additionally, a notable proportion of households had to consume food they did not want, and a substantial number frequently consumed smaller meals. A significant portion of the households had no food of any kind in the household, went to sleep hungry, and went a whole day and night without eating.

Table 2.5: Summary of the percentage of the responses to the HFIAS questions, Borena Zone (N=417)

HFIAS frequencyquestions	Happened for the last 30 days in the last year		
	No & rarely	Sometimes	Often
Worried about food	4.5	32.7	25.2
Unable to eat preferred food	78.5	40.2	13.1
Eat just a few kinds of foods	15.0	38.3	45.8
Eat foods they really do not want to eat	21.5	28.0	15.9
Eat a smaller meal	10.3	47.7	41.1
Eat fewer meals in a day	12.1	56.1	29.9
No food of any kind in the household	27.1	23.0	4.0
Go to sleep hungry	35.5	36.0	2.0
Go a whole day and night without eating	36.0	11.0	0.0

Sources: Researcher's own construction (2023)

Food secured | Moderately food insecure
Mildly food insecure | Severely food insecure

The HFIAS analysis result shed light that great majority of households were food insecure which indicate the existence of persistent food insecurity in the study sites. These findings are consistent with previous studies conducted in different parts of Ethiopia (Bekele et al., 2020). In addition Rufino et al., (2013) reported that food insecurity was common at all sites with an annual rainfall of 800 mm or less, and critical levels are seen at sites with <700 mm which is the case of Borena lowland.

The statistics in table 3.6 provide insights into the high prevalence and severity of household food insecurity in the Borena zone.

Table 2.6: Status of household food insecurity access scale (HFIAS), among pastoral and agropastoral households in Borena Zone (N= 417)

No	Household food insecurity access scale	Frequency	Percent
1.	Food secure	19	4.5
2.	Mildly food insecure	100	24.0
3.	Moderately food insecure	150	36.0
4.	Severely food insecure	148	35.5

3.4.4. Effects of perceived climate variability

The key finding in Table 3.7 is that the marginal effect of the perception of the effect of temperature increase on crop and livestock has significantly increased the adoption of land contracting ($p<0.1$) which aligns with different studies (Gbetibouo, 2009; Maddison and Bank, 2007) suggesting farmers seek alternative land use or diversification due to perceived threats to existing crops and livestock. Also it increased borrowing from credit unions ($p<0.01$) whichresonates with Giordano et al.,(2023) where perceived climate risks motivate investment in adaptation measures like improved seeds or infrastructure, often requiring credit. Similarly, adoption of selling fuel wood and daily labor increased ($p<0.01$) while reduces the adoption of selling charcoal ($p<0.01$), free support of resources ($p<0.01$), and reduction of expenses ($p<0.01$) as a coping response to climate variability among pastoralists and agropastoral. Thus, the perception of the impact of temperature increase on crops and livestock plays a significant role in shaping the choices of coping responses. It appears to influence their decisions to engage in certain coping strategies while discouraging others. Whereas the marginal effect of the perception of the impact of decrease in annual rainfall on crop and livestock has significantly increased the adoption of borrowing money from friends or families and free support of resources ($p<0.01$) while reduces the adoption of borrowing from credit union ($p<0.01$) among pastoralists and agropastoral (table 3.7). The marginal effect of following business-as-usual approach increases the adoption of borrowing from credit union ($p<0.01$), free support of resources ($p<0.1$), and migration ($p<0.01$) while reduces the adoption of selling of wood tree ($p<0.05$), reduction of expenses ($p<0.01$) and selling of assets ($p<0.1$) as a coping response to climate variability among pastoralists and agropastoral. The chi-square test (X^2 (3) = 12.0187) assesses the overall significance of the model. The reported p-value (Prob > X^2 = 0.0073) indicates that the variables collectively have a significant effect on the dependent variable.

The qualitative data collected through FGD, and key informants were also in agreement with the quantitative analysis. Mostly, the agropastoral households do more land contracting when they anticipate temperature increases to avoid risk. Borrowing from credit unions is becoming a practice for the pastoralists, whenever they perceive temperature increase and decrease in rainfall. During severe periods people are less likely to borrow from friends and family because they are all in similar circumstances and may not have spare money to lend to others. The quantitative and qualitative result demonstrate that choices about coping strategies are heavily influenced by how one perceives the impact of rising temperatures on cattle and crops. Both the quantitative and qualitative data confirms that it appears to influence their decisions to engage in certain coping strategies while discouraging others.

The study results highlight the significant role of perceptions of temperature increase and rainfall decrease in shaping the choices of coping responses among pastoralists and agropastoral. This aligns with existing literature emphasizing the importance of subjective experiences and risk perception in influencing adaptation strategies.

Table 2.7: Determinants of perceived climate variability on coping response among participant households in Borena Zone (N= 417)

Variables	Effect of temperature increase on crop, and livestock productivitydy/dx	Effect of annual rainfall decrease on crop and livestock productivity dy/dx	Business as usual approach dy/dx
Coping responses			
Land contracting	1.03*	4.49	-0.09

Borrowing from credit union	1.04***	-1.12***	0.83***
Borrowing from friends or families	-7.01	0.95***	0.11
Selling wood tree	0.73***	-0.66	-0.39**
Selling charcoal	-0.49**	-0.01	-0.17
Free support of resources	-0.51***	1.6***	0.31*
Migration	0.49	-13.45	0.61***
Reduction of expenses	-2.46***	-12.77	-0.54***
Daily labor	1.86***	0.33	-0.70
Sell assets	0.12	9.48	-0.85*
chi2(3) = 12.0187		Prob > chi2= 0.0073	

Source: Authors calculation (2023)

***, **, * are significant at 1 %, 5 %, and 10 %, respectively.

3.4.5. Determinants of household food security among pastoral and agropastoral households in Borena Zone

The OLS regression showed that selling of charcoal ($p<0.01$) and migration ($p<0.01$) increased the food insecurity of households while borrowing from credit union ($p<0.01$), borrowing from friends or families ($p<0.01$), and reduction of expenses ($p<0.01$) has reduced the food insecurity among pastoralists and agropastoral households (Table 3. 8). In many cases, household heads often resort to migration in search of income for their families, leaving behind the children and women with limited options. Unfortunately, those who remain behind often face significant food insecurity, particularly during times of drought. Additionally, the sale of charcoal, which is a common income-generating activity, does not provide substantial earnings due to the lack of alternative income sources. As a result, these households continue to experience food insecurity despite engaging in charcoal sales. The marginal effects for the age of sample pastoralists and agropastoral is 0.047. This suggests that a one-year increase in age is associated with a decrease in household food security by 0.047 unit, and this effect is statistically significant at 1% level of significance. The marginal effects for family size are -0.37. This indicates that households that have large family size significantly food secured compared to those have small family size. Each unit increase in family size is associated with a decrease in food insecurity by 0.37 units. Access to extension service is statistically significant at 1% level of significance. On average, households with access to extension services have a good food security status that is 0.02 units thanhouseholds without access, holding other factors constant.

Table 8 shows that, the F-test with a value of 9.97 and a p-value of 0.000 indicates that the regression model is statistically significant, implying that at least one of the independent variables is significantly associated with household food security. The F-test value (9.97) and the associated p-value (0.000) suggest that the overall model is statistically significant. The R-squared value of 0.82 indicates that the independent variables included in the regression model explain approximately 82% of the variation in household food security. This suggests that the model has good explanatory power. These findings are consistent with research like Nhemachena et al., (2018) suggesting that resource depletion through charcoal production and displacement through migration can undermine long-term food security and income generation. In addition, borrowing from credit union ($p<0.01$), borrowing from friends/families ($p<0.01$), and reduction of expenses ($p<0.01$) which align with studies like Giordano, (2023) where access to credit or social support enables investment in food production, resource purchase, or cost-cutting measures, thereby improving food security.

Table 2.8: Determinants of household food insecurity among pastoral and agropastoral households in Borena Zone, N= (417)

Variables	Standard errors	T-value	Marginal effects
Land contracting	0.832	-0.72	-0.42
Borrowing from credit union	0.43	-3.34	-1.06***
Borrowing from friends or families	0.534	-5.35	-2.58***
Selling wood tree	0.553	-0.55	-0.62
Selling charcoal	0.535	4.84	2.67***
Free support money	0.463	0.39	-0.21
Migration	0.602	4.83	2.56***
Reduction of food expenses	0.487	-3.86	-1.87***
Looking for daily labor	0.516	-0.17	-0.29
Sell assets	1.216	-0.07	-0.07
Age of head	0.013	3.55	-0.047***

Sex of head	0.38	1.16	0.44
Family size of head	0.10	-3.60	-0.37***
Education level	0.4	-2.13	-0.85**
Access to extension services	0.38	-0.08	-0.02***
Market distance	0.03	3.83	0.12
Mean dependent variable=14.688		R-squared =0.82	
F-test = 9.97		Prob > F =0.000	

Source: Authors computation (2023)

, * significant at and 5%, and 1%

3.5. Conclusion and policy implications

The findings of the study indicated that households in the study area were facing the dual challenges of climate variability and food insecurity. Substantial proportion of them perceived the effect of temperature increase and decrease reflected in annual rainfall variability, crop failure and death of livestock. Approximately 77% of the households perceived that the effect of temperature increases on crop and livestock. Around 89% of the households perceive that decrease in annual rainfall affects agriculture and livestock productivity. In effect, food security became one of the major concerns in the community where about 95% of households faced different levels of food insecurity with about 36 % falling under either severely or moderately food insecure category. The findings further depict that households employ a range of coping strategies in response to increasing climate variability and food insecurity. Receiving humanitarian aid from government or NGOs, migration, borrowing from friends or families, reduction of expenses, daily labor, sell of charcoal and fuel wood were the most frequently reported coping strategies. Perception of the effect of temperature increase on crop and livestock has significantly increased the adoption of land contracting adoption of selling fuel wood and daily labor increased as a coping response to climate variability among pastoralists and agropastoral. The perception of the impact of decrease in annual rainfall on crop and livestock has significantly increased the adoption of borrowing from friends or families and free support of resources among pastoralists and agropastoral. The finding also shows borrowing from credit union, borrowing from friends or families, and reduction of expenses has reduced the food insecurity among pastoralists and agropastoral households. To address these pressing issues, specific coping responses have emerged, aiming to enhance resilience and ensure the well-being of the local population. These coping responses have proven crucial in navigating the complexities of climate variability and its impact on food security in the region. Borena pastoralists and agropastoral have developed traditional knowledge and resource management practices to cope with climate variability and food insecurity. They employ various coping strategies to enhance reduce the effect of climate variability and food insecurity on their livelihood.

The overall findings imply the need for integrated interventions that consider the livelihood strategies of pastoral areas that concurrently address poverty, climate change, and access to acceptable diet. The use of behavioral change communication advocacy will serve as a strategic bridge to raise awareness about climate change risk management and reduce malnutrition in all its forms through better diet. Most importantly, a paradigm shifts towards inclusive, community-oriented, indigenous, knowledge-based climate change adaptive capacities, food and nutrition policies would be a noble investment.

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CHAPTER 4: CLIMATE VARIABILITY PERCEPTIONS AND ADAPTATION RESPONSE TO ENSURE HOUSEHOLD FOOD SECURITY IN BORENA ZONE, ETHIOPIA

4.1. Abstract

The article examines pastoral household climate variability perceptions and adaptation response to ensure their food security in Borena Zone of Ethiopia. A mixed research design was employed to gain comprehensive insights into the perceptions and adaptation responses of pastoral and agro-pastoral households, aiming to ensure their food security. Quantitative data were gathered from a randomly selected sample of 417 pastoral and agro-pastoral households in the Borena zone. Additionally, qualitative data were obtained from deliberately chosen key informants and participants in focus group discussions. The study utilized both descriptive and econometric analysis methods. Descriptive statistics such as mean, standard deviation, percentages, and frequency, along with statistical tests like Chi-square and T-test, were employed to assess the perceptions of pastoral and agro-pastoral households and the impact of adaptation on food security. Furthermore, a multivariate probit model was applied to identify determinants influencing climate variability adaptation responses. The endogenous switching regression (ESR) model was utilized to evaluate the effect of adaptation responses on the food security status of households. the result reveals that majority of respondents (94.7% and 83.9%) perceived an increase in temperature and drought frequency respectively, while 87.8% observed a decrease in rainfall. Notably, households perceiving drought exhibited better food security statuses, highlighting the positive influence of perceptions on food security. Both pastoral and agro-pastoral households employed various adaptation measures, including destocking, feed storage, haymaking, drought resistant livestock varieties, index-based livestock insurance, water and soil conservation, early maturing crop varieties, and savings, to ensure food security. Moreover, the study suggests that specific adaptation strategies are linked to households' perceptions of temperature increase, rainfall decrease, and drought frequency. Furthermore, the research emphasizes the deep understanding of climate change and extremes behavior among pastoral *and agro-pastoral households. It concludes that the food security situation of these households is influenced by their perceptions of climate change and their adaptation responses. Therefore, interventions focused on raising awareness and identifying feasible adaptation responses could enhance their resilience to climate change. Additionally, improving access to basic infrastructures for pastoral and agro-pastoral households is deemed crucial for enhancing their adaptive capacity.*

Keywords: Adaptation, Climate Variability, Food security, Endogenous switching model, Borena

4.2. Introduction

Climate variability and extremes poses significant challenges to pastoral households' food security status, as it disrupts pastoral livelihood and agro-pastoral agricultural systems (Birkmann et al. 2022). In response to these challenges, adaptation measures have been developed to respond to the adverse effects of climate variability and enhance food security (Yared et al., 2022; IPCC, 2019).

Ever rising temperature, erratic precipitation behavior, and recurrent drought have implications on pastoral and agro-pastoral households food security (Ayal and Filho, 2017). Pastoral and agro-pastoral communities, whose livelihoods depend on livestock rearing and semi-nomadic or nomadic practices, are particularly vulnerable to the adverse effect of climate variability. Climate variability and extremes could compromise pastoralists' and agro-pastoralists’ access to water and forage for their livestock (Birkmann et al., 2022; Radeny et al. 2019). These changes could lead to proliferation of livestock diseases, extending Calvin at first and Calvin in between, reduced milk production, and increased vulnerability to food insecurity (Alhamshry et al., 2020; Ayal et al., 2017; Conway et al., 2004).

The effect of climate variability and extremes on pastoral households extend beyond their livestock. Crop failures due to erratic rainfall patterns and prolonged droughts further exacerbate food insecurity. Additionally, changes in temperature and precipitation patterns could trigger rangeland degradation, prevalence of livestock diseases and incur extra resources for the livestock management (Filho et al., 2020; Ayele, Dedecha and Duba, 2020).

Perceptions of climate variability and extremes among pastoral households are influenced by socio-cultural contexts (Ayal et al., 2021; Ayal & Filho, 2018). Cultural beliefs, customs, and traditional practices shape their understanding of climate patterns and changes. For instance, indigenous knowledge systems include specific rituals or practices to mitigate the impacts of climate variability, such as rainmaking ceremonies during droughts. Recognizing and incorporating local knowledge and perceptions of climate variability is crucial for developing context-specific adaptation responses (Debela et al. 2019).

Pastoral and agro-pastoral households employ various adaptation responses to ensure food security in the face of climate variability and extremes. These strategies encompass diverse dimensions and are often multifaceted in nature. In general, livestock management practices play a central role in adaptation efforts. For instance, they adjust their herd size, diversify their livestock species, and practice mobility to access grazing areas that are less affected by climate variability (Kemal et al., 2022). These strategies help maintain livestock productivity, prevent overgrazing, and reduce vulnerability to droughts.

Agro pastoral households employ strategies such as cultivating drought-tolerant crops and practicing intercropping to reduce the risk of crop failures and increase agricultural production (Yadav et al., 2018 Rufino et al. 2023). Similarly, pastoral communities also implement water resource management strategies, including the construction of water harvesting structures and the adoption of water-saving techniques. These practices are aimed at ensuring consistent access to water for both livestock and crop cultivation (Ayal and Filho, 2017).

In addition to livestock and crop agriculture-based strategies, pastoral households often engage in income diversification activities. This includes off-farm employment, small-scale businesses, and the sale of non-livestock products. Income diversification reduces their reliance on livestock-based livelihoods and provides alternative income sources to cope with climate variability shocks. Integrated approaches that combine multiple adaptation responses are crucial for enhancing food security in pastoral communities. The combination of livestock management, crop diversification, water resource management, and income diversification strategies can help pastoral households build resilience, reduce vulnerability, and ensure sustainable food production systems.

The conceptual framework guiding this paper is based on the vulnerability and adaptation theory. This theory posits that vulnerability to climate change is influenced by both exposure to climate hazards and the capacity to adapt (Adger et al., 2007). The theory further states that household food security is determined by the interaction between climate variability perceptions, adaptation responses, and socio-economic factors within the Borena Zone context.

The Borena people are predominantly pastoralist who inhabits arid and semi-arid environments where climate is variable and frequency and intensity of droughts and floods are increasing

(Berhanu and Beyene, 2015). The livelihood resources of the livestock production mainly depend on natural assets that in turn are affected by climatic impacts. Climate related risks such as increased incidence of recurrent drought, high temperature, low and erratic rainfall affect the livelihood of the communities (Alemu and Adugna, 2015; Alemu et al., 2019). Droughts and other climate-related shocks can have severe impacts on the livelihoods of the Borena people, as the people are highly dependent on livestock and natural resources for their survival. These changes have severe implications for agricultural productivity and food availability in the region (Nigussie et al., 2018).

Deressa et al. (2015) found that agro-pastoralist farmers in Borena perceived changes in temperature and rainfall patterns and associated these changes with negative impacts on crop yields. Similarly, Alemu and Adugna (2015) reported that agro-pastoralist farmers recognized the increasing variability in rainfall and its adverse effects on their agricultural activities. On the other hand, Alemu and Adugna (2015) found that pastoralists recognized the changing rainfall patterns and associated these changes with negative impacts on pasture availability and livestock productivity. Deressa et al. (2015) also reported that pastoralists perceived changes in temperature and rainfall, which influenced their decision-making regarding herd management and mobility.

Consequently, pastoralist and agro-pastoralist households have adopted various adaptation responses to ensure food security. Among agro-pastoralists, crop diversification emerged as a common adaptation strategy (Nigussie et al., 2018), with transitioning from traditional crops to more drought-tolerant and resilient varieties (Alemu et al., 2019). Livestock management practices, such as adjusting herd size and providing feed supplementation, have also been implemented to reduce climate change related risks (Alemu, 2017). Conversely, pastoralists have implemented diverse adaptation responses. Mobility stands out as a commonly employed strategy, enabling pastoralists to access grazing areas in response to the pasture scarcity (Alemu, 2017). Additionally, herd diversification and destocking have been identified as adaptation responses to manage feed scarcity during droughts (Nigussie et al., 2018). The literature review underscores that pastoralists' perceptions of climate variability and their adaptive strategies are influenced by their dependence on livestock and mobility as primary livelihood strategies.

However, studies on climate variability perceptions and adaptation responses in pastoral communities in Ethiopia, including the Borena zone, remain scarce. Besides, the existing studies in Ethiopian pastoral communities (e.g., Alqeer et al., 2023; Bekele et al., 2020; Alemu et al., 2019; Nigussie et al., 2018; Gurmu, 2018) have primarily focused on the determinants of food security and/or the economics of climate variability. To fill this gap, this study aims to explore pastoral and agro-pastoral households' perceptions of climate variability and their adaptation responses in the Borena Zone. By generating empirical evidence, this study seeks to inform policymakers, development practitioners, and communities in developing context-specific interventions to enhance climate change resilience and food security among pastoral and agro-pastoral households in the Borena Zone.

Understanding how pastoral and agro-pastoral households perceive climate variability is vital for crafting effective adaptation responses. Additionally, comprehending the impact of these adaptation responses on pastoral households' food security is crucial for designing effective interventions and policies, as they heavily rely on livestock and agriculture for their livelihoods, rendering them particularly vulnerable to disruptions caused by climate variability. Thus, by identifying effective adaptation responses, policymakers, researchers, and practitioners can formulate targeted interventions and programs to support pastoral households in building resilience and improving their food security.

4.3. Materials and Methods

4.3.1. Data Source and Type

The study used both primary and secondary data sources. A cross-sectional research design was used to obtain primary quantitative data from pastoralists and agro-pastoralists through structured questionnaires, while qualitative data were collected using 12 focus group discussions (FGDs), 12 in-depth interviews, 2 case studies, and observations. In addition, secondary data were collected from reports of the Borena Zone office, farmers' cooperative, central statistical agency (CSA), and published and unpublished documents. During primary data collection, well-trained enumerators who have good experience in the household survey were employed and deployed.

4.3.2. Sampling Technique, and Sample Size Determination

A multi-stage sampling technique was used to select pastoralist and agro-pastoralist households. At the first stage representative districts were selected using simple random sampling. The second stage was followed the proportional, and random selection of kebeles within the specified districts. The study has chosenpastoralists and agro-pastoralists from each kebeleby referring to the kebeles register as the studysampling frame**.**

The sample size was determined using Cochran's (1977) formula by taking the following assumptions: the estimated proportion of an attribute that is present in the population of 50% (to get maximum sample size), and 5% margin of error at 95% confidence level. The calculated sample size was 384 and 10% non-responses and incomplete responses i.e., 38 pastoral and agro-pastoral households were added. Hence, the final estimated sample size was 422 households. The nonresponse was 5 people, which resulted in the final sample size to be 417 households (98.8 percent actual response rate).

4.3.3. Method of Data Analysis

The analysis was performed using STATA 17, and R statistical software packages. Both descriptive and econometric analyses were used. Mean, standard deviation, percentages, ratios, and frequency distributions were used to portray the characteristics of the pastoral and agro-pastoral households. Multivariate Probit Model (MVP) and Endogenous Switching Regression (ESR) Model were used to further examine the effects of perception and adaptation on the outcome variable. Moreover, Chi-square test, F test, and T- test were used to test the existence of any bivariate statistically significant association between different adaptation responses and household food security status.

4.3.3.1.Econometrics Analysis

Multivariate Probit (MVP)

A multivariate probit (MVP) model was applied to identify adaptation responses adopted based on the perceived climate variability. The dependent variable of this study was a binary variable indicating whether a particular adaptation response has been employed. The variable takes a value of 1 if the household has adopted the specified climate variability adaptation response and takes a value 0 otherwise.

The MVP models the influence of a set of different climate variability perceptions on the adopted adaptation responses while allowing unobserved and unmeasured factors (error terms) to be freely correlated. When they decide to adopt based on the perceived climate variability, one source of correlation might be the synergy (positive correlation) and trade-off (negative correlation) of these perceptions. The essence of using MVP stems from the fact that smallholder farmers, by observation, have multiple climate variability perceptions. Some of these perceptions produce a synergistic (complimentary) effect, while others produce a trade-off effect (substitutes). As a result, failing to account for these unobserved factors and effects among the perceptions will result in biased and inefficient estimates (Greene, 2003).

Model specification of multivariate probit (MVP) model

The MVP econometric model is characterized by a set of binary dependent variables (Y_{ij}), such that:

$$Y_{ij}^{*} = \beta_i{}' X_{ij} + \varepsilon_{ij}\,, \qquad (1)$$

And

$$Y_{ij} = \{1,\ if Y_{ij}^{*} > 0 0,\ otherwise \qquad (2)$$

Where i=1,2,3 denotes the climate variability perceptions such as 1=increasing temperature 2=decreasing precipitation, 3= increasing drought; and j=1, ..., n and n denote the sample size. The Eq. (1) assumption is that a rational jth household has a latent variable, Y*ij , which captures the unobserved preferences derived from the ith climate variability perception. This latent variable is assumed to be a linear combination of adaptation responses adopted (Xij), as well as unobserved characteristics captured by the stochastic error term εij. The vector of parameters to be estimated is denoted by βi. Given the latent nature of Y*ij, the estimations are based on observable binary discrete variables Yij, which indicate whether a household perceived the ith climate variability perception. If the specific perceived climate variability is independent of another climate variability perception, then Eqs. (1) and (2) specify univariate probit models where information on households' climate variability perceptions does not alter the prediction of the probability that they have another perceived climate variability. Since we assumed that a household could have multiple climate variability perceptions, the error terms in Eq. (1) jointly follow a multivariate normal (MVN) distribution, with 0 conditional mean and variance normalized to 1. Where ($\rho 1, \rho 2, \rho 3$) distributed MVN (0, Ω″) and the symmetric variance - covariance matrix ″ is given by:

$$\Omega = [1 \rho_{12} \rho_{13} \rho_{21} 1 \rho_{23} \rho_{31} \rho_{32} 1]$$

where (ρ_{im})denotes the pairwise correlation coefficient of the error terms corresponding to any two perceived climate variability equations to be estimated in the model.

The off-diagonal elements in the covariance matrix, ρ_{im} which represent the unobserved correlation between the stochastic component of the i^{th} and m^{th} perceived climate variability, are important. This assumption means that Eq. (2) tests whether an MVP model was appropriate for the analysis or the univariate probit model suffices for the analysis.

To determine the effect of independent variables on climate variability perceptions against adaptation response, the final analysis contains marginal effect analysis results based on Eq (3) (Greene, 2012). Therefore, the marginal effect of adaptation responses (X_{ij}) was calculated because marginal effects measure the impact that a specific adaptation response has on the perceived climate variability of households while all other variables are held constant.

Marginal Effect of $X_{ij} = \Pr(Y_i = 1|X, X_{ij} = 1) - \Pr(Y_i=1|X, X_{ij} = 0)$ (3)

Endogenous Switching Regression (ESR) model

The second objective of the study was focused on the impact of climate variability adaptation responses on agro pastoral, and pastoralists food security. To analyze the impact of climate variability adaptation responses on agro pastoral's, and pastoralist's food security the study used an endogenous switching regression (ESR) model. The model accounts for potential endogeneity and self-selection bias and allows interactions between climate change decisions and other explanatory variables in the household food security outcome function. The model consists of two equations: a selection equation (adoption of adaptation responses) and an outcome equation (food security). The selection equation models the probability of selecting into the group that adopts the outcome, while the outcome equation models the relationship between the binary outcome and the explanatory variables (Wooldridge, 2003). The selection equation and the outcome equation are estimated jointly using maximum likelihood estimation.

To account for selection biases, an ESR model was used for the outcome variables (food security) in which farmers face two regimes: (Regime 1) to use adaptation responses and (Regime 2) not used adaptation responses, as defined as follows:

$$U_{1i} = X_i\beta_1 + \epsilon_{1i} \quad (4)$$

$$U_{2i} = X_i\beta_2 + \epsilon_{2i} \quad (5)$$

$$G_i^* = \partial(U_{1i} - U_{2i}) + Z_i\alpha + u_i \quad (6)$$

Here G_i^* is a latent variable that determines the utility obtained whether the household I used adaptation responses or not; U_{ji} is the outcome variable value of a household i who used adaptation responses and j= Regiem1 and Regime 2; $Z_i$is a vector of characteristics that influences the decision to use adaptation responses but not the outcome variable value. X_i is a vector of household characteristics that are thought to influence the decision to adopt the innovation, β_1, β_2, and γ are vectors of parameters, and u_i, ϵ_{1i}, and $\epsilon_{2i}$are the error terms.

The regression model coefficient of adaptation responses, which measures the impact of adaptation responses, should be random. But in the case of adaptation responses, farmers freely choose the particular adaptation responses they want to adopt with their consent. Hence, there is the problem of self-selection, which leads to selection bias. The decision to use adaptation responses is likely to be affected by unobservable characteristics that may be correlated with the outcome variables (food security). Finally, the error terms in equations (4), (5), and (6) are assumed to have a tri-variate normal distribution$(\upsilon, \varepsilon_1, \varepsilon_2) \sim$ N $(0, \Sigma)$

$$\sum = \sigma_\upsilon^2 \sigma_{\upsilon 1} \sigma_{\upsilon 2} \sigma_{1\upsilon} \sigma_1^2 . \sigma_{2\upsilon} . \sigma_2^2$$

where σ_υ^2 is the variance in the adoption equation (6), which is equal to 1, since the coefficients are estimable only up to a scale factor, $\sigma_1^2$and σ_2^2 are the variances of the error terms in the outcome variable functions (4) and (5), and $\sigma_{1\upsilon}$ and $\sigma_{2\upsilon}$ represent the covariance of υ_i and ε_{1i}

and ε_{2i}. Since equations (4) and (5) are not observed simultaneously the covariance between ε_{1i} and ε_{2i} is not defined (reported as dots in the covariance matrix. An important implication of the error structure is that because the error term of the selection equation (6) u_i is correlated with the error terms of the outcome variable functions (4) and (5) (ε_{1i} and ε_{2i}), the expected values of ε_{1i} and ε_{2i} conditional on the sample selection are nonzero:

$$E = (G_i = 1) = \sigma_{1v} \frac{\phi(Z_i\alpha)}{\Phi(Z_i\alpha)} = \sigma_{1v}\lambda_{1i} \quad (7)$$

$$E = (G_i = 0) = \sigma_{1v} \frac{\phi(Z_i\alpha)}{1-\Phi(Z_i\alpha)} = \sigma_{2v}\lambda_{2i} \quad (8)$$

Where $\phi(.)$is the standard normal probability density function, $\Phi(.)$the standard normal cumulative density function, and $\lambda_{1i}= \frac{\phi(Z_i\alpha)}{\Phi(Z_i\alpha)}$, and λ_{2i} = - $\frac{\phi(Z_i\alpha)}{1-\Phi(Z_i\alpha)}$. If the estimated covariances σ_{1v} and $\sigma_{2v}$are statistically significant, then the decision to adopt and the outcome variable are correlated, that is evidence of endogenous switching was found and reject the null hypothesis of the absence of sample selectivity bias. An efficient method to estimate endogenous switching regression models is full information maximum likelihood estimation (Lee L., and Robert H. 1984). The logarithmic likelihood function given the previous assumptions regarding the distribution of the error terms is

$$ln\ Li = \sum_{i=1}^{N} A_i\left[ln\ ln\ \phi\left(\frac{\epsilon_{1i}}{\sigma_1}\right) - ln\ ln\ \sigma_1 + ln\ ln\ \Phi(\theta_{1i})\right] + (1-Ai)[ln\ ln\ \phi(\frac{\epsilon_{2i}}{\sigma_2}) - ln\ ln\ \sigma_2$$
$$+ ln\ ln\ (1-\Phi(\theta_{2i}))\ ] \quad (9)$$

where $\theta_{ji}= \frac{Z_i\alpha+\frac{\varepsilon_{ij}}{\sigma_j}\rho_j}{\sqrt{(1-\rho_j^2)}}$, j = 1, 2, with $\rho_j$denoting the correlation coefficient between the error term $u_i$of the adaptation response equation (6) and the error term $\varepsilon_{ji}$of equations (7), respectively. The ESR model can be used to compare the expected outcome variable of the pastoralists and agro pastoralist households that used a particular adaptation responses to the farm households that did not used adaptation responses, and to investigate the expected outcome variable result in the counterfactual hypothetical cases that the pastoralists and agro pastoralist households that did not used adaptation responses , and that if the pastoralists and agro pastoralist household who did not used adaptation responses what is they used.

a) $E(U_{1i}|G_i=1) = X_{1i}\beta_1 + \sigma_{1v}\ \lambda_{1i}$

$b)\ E(U_{2i}|G_i=0) = X_{2i}\beta_2+\sigma_{2\upsilon}\ \lambda_{2i}$

$c)\ E(U_{2i}|G_i=1) = X_{1i}\beta_2+\sigma_{2\upsilon}\ \lambda_{1i}$

$d)\ E(U_{1i}|G_i=0) = X_{2i}\beta_1+\sigma_{1\upsilon}\ \lambda_{2i}$

In addition, the effect of the treatment "to use adaptation responses" on the treated (ATT) was calculated as

$ATT = E\ (U_{1i}|G_i = 1) - E\ (U_{2i}|G_i = 1) = X_{1i}\ (\beta_1 - \beta_2) + (\sigma_{1\upsilon} - \sigma_{2\upsilon})\lambda_{1i}$

which represents the impact of adaptation responses on the outcome variable result of the pastoralist and agro pastoralist households that used a particular adaptation response. Similarly, the effect of the treatment on the untreated (TU) for the pastoralist and agro pastoralist households that did not used to be calculated as:

$ATU = E\ (U_{1i}|G_i = 0) - E\ (U_{2i}|G_i = 0) = X_{2i}\ (\beta_1 - \beta_2) + (\sigma_{1\upsilon} - \sigma_{2\upsilon})\lambda_{2i}$.

4.3.4. Household Food Security Analysis Methods

Food security in this study was measured using proxy analysis using household food insecurity access scale and household dietary diversity score. Household food insecurity access scale (HFIAS) consistsof two types of related questions. The first question type is called anoccurrence question. There are nine occurrence questions that ask whether a specific conditionassociated with the experience of food insecurity ever occurred during the previous four weeks(30 days). Each severity question is followed by a frequency-of-occurrence question, which askshow often a reported condition occurred during the previous four weeks. The HFIAS score is a continuous measure of the degree of food insecurity (access) in thehousehold in the past four weeks (30 days). First, a HFIAS score variableis calculated for eachhousehold by summing the codes for each frequency-of-occurrence question. The higher the score, the more food insecurity (access) thehousehold experienced. The lower the score, the less food insecurity (access) a household hadexperienced. The HFIAS indicator categorizes households into four levels of household food insecurity(access): food secure, and mild, moderately, and severely food insecure. Households arecategorized as increasingly food insecure as they respond affirmatively to more severe conditionsand/or experience those conditions more frequently (Coates, J. et al., 2007).

4.4.Results and discussion

4.4.1. Description of socio-demographic characteristics

Table 4.1 shows that the study population has a relatively mature age profile, with an average age of 44.4 years. The gender distribution among household heads is relatively balanced, with 51.8% male and 48.2% female. Most of the population is married (84.2%), while a smaller proportion is single (5.5%), widowed (6.9.0%) and others (3.4%). Finally, a significant majority of the population (77.2%) lacks basic literacy skills, while only 32.8% are considered literate**.**

Table 0.1: Socio-demographic characteristics

Variables	Category	Mean/Percent
Age		44.4
Sex of family head	Male	51.8
	Female	48.2
Marital status	Married	84.2
	Single	5.5
	Widowed	6.9
	Others	3.4
Education	No formal education	77.2
	Primary (1-8)	18.9
	Highschool /preparatory	2.9
	Diploma and above	1.0

Source: Own author's computation (2023)

4.4.2. Climate variability perceptions and adaptation of respondents

Table 4.2 provides details about the dependent and explanatory variables associated with climate adaptation responses that pastoralist and agro-pastoralist households put on. The dependent variables encompass temperature perception, rainfall perception, and drought perception. The percentages indicate that 94.7% of respondents perceived an increase in temperature, 87.8% perceived a decrease in rainfall, and 83.9% perceived an increase in drought.

The explanatory variables represent the various adaptation responses categorized into livestock, crop, and other adaptation responses. Livestock adaptation responses include feed storage (61.9 percent), destocking practice (39.6 percent), rainwater harvesting (67.4 percent), haymaking or *dirkosh* (59.0 percent), growing livestock feed (31.2 percent), and participate in index-based livestock insurance (27.3 percent). Crop adaptation responses include use of drought-resistant varieties DRV(61.8%) adjusting planting and harvesting dates (59.5 percent), water and soil conservation (71.5 percent), and planting early maturing varieties (61.8 percent). Other adaptation responses such as consuming stored food (83.7 percent), borrowing from a credit union (36.5 percent), using media (14.9 percent), saving crop seed or money (59.8 percent), receiving free support (76.8 percent), and livelihood diversification (petty trade or daily labor) (50.0 percent).

Table 0.2: List of dependent and explanatory variables and their measures

Variable	Description of variables	Percent	
Dependent Variables			
Temperature Perception	Dummy = 1 if household perceived temperature increases, 0 otherwise	Perceived	94.72
		Not perceived	5.28
Rainfall Perception	Dummy = 1 if household perceived rainfall decreases, 0 otherwise	Perceived	87.77
		Not perceived	12.23
Drought Perception	Dummy = 1 if household perceived drought increase, 0 otherwise	Perceived	83.93
		Not perceived	16.07
Food security (HFIAS)	Scale (0-27)	Mean =14.69	
Explanatory Variables			
Livestock adaptation responses			

Feed storage	Dummy = 1 if household adopt feed storage, 0 otherwise	Yes No	61.87 38.13
Destocking practice	Dummy = 1 if the household adopts destocking practice, 0 otherwise	Yes No	39.57 60.43
Rainwater harvesting	Dummy = 1 if the household adopt rainwater harvesting, 0 otherwise	Yes No	67.39 32.61
Haymaking / *dirkos*h	Dummy = 1 if the household adopt haymaking / dirkosh, 0 otherwise	Yes No	59.03 41.97
Growing livestock feed	Dummy = 1 if household adopt growing livestock feed, 0 otherwise	Yes No	31.16 68.82
Index-based livestock insurance	Dummy = 1 if the household adopts index-based livestock insurance, 0 otherwise	Yes No	27.34 72.66
Drought resistant feed varieties	Dummy = 1 if the household adopts drought resistant varieties, 0 otherwise	Yes No	68.35 31.65
Crop adaptation responses			
Adjusting planting and harvesting dates	Dummy = 1 if the household adjust planting and harvesting dates, 0 otherwise	Yes No	59.47 40.53
Water and soil conservation	Dummy = 1 if the household adopts water and soil conservation, 0 otherwise	Yes No	71.46 28.54
Consume stored food	Dummy = 1 if the household consume stored food, 0 otherwise	Yes No	83.69 16.31
Early maturing varieties	Dummy = 1 if the household adopt early maturing varieties, 0 otherwise	Yes No	61.77 38.37
Other adaptation responses			
Borrowing from a credit union	Dummy = 1 if the household adopts borrowing from a credit union, 0 otherwise	Yes No	36.45 63.55
Using media	Dummy = 1 if the household adopt using media, 0 otherwise	Yes No	14.87 85.13
Saving crop seed or money	Dummy = 1 if the household adopts Saving crop seed or money, 0 otherwise	Yes No	59.75 41.25
Receiving free support	Dummy = 1 if the household received free	Yes	76.83

	support, 0 otherwise	No	37.17
Livelihoods Diversification	Dummy = 1 if the household diversify livelihoods petty trade or daily labor, 0 otherwise	Yes	50.02
		No	49.88

Own survey computation (2023)

4.4.3. Pastoral Household Climate Variability Perceptions against Adaptation Response

Table 4.3 shows the relationship between agro-pastoral, and pastoral household's climate variability perceptions and the adoption of various adaptation responses. The table shows the marginal effect values of adaptation responses on climate variability perceptions of increase in temperature, decrease in rainfall, and increase in drought frequency.

The increase in temperature perception had a positive and statistically significant effect on the adoption of Growing livestock feed, saving (crop seed, money), and receiving free support from NGOs and Government ($p<.01$). However, the increase in temperature perception had a negative and statistically significant effect on the adoption of index-based livestock insurance and early maturing varieties, ($p<.01$).

A decreasing trend of rainfall perception among pastoralist and agro-pastoralist communities increases the adoption adaptation responses such as feed storage, destocking practice, rainwater harvesting, haymaking or *dirkosh*, drought resistant varieties (DRVs), planting early maturing varieties, use of media, and livelihood diversification. However, A decreasing trend of rainfall perception among pastoralist and agro-pastoralist decreases the adoption of index-based livestock insurance, borrowing from credit union, saving (crop seed, money), and receiving free support from NGOs and Government.

An increase in drought frequency perception among pastoralists improves the adoption of Growing livestock feed, index-based livestock insurance**,** borrowing from credit union, and saving (crop seed, money). However, the increase in drought frequency perception decreases the adoption of livestock adaptation responses such as feed storage, destocking practice, rainwater harvesting, and hay making/dirkosh, drought-resistant varieties, practice of water and soil conservation, and livelihood diversification.

Table 0.3: Results of Probit model pastoral household climate variability perceptions against adaptation response

Variables	Increase in temperature perception dy/dx	Decrease in Rainfall perception dy/dx	Increase in Drought frequency perception dy/dx
Livestock adaptation responses			
Feed storage	-0.380	-0.83***	-1.40***
Destocking practice	-0.44	-1.20***	-1.08***
Rainwater harvesting	-0.28	-0.75***	-0.57***
Hay making / dirkosh	-0.38	-0.41	-0.56***
Growing livestock feed	1.04***	-0.04	0.78***
Index based livestock insurance	-0.56***	1.42***	1.6***
Drought resistant varieties	-0.35	-0.76***	-0.62***
Crop adaptation responses			
Adjusting planting and harvesting dates	-0.15	-1.11	-0.20
Water and soil conservation	0.26	-1.63	-3.8***
Early maturing varieties	-1.05***	-0.16***	-2.66
Other adaptation responses			
Borrowing from credit union	0.20	0.49***	0.56***
Using media	-.35	-0.53***	-0.03
Saving (crop seed, money)	1.14***	1.16***	0.91***

Receiving free support	0.81***	0.91***	0.2
Livelihoods Diversification	-0.05	-0.23***	-0.44***

Own survey computation (2023)

***, **, * are significant at 1 %, 5 %, and 10 %, respectively.

The pairwise correlation coefficients matrix, Table 4.4, shows that temperature perception is moderately correlated with rainfall perception and weakly correlated with drought perception. Rainfall perception and drought perception, on the other hand, exhibit a strong positive correlation. These findings imply that households' perceptions of temperature, rainfall, and drought are interconnected, with some degree of consistency in how they perceive these climate change variables. Hence, this test shows the appropriateness of the multivariate probit (MVP) model for modeling the interaction of climate variability perception and adaptation responses among pastoralist and agro-pastoralist communities.

Table 0.4: Pairwise correlation of climate change perceptions

Variables	Temperature perception	Rainfall perception	Drought perception
Temperature perception	1.00		
Rainfall perception	0.534***	1.00	
Drought perception	0.334**	0.7137***	1.00

***, **, * are significant at 1 %, 5 %, and 10 %, respectively

Own survey computation (2023)

4.4.4. Household Climate Variability Perceptions and Food Security

Table 4.5 shows the relationship between pastoral household climate variability perceptions (temperature increase perception, rainfall decrease perception, and drought frequency increase

perception) and the household dietary diversity score (HDDS). The analysis aims to understand how households' perceptions of climate change are associated with their dietary diversity.
Hence, among households that perceived drought increase, 47.1 percent have low, 30.9 percent medium, and 22.0 percent high HDDS. The chi-square test result ($\chi 2 = 5.61$, $p<0.05$)) suggests a statistically significant association between drought perception and household dietary diversity scores. Based on the results, households that perceived increased frequency of drought were more likely to have low dietary diversity scores compared to households that did not perceive drought increase. This suggests that increase in frequency of drought perception influence food security outcomes in pastoral households.

In addition, among households that did not perceive an increase in frequency of drought, the mean household dietary diversity score is 5.1 while that perceived higher levels of drought, the mean household dietary diversity score is 4.4. These mean estimations provide that households who did not perceive or experienced higher levels of drought have a higher mean dietary diversity score compared to households that perceived higher levels of drought experience.

Table 0.5: Pastoral household climate variability perceptions and Household Diet Diversity Score

Climate change perception		Household dietary diversity score			
		Low (%)	Medium (%)	High (%)	X^2
Temperature perception	Perceived	45.57	31.14	23.29	1.97
	Not perceived	36.36	27.27	36.36	
Rainfall perception	Perceived	45.90	30.6	23.50	0.84
	Not perceived	39.22	33.33	27.45	
Drought perception	Perceived	47.14	30.86	22.00	5.61**
	Not perceived	34.33	31.34	34.33	

** is significant at 5 %

Own survey computation (2023)

Table 4.6 illustrates the correlation between climate variability perceptions (specifically, perceptions of temperature increase, rainfall decrease, and drought increase) among pastoral and agro-pastoral households, and their level of food insecurity as measured by the Household Food Insecurity Access Scale (HFIAS). Notably, households that perceived a decrease in rainfall had an average HFIAS score of 15.03. The T-test results ($t=5.29$, $p<0.05$) indicate a statistically significant difference in HFIAS scores between households that perceived rainfall decrease and those that did not. Similarly, households that perceived higher levels of drought had an average HFIAS score of 14.86, with a significant difference ($t=6.78$, $p<0.01$) compared to households that did not perceive higher drought levels. There are significant differences in the scores based on rainfall perception and drought perception. Households that perceive higher rainfall levels and higher levels of drought tend to have higher mean household food insecurity access scale scores, indicating greater food insecurity. These findings highlight the potential impact of climate change perceptions on household food insecurity in pastoral communities.

Table 0.6: Results of Independent sample t-test for association between pastoral household climate variability perceptions and HFIAS

Climate variability perception	**Mean**		**Standard error**	**T-test**
Temperature perception	Perceived	14.8	4.28	1.77
	Not perceived	12.68	3.41	
Rainfall perception	Perceived	15.03	4.27	5.29**
	Not perceived	12.21[B2]	3.28	
Drought perception	Perceived	14.86	4.39	6.78***
	Not perceived	13.76	3.38	

*** and ** are significant at 1 % and 5 %, respectively

Own survey computation (2023)

4.4.5. Effect of adaptation responses on agro pastoralists, and pastoralists food security, Borena zone

Table 4.7 shows the impact of different climate variability adaptation responses on pastoral household food security. The T-test is used to assess the statistical significance of the adaptation responses to the effects of pastoralist and agro-pastoralist households' food insecurity (HFIAS). Hence, households that adopted growing livestock feed as an adaptation response have an average treatment effect (ATT) of 15.6 while the average treatment effect on the untreated (ATU) for non-adopters was 18.4 with a t-test result ($t = -2.8$, $p<0.01$). Similarly, adopters of feed storage as an adaptation response have an average treatment effect (ATT) of 14.1 while the average treatment effect on the untreated (ATU) was 22.4 with a t-test result ($t = -8.3$, $p<0.01$). This result indicates that growing livestock feed and feed storage as an adaptation response has reduced food insecurity, i.e., improved the food security of the pastoralist and agro-pastoralist households. Again, households that adopted soil and water conservation (SWC) measures as an adaptation response have an average treatment effect (ATT) of 14.2 while non-adopters have an average treatment effect on the untreated (ATU) of 23.8 with a t-test result ($t = -9.6$, $p<0.01$) that indicates adoption of SWC has reduced food insecurity, i.e., improved the food security of agro-pastoralist and pastoralist households. Also, households that adopted saving crop seed or money as an adaptation response have an average treatment effect (ATT) of 14.6 while non-adopters have an average treatment effect on the untreated (ATU) of 21.3 with a T-test result ($t = -6.7$, $p<0.01$) that indicates adoption of saving crop seed or money has reduced food insecurity, i.e., improved the food security of the households.

In addition, households that received free support as an adaptation response have an average treatment effect (ATT) of 14.7 while non-adopters have an average treatment effect on the untreated (ATU) of 21.7, with a T-test result ($t = -7.0$, $p<0.01$) that indicates receiving free support has reduced food insecurity, i.e., improved the food security of agro-pastoralist and pastoralist households. Besides, households that listen to mass media as an adaptation response have an average treatment effect (ATT) of 12.8 while non-adopters have an average treatment effect on the untreated (ATU) of 21.5 with a t-test result ($t = -8.7$, $p<0.01$) that indicates listening to mass media has reduced food insecurity, i.e., improved the food security of agro-pastoralist and pastoralist households. The analysis demonstrates that several climate variability adaptation responses have a significant impact on pastoral household food security. Adopters of feed storage, growing livestock feeds, soil and water conservation measures, saving crop seed, free support, and the use of media tend to have better food security outcomes compared to non-adopters. These findings highlight the importance of implementing and promoting these adaptation responses to enhance food security in pastoral communities facing climate variability challenges.

Table 0.7: Result of Endogenous Switching Regression model for effect of adaptation responses on agro pastoralists, and pastoralists food security, n=417

Adaptation responses	**Treatment effect**	**Decision stage**		**T-test**
		Adopter	Non-adopter	
Feed storage	ATT	14.1	22.4	-8.3***
	ATU	18.7	15.6	3.1***
Growing livestock feed	ATT	15.6	18.4	-2.8***
	ATU	16.3	14.2	2.1***
Soil and water conservation	ATT	14.2	23.8	-9.6***
	ATU	16.4	16.0	0.4**
Saving (crop seed, money)	ATT	14.6	21.3	-6.7***
	ATU	15.8	14.7	1.1***
Receiving free support	ATT	14.7	21.7	-7.0***
	ATU	20.9	14.6	6.3***
Use of medias	ATT	12.8	21.5	-8.7***
	ATU	16.0	15.0	1.0***

Source: Own survey computation (2023)

, and * Significant at 5%, and 1 % level of significance respectively

4.5. Discussions of findings

The results in general revealed that pastoralist and agro pastoralist in Borena strongly perceived climate variability through increase in temperature, decrease in rainfall, and increase in frequency of drought. Hence, they adopt livestock adaptation responses include feed storage, destocking practice, rainwater harvesting, haymaking or *dirkosh*, growing livestock feed, and participate in index-based livestock insurance. They also adopt crop adaptation responses including drought-resistant varieties (DRVs), planting early maturing varieties, adjusting planting, and harvesting dates, soil and water conservation (SWC) measures. Furthermore, they adopt other adaptation responses such as consuming stored food, borrowing from a credit union, using media, saving crop seed or money, receiving free support, and livelihood diversification (petty trade or daily labor).

The comparison of climate variability perceptions and adaptation responses among pastoral households revealed interesting insights. While most pastoral households demonstrated a strong understanding of climate variability and its impacts, there were variations in their perceptions based on socio-cultural contexts. These results were supported by the findings by Shibru et al., (2023) who reported the lack of consensus among stakeholders as to the causes and aggravating factors of these climate changes impede adaptation actions. This highlights the importance of incorporating local knowledge and indigenous practices in designing effective adaptation responses.

Hence, the adaptation responses employed by pastoral households were diverse and reflected their responses to climate variability challenges. The increase in temperature perception had a positive and statistically significant effect on the adoption of growing livestock feed, saving (crop seed, money), and receiving free support from NGOs and government. A decreasing trend of rainfall perception among pastoralist and agro-pastoralist communities increases the adoption adaptation responses such as feed storage, destocking practice, rainwater harvesting, haymaking or *dirkosh*, drought resistant varieties (DRVs), early maturing varieties, use of media, and livelihood diversification. An increase in drought frequency perception among pastoralists improves the adoption of Growing livestock feed, index-based livestock insurance**,** borrowing from credit union, and saving (crop seed, money). Livestock management, crop diversification, and water resource management emerged as key strategies. Similarly, the study by MacLeod, (2023) and Mekuyie & Mulu, (2021) supported our finding.

In terms of the effect of adaptation response on food security, growing livestock feed and feed storage as an adaptation response has reduced food insecurity, i.e., improved the food security of the pastoralist and agro-pastoralist households because fodder planting and rangeland restoration provide moderate increases in production and profit (MacLeod et al., 2023). Also, this finding supports MacLeod et al. (2023), who reported that growing feed not only improved food security but also reduced GHG emissions. Because of shortages of animal feed or pasture and outbreaks of livestock and crop diseases and pests, recently in 2021 livestock loss and crop failure in pastoral and agro-pastoral communities in Borena lead to severe food insecurity (Tofu et al., 2023b). Similarly, receiving free support from NGOs and Government has improved the food security of agro-pastoralist and pastoralist households. This finding is supported by Ng'ang'a et al., (2016) and Mekuyie et al., (2018) who reported that policies that support safety nets and market and infrastructural development has improved food security.

The findings have important implications for household food security in pastoral communities facing climate variability and the adoption of diverse adaptation responses was associated with improved food security outcomes that support the finding by Megersa et al., (2014). Livestock-based strategies helped maintain livestock productivity and reduced vulnerability to droughts, ensuring a stable source of food and income. Crop diversification strategies increased agricultural production and provided a wider range of food sources, enhancing dietary diversity and nutrition which supports the finding by Megersa et al., (2014). Water resource management strategies i.e. soil and water conservation measures, contributed to improved water availability for both livestock and crop production, which is essential for sustaining food production systems (Shigute et al., 2023). The integration of various adaptation responses together with supportive policies, institutions, and social networks is vital for building resilience and ensuring sustainable food security in the face of climate variability (Mekuyie, 2021; Tolera &Senbeta, 2020).

4.6.Conclusion and recommendations

4.6.1. Conclusion

In this study, we examined climate variability perceptions, adaptation responses, and their implications for household food security among pastoral households in the Borena Zone, Southern Ethiopia. Pastoralists and agro pastoralist in Borena strongly perceived climate variability through increase in temperature, decrease in rainfall, and increase in frequency of drought. They adopt livestock adaptation responses include feed storage, destocking practice, rainwater harvesting, haymaking or *dirkosh*, growing livestock feed, and participate in index-based livestock insurance. They also adopt crop adaptation responses including drought-resistant varieties (DRVs), planting early maturing varieties, adjusting planting, and harvesting dates, soil and water conservation (SWC) measures. Furthermore, they adopt other adaptation responses such as consuming stored food, borrowing from a credit union, using media, saving crop seed or money, receiving free support, and livelihood diversification (petty trade or daily labor).

The increase in temperature perception had a positive and statistically significant effect on the adoption of growing livestock feed, saving (crop seed, money), and receiving free support from NGOs and government ($p<.01$). A decreasing trend of rainfall perception among pastoralist and agro-pastoralist communities increases the adoption adaptation responses such as feed storage, destocking practice, rainwater harvesting, haymaking or *dirkosh*, drought resistant varieties (DRVs), early maturing varieties, use of media, and livelihood diversification. An increase in drought frequency perception among pastoralists improves the adoption of Growing livestock feed, index-based livestock insurance**,** borrowing from credit union, and saving (crop seed, money).

Adopters of growing livestock feeds, feed storage, soil and water conservation measures, saving crop seed, free support, and the use of media tend to have better food security outcomes compared to non-adopters. These findings highlight the importance of implementing and promoting these adaptation responses to enhance food security in pastoral communities facing climate variability challenges.

4.6.2. Recommendations

Considering the results, several policy suggestions can be made to improve food security and climate resilience for pastoral households:
Increase the accessibility and availability of extension programmes, support services, and climatic data that are suited to the requirements of pastoral communities. This will enable pastoral homesto respond to adaptations effectively and make well-informed decisions.Encourage neighbourhood-based projects and fortify social networks in pastoral areas.

Provide forums for information exchange, teamwork, and group initiatives. These can help adaption strategies become more widely known and used.

Provide financial tools like index-based insurance and others that give pastoral households access to credit and risk management resources, such as insurance policies and microfinance programmes. Such provisions enable the pastoralists and agro pastoralists to deal with shocks caused by climatic variability and invest in adaptation responses as a result.Promote water and land use that is sustainable and appropriate for the local setting.

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CHAPTER 5: DETERMINANTS AND PERCEIVED CLIMATE VARIABILITY ADAPTATION SUCCESSFULNESS OF PASTORAL, AND AGROPASTORAL HOUSEHOLDS IN BORENA ZONE, SOUTHERN ETHIOPIA

5.1. Abstract

The article identifies climate change adaptation response determinants and examines perceived adaptation successfulness among pastoral households in Borena zone of Southern Ethiopia. In this study a mixed research design was used. Different type of data was collected from 417 sample households selected using multistage sampling methods, key informants and focus group discussion participants. Descriptive statistics (e.g. mean, percentage) and econometrics analysis (e.g. multivariate probit model) were used to analyze quantitative data while content analysis was used for qualitative data. The study reveals that a combination of demographic, socio-economic, and environmental factors influence the adoption of these strategies. The analysis identifies variables such as education level, credit association membership, access to extension services, and climate change training as consistently significant factors associated with multiple adaptation strategies. This suggests that knowledge, resource accessibility, and skills development play crucial roles in enabling households to implement effective adaptation measures. Additionally, the results highlight the significance of gender in shaping adaptation strategies. The study also finds notable associations between market distance, life experience in the area, and certain adaptation strategies, suggesting that proximity to markets and local knowledge impact the feasibility and effectiveness of specific adaptation measures.The findings provide valuable insights into the complex factors that shape food insecurity adaptation strategies. This understanding enables policymakers, practitioners, and stakeholders to develop targeted interventions, programs, and policies that enhance resilience and reduce food insecurity in vulnerable populations.

Key words: adaptation strategies, Borena, pastoralists, agropastoral, climate variability, perceptions.

5.2. Introduction

Anthropogenic climate change is the dominant driver of observable global climate change over the past century (IPCC, 2021). Global average surface temperature has risen by about 1.1°C (2°F) since the late 19th century, with the past four decades being the warmest on record (NOAA, 2022). Temperature increase is causing a wide range of impacts across the globe inter alia, altering precipitation patterns worldwide, with some regions experiencing increases in heavy rainfall events and flooding, while others face more frequent and severe droughts (IPCC, 2021). In addition, shifts in the water cycle disrupt agricultural productivity, water supplies, and natural ecosystems. Hence, frequency and intensity of droughts has increased in the Mediterranean, Africa and northeastern Brazil in recent decades (Spinoni et al., 2019).

Sub Saharan Africa is one of the most vulnerable continents to the impacts of climate change due to its high exposure, low adaptive capacity, and dependence on climate-sensitive sectors like agriculture (IPCC, 2022). Average temperatures across Africa have increased by around 0.7°C over the past century, with more frequent and intense heat waves (Niang et al., 2014). Further warming of 2-6°C is projected by the end of the 21st century, depending on emissions pathways (IPCC, 2022). Trends show decreasing rainfall in parts of North and Southern Africa, while the Sahel region has experienced increased rainfall variability (Niang et al., 2014). Climate models indicate more intense wet and dry extremes, including droughts and flooding, with complex regional variations (IPCC, 2022). Crop yields, especially for staple foods like maize, millet, and sorghum, are projected to decline significantly due to the combined effects of higher temperatures, shifting rainfall, and increased pests/diseases (Schlenker & Lobell, 2010).

Ethiopia is considered one of the most vulnerable countries to the impacts of climate change in Africa due to its high dependence on climate-sensitive sectors like agriculture, limited adaptive capacity, and exposure to extreme weather events (IPCC, 2022). Average temperatures in Ethiopia have increased by about 1°C over the past century, with more frequent and intense heat waves (Conway & Schipper, 2011). Climate models project further warming of 1-5°C by the end of the 21st century, depending on emissions pathways (IPCC, 2022). Crop yields, especially for key staples like teff, maize, and sorghum, have declined due to the combined effects of rising temperatures, shifting rainfall, and increased pests/diseases (Deressa et al., 2011). Livestock productivity is also threatened by heat stress, water scarcity, and pasture degradation (Legesse et al., 2014). Food insecurity and malnutrition are major concerns, as 80% of the population relies on rain-fed subsistence farming (FDRE, 2019).

As climate change impacts continue to manifest around the world, the success of adaptation efforts has become an important area of research and evaluation. Numerous studies have examined the outcomes and effectiveness of various climate change adaptation strategies implemented at the local, national, and global levels (Degla et al., 2016; Gezie, 2019; Hilemelekot et al., 2021; Temesgen et al., 2014; Tofu et al., 2020). Factors contributing to successful adaptation include stakeholder engagement and collaboration, institutional and governance capacity, robust knowledge, and information, flexible and iterative approaches, and adequate and sustainable financing.

Research has identified several key factors that contribute to the successfulness of climate change adaptation efforts. Adaptation measures are more likely to succeed when they involve the active participation and buy-in of relevant stakeholders, including local communities, policymakers, the private sector, and civil society organizations (Shackleton et al., 2015; Ensor & Berger, 2009). Strong institutions, clear policy frameworks, and effective governance structures are critical for the successful planning, coordination, and implementation of adaptation interventions (Biesbroek et al., 2013; Oberlack, 2017). Adaptation efforts benefit from a solid understanding of local climate risks and vulnerabilities, as well as access to reliable data, tools, and scientific knowledge to inform decision-making (Lemos et al., 2012; Moser & Ekstrom, 2010). Adaptation strategies that are adaptable, flexible, and able to evolve based on changing conditions and new information tend to be more successful in the long run (Wise et al., 2014; Fazey et al., 2016). Sufficient and reliable financial resources are necessary to support the implementation, monitoring, and long-term maintenance of adaptation interventions (Paavola & Adger, 2006; Buchner et al., 2019).

Assessing the successfulness of climate change adaptation requires a conceptual framework that considers the multifaceted and context-dependent nature of these efforts. Several theoretical perspectives have been applied to analyze the factors influencing adaptation outcomes. These are vulnerability reduction framework, resilience-based frameworks, transformative change frameworks, process-oriented approaches, and outcome-based frameworks.

Vulnerability reduction framework evaluates adaptation success based on the extent to which interventions reduce the vulnerability of communities, ecosystems, or systems to climate change impacts. Key indicators include reduced exposure, sensitivity, and enhanced adaptive capacity (Eriksen & Kelly, 2007; Adger, 2006). Resilience theory emphasizes the ability of social-ecological systems to absorb change, self-organize, and adapt in the face of disturbances. Successful adaptation is assessed by improvements in system resilience, including diversity, modularity, and the capacity for learning and renewal (Folke, 2006; Berkes et al., 2003). Transformative change frameworks evaluate adaptation in terms of its potential to catalyze deeper, systemic changes in social, economic, and environmental systems. Successful adaptation is seen as facilitating fundamental shifts in values, behaviors, and institutional structures (Pelling, 2011; O'Brien, 2012). Process-oriented approaches focus on the quality of the adaptation process itself, including stakeholder engagement, institutional capacity, governance arrangements, and social learning. Success is determined by the robustness of these process-related factors (Moser & Ekstrom, 2010; Biesbroek et al., 2013). Outcome-based frameworks assess the tangible impacts and benefits of adaptation, such as improved food security, water access, disaster resilience, or ecosystem health. Success is measured directly against these concrete objectives (Adger et al., 2005; UNFCCC, 2010).

These different theoretical lenses offer complementary insights and can be used in combination to provide a more holistic understanding of adaptation successfulness. Successful adaptation is often a function of the interplay between these various factors, including vulnerability reduction, system resilience, transformative change, process quality, and tangible outcomes.

Based on the current literature on climate change adaptation, there appears to be a research gap in understanding the successfulness of adaptation efforts in lowland areas of Ethiopia. As much of the existing research on climate change adaptation in Ethiopia has focused on the highland and midland areas of the country, there is research gap on in lowland areas. However, there are a dearth of empirical studies that systematically evaluate the outcomes and success of adaptation interventions specifically in the lowland regions (Asfaw &Admassie, 2004; Deressa et al., 2009). Second, because of the unique socio-ecological context of lowlands there are lack of literature on factors like pastoralist livelihoods, water scarcity, and ecosystem fragility that create a unique context for adaptation and may require different approaches and indicators of success (Bekele, 2017; Aklilu & Alebachew, 2009). Third, there is lack of inadequate consideration of local knowledge and participation. Adaptation initiatives in the Ethiopian lowlands have often been top-down, with insufficient incorporation of local communities' traditional coping strategies and meaningful participation in the design and implementation of programs (Ayal et al., 2015; Debela et al., 2015). Fourth, there is lack of long-term monitoring and evaluation. There is a general paucity of longitudinal studies that track the long-term outcomes and sustainability of adaptation projects in the lowland regions. Most assessments have been snapshot evaluations without comprehensive monitoring frameworks (Gebrehiwot & van der Veen, 2013; Tesfahunegn et al., 2016). Finally, disconnect between adaptation and development priorities. Adaptation efforts in the Ethiopian lowlands are often not well integrated with the broader development agenda and priorities of these marginalized regions. This disconnection can undermine the effectiveness and scalability of adaptation interventions (Asfaw &Admassie, 2004; Deressa et al., 2009). Addressing these research gaps through in-depth, context-specific studies in the Ethiopian lowlands could provide valuable insights to identify the determinants of successfulness of climate change adaptation in Borena area and there by improve them. Therefore, this paper will examine the determinants of perceived climate change adaptation successfulness in Borena, Southern Ethiopia.

5.3. Materials and methods

5.3.1. Data Sources and Research Design

The research design for the study on determinants and perceived climate variability adaptation successfulness of pastoral and agro-pastoralist households in Borena Zone, Ethiopia involved a mixed-method approach. Firstly, a cross-sectional survey was conducted to collect quantitative data from a representative sample of pastoral and agro-pastoralist households in the study area.

The survey included questions related to household demographics, socio-economic characteristics, climate variability adaptation strategies, and perceived success of these adaptation efforts. Additionally, qualitative data were gathered through in-depth interviews and focus group discussions with key informants and community members to gain a deeper understanding of the determinants influencing climate adaptation success. The combination of quantitative and qualitative data has provided a comprehensive understanding of the factors impacting climate variability adaptation success among pastoral and agro-pastoralist households in Borena Zone, Ethiopia.

5.3.2. Sampling technique and sample size determination

The study used a multi-stage sampling technique to select the sample. The target population for this study was the pastoral and agro-pastoral households in the Borena zone, Ethiopia.The sample frame was the list of all households in the selected districts (woredas) of Borena zone. The Borena zone was selected due to vulnerability of climate variability, and low implementation of adaptation strategies, and coping response, and high food insecurity level. In the first stage, four districts were selected with purposive sampling technique. At the second stage, sample kebeles were selected using simple random sampling. In the third stage, representative sample households were selected using stratifies sampling technique. The sample size determination and non-response bias were critical considerations for the quantitative survey. The sample size was determined using Cochran’s (1977) formula, which is widely used when there is a large population and when the study requires accurate variability and heterogeneity of the population.

$$n = \frac{z^2pq}{e^2}$$

n = required sample size

Z = standard normal value which is 1.96 for 95% confidence interval (5% significance level)

p = estimated proportion of population (maximum variability) (0.5)

q = (1-p) or estimated proportion of failure

e = the desired level of precision (0.05)

Therefore, the estimated sample size yield 384 household heads. The final sample size was 417 by considering the 10% non-response rate.

5.3.3. Data collection: tools and procedure

Primary data were collected from pastoral and agro-pastoral households using structured questionnaires. The survey gathered information on household demographics, socio-economic characteristics, climate variability adaptation strategies, and perceived success of these adaptation efforts. In addition to the surveys, qualitative data was collected through in-depth interviews and focus group discussions (FGDs) with key informants (KIIs) and community members. For FGD, a total of 12 heterogeneous FGD participants were selected, representing a broad cross-section of the pastoral and agro-pastoral communities. In addition, 12 key informants, and 2 case studies were conducted. Thus, quantitative, and qualitative data provided a comprehensive understanding of the determinants and perceived successfulness of climate variability adaptation among pastoral and agro-pastoralist households. In addition, secondary data were collected from reports of the Borena Zone office, farmers' cooperative, central statistical agency (CSA), and published and unpublished documents. Finally, experienced enumerators were recruited and trained to collect data from the sample households.

5.3.4. Method of data analysis

The data were analyzed using STATA version 17 statistical software. Descriptive statistics, and econometrics analysis were used to analyze quantitative data while content analysis was used to analyze qualitative data. The frequency and percentage of perceived adaptation successfulness were portrayed. Thematic content analysis was used to identify recurring patterns and themes in the qualitative data, complementing the quantitative findings to offer a comprehensive understanding of the research focus.

After collecting the qualitative data, it was transcribed and organized, followed by the identification of key emerging themes and patterns. Subsequently, the data was coded to categorize and label it according to the identified themes and patterns. A coding framework or codebook outlining the categories, subcategories, and definitions used for coding the data was then created, followed by an analysis examining the frequency and distribution of different themes and patterns.

Econometrics analysis

In this study econometric analysis was applied to examine the determinants and perceived climate variability adaptation successfulness. The dependent variable of this study is a binary variable indicating perceived climate change adaptation successfulness i.e. successful=1; not successful=0. To identify the determinants and perceived climate variability adaptation successfulness a multivariate probit model was applied.

The multivariate probit model is a statistical model that is used to estimate several correlated binary outcomes jointly (Greene, 2012). The multivariate probit model was justified for researching the perceived climate variability adaptation successfulness due to its ability to analyze multiple correlated dependent variables simultaneously. This model allows for the examination of the complex relationships between various aspects of perceived climate variability adaptation successfulness and providing a more comprehensive understanding of the interplay between these factors. Compared to other possible models, the multivariate probit model offers the advantage of capturing the joint distribution of the dependent variables, which is essential for studying the interconnected nature of perceived climate variability adaptation successfulness.

The MVP econometric model is characterized by a set of binary dependent variables (Y_{ij}), such that:

$Y_{ij}^{*} = \beta_i{}' X_{ij} + \varepsilon_{ij}$, --(2)

And

$Y_{ij} = \{1,\ if Y_{ij}^{*} > 0 0,\ otherwise$ ---(3)

Where i=1,2 denotes perceived climate variability adaptation successfulness for food insecurity such as 1= risk sharing and 2= on weather information. Whereas for perceived climate variability adaptation successfulness, wherei=1, 2,8, denotes 1=veterinary service, 2=water harvesting;3=feed conservation;4=seasonal migration;5=modern forecast info precision;6=extended search for feed; 7=destocking, and 8=receiving government aid

The Eq. (2) assumption is that a rational j^{th} household has a latent variable, Y*ij, which captures the unobserved preferences derived from the i-th perceived climate variability adaptation successfulness. This latent variable is assumed to be a linear combination of copying responses of climate variability (Xij), as well as unobserved characteristics captured by the stochastic error term εij. The vector of parameters to be estimated is denoted by βi. Given the latent nature of Y*ij, the estimations are based on observable binary discrete variables Yij, which indicate whether pastoral and agro pastoral households have the i-th perceived climate variability adaptation successfulness. If the specific perceived climate variability adaptation successfulness is independent of another perceived climate variability adaptation successfulness, then Eqs. (2) and (3) specify univariate probit models where information on pastoral and agro pastoral household perceived climate variability adaptation successfulness does not alter the prediction of the probability that they have another perceived climate variability adaptation successfulness. Since we assumed that a pastoral and agro pastoral household have multiple perceived climate variability adaptation successfulness, the error terms in Eq. (2) jointly follow a multivariate normal (MVN) distribution, with 0 conditional mean and variance normalized to 1. Where ($\rho 1$,$\rho 2$,$\rho 3$) distributed MVN (0, Ω″) and the symmetric variance-covariance matrix ″ is given by:

$$\Omega = [1 \rho_{12} \rho_{13} \rho_{21} 1 \rho_{23} \rho_{31} \rho_{32} 1] \text{--(4)}$$

where (ρ_{im}) denotes the pairwise correlation coefficient of the error terms corresponding to any two perceived effects climate variability equations to be estimated in the model.

The off-diagonal elements in the covariance matrix, ρ_{im} which represent the unobserved correlation between the stochastic component of the i^{th} and m^{th} perceived climate variability adaptation successfulness, are important. This assumption means that Eq. (3) tests whether an MVP model was appropriate for the analysis or the univariate probit model suffices for the analysis.

To determine the effect of independent variables on perceived climate variability adaptation successfulness against socio-economic and institutional variables, the final analysis contains marginal effect analysis results based on Eq (5) (Greene, 2012). Therefore, the marginal effect of socio-economic and institutional variables (X_{ij}) was calculated because marginal effects measure the effects that a specific socio-economic and institutional variable has on the perceived climate variability adaptation successfulness of pastoral and agro pastoral households while all other variables are held constant.

Marginal Effect of X_{ij} = Pr (Y_i = 1|X, X_{ij} = 1) – Pr (Y_i=1|X, X_{ij} = 0) -------------------------------- (5)

5.4. Results

The survey result showed that most of pastoralist and agro pastoralist rate their adaptation successful except destocking. The success rate for veterinary services was 55.0%, indicating that more than half of the households reported that veterinary services has assisted in successfully adapting to climate change. As access to veterinary services is vital for the health and well-being of livestock, which are the primary assets for pastoralists and agro-pastoralists, the high success rate suggests that effective veterinary services have played a significant role in supporting livestock health and adaptation when facing climate variability.

Water scarcity is a major challenge in arid and semi-arid regions, making water harvesting technology critical. It has a success rate of 45.0%, suggesting that there is room for improvement in the effectiveness of water harvesting technologies in these contexts. Enhancing water availability and management through improved technologies can contribute to successful adaptation in the face of water scarcity.

The success rate for feed conservation and storing practices is particularly relevant in the context of pastoralism and agro-pastoralism, where access to adequate and nutritious animal feed can be limited. Hence, a higher success rate of 71.0% implies effective feed conservation and storage practices have positively contributed to the adaptation of livestock rearing, ensuring availability of feed during lean periods and improving overall resilience.

Seasonal migration is a common adaptive strategy employed by pastoralists and agro-pastoralists to cope with the variability of resources across different regions and seasons. A success rate of 69.0% showed that seasonal migration has been an effective adaptation strategy in these contexts. By moving livestock to areas with better forage and water availability, pastoralists and agro-pastoralists can optimize their livestock production and reduce their vulnerability to resource scarcity due to the impact of climate change.

Accurate and timely weather forecasts are crucial for pastoralists and agro-pastoralists to make informed decisions regarding resource management and livestock mobility. A notable success rate of 73.0% for modern forecast information precision indicates that access to reliable forecast information has played a significant role in successful adaptation, enabling pastoralists and agro-pastoralists to anticipate and respond to climatic variations effectively.

Extended search for feed is particularly relevant in the pastoralist and agro-pastoralist context, where forage availability can be limited. An impressive success rate of 81.0% for this variable, suggesting that the efforts invested in finding alternative sources of feed have yielded positive results. The practice of actively seeking out additional feed resources has contributed to successful adaptation, ensuring adequate nutrition for livestock and maintaining their productivity even during resource-scarce periods.

Destocking, which involves reducing livestock numbers during periods of resource scarcity, is an important adaptive strategy for pastoralists and agro-pastoralists. Surprisingly, the data shows a lower success rate of 27.0% for destocking indicates that the effectiveness of destocking as an adaptation strategy could be limited in these contexts. Alternative approaches, such as targeted off-take programs or market-based interventions, might need to be explored to improve the outcomes of destocking practices (table 5.1).

In the pastoralist and agro-pastoralist context, government support and assistance programs play a crucial role in enhancing adaptation and resilience. The data reveals a success rate of 62.0% for receiving aid from the government, indicating that such support has been effective in facilitating successful adaptation. Government interventions, including financial assistance, provision of veterinary services, and infrastructure development, have contributed to improved livelihoods and adaptive capacity in these systems.

The findings highlight the importance of veterinary services, feed conservation and storage, seasonal migration, access to accurate forecast information, and the active search for alternative feed sources. However, there is room for improvement in water harvesting technologies, destocking practices, and further enhancing government support. These insights can guide policymakers, practitioners, and communities in formulating targeted interventions to strengthen adaptive capacity and resilience in pastoralist and agro-pastoralist contexts.

Table 0.1: Perceived climate variability adaptation successfulness, Borena Zone (N=417)

Variables	**Adaptation successfulness**	
	Not Successful (%)	**Successful (%)**
Veterinary service	45.0	55.0
Water harvesting technology	55.0	45.0
Feed conservation and storing	29.0	71.0
Seasonal migration	31.0	69.0
Modern forecast info precise	27.0	73.0
Extended search for feed	19.0	81.0
Destocking	73.0	27.0
Receiving aid government	38.0	62.0

Source: own computation (2023)

In the pastoralist and agro-pastoralist context, several variables play a crucial role in shaping the livelihoods and adaptation strategies of the communities involved such as the socioeconomic characteristics and access to resources among the population. The mean age of the heads of households or key decision-makers is 44.40 years. This indicates that the responsibility for managing the livelihoods and making important decisions falls on individuals who have accumulated significant life experience. The age factor is important as it influences the knowledge, skills, and decision-making capacity within the community.

The mean income of 1431.26 Birr reflects the economic situation of the population. It provides an understanding of the financial resources available to the households and their capacity to invest in productive activities, purchase necessary inputs, and withstand economic shocks. The income level is closely linked to the success and resilience of pastoralist and agro-pastoralist livelihoods.

Market distance, with a mean of 10.19 kilometers, is a critical factor in accessing and participating in economic activities. The proximity to markets affects the availability and affordability of goods and services, as well as the opportunities for selling agricultural products or acquiring necessary inputs. The longer the market distance, the greater the challenges faced by the community in engaging in trade and accessing a variety of resources.

Household size, with a mean of 6.51 adult equivalents, provides insights into the size and composition of households. It helps determine the labor force available for agricultural activities and the division of responsibilities within the family. The larger the household size, the greater the need for resources, including land, water, and food, to sustain the livelihoods of all household members.

Land size, with a mean of 1.82 hectares, is a critical resource for pastoralists and agro-pastoralists. It represents the average amount of land available for cultivation or livestock rearing per household. The land size directly impacts the productivity and sustainability of agricultural activities, as well as the resilience of the community to external shocks and resource scarcity.

The gender distribution among the heads of households reveals that 51.80% are male, while 48.20% are female. This highlights the importance of considering gender dynamics and ensuring equitable participation and decision-making in the context of pastoralism and agro-pastoralism. Gender-sensitive approaches can facilitate the empowerment of women and promote inclusive and sustainable development.

Education levels within the population indicate that a significant proportion, 77.22%, has no formal education. This highlights the need for targeted interventions to improve access to education and promote literacy and numeracy skills among the population. Education plays a crucial role in enhancing livelihood opportunities, improving resilience, and enabling communities to adapt to changing circumstances.

Access to climate change training, with 45.32% of the population having access, signifies the importance of building knowledge and capacity to understand and respond to the challenges posed by climate change. Training programs can equip individuals with the skills and information necessary to adopt climate-smart practices, mitigate risks, and adapt their livelihood strategies to changing environmental conditions.

Access to weather information, with 75.30% of the population having access, is a valuable resource for agricultural planning and decision-making. Timely and accurate weather forecasts enable individuals to adjust their farming practices, anticipate climatic variations, and make informed choices regarding crop cultivation, water management, and livestock rearing.

Credit access, with only 32.61% of the population having access to credit, points to the need for expanding financial services in pastoralist and agro-pastoralist contexts. Access to credit can facilitate investment in productive assets, diversification of income sources, and the adoption of innovative practices. Improving financial inclusion is crucial for enhancing economic resilience and reducing vulnerability.

The engagement in off-farm and non-farm activities by 63.07% of the population highlights the diversification of livelihood strategies beyond traditional agriculture. This broader economic participation can provide additional income streams, reduce dependence on environmental resources, and enhance the overall adaptive capacity of the community.

Access to extension services by 42.21% of the population signifies the importance of technical support and knowledge dissemination in improving agricultural practices (table 5.2). Extension services play a vital role in disseminating information, introducing new technologies, and providing guidance to enhance productivity, natural resource management, and adaptation to changing conditions.

In conclusion, the analysis of socioeconomic characteristics and access to resources among pastoralist and agro-pastoralist communities provides valuable insights into the factors that shape their livelihoods and adaptation strategies. These findings can inform policymakers, development practitioners, and researchers in designing targeted interventions, policies, and investments to address the specific needs and challenges faced by these communities. By recognizing the importance of factors such as age, income, market proximity, land size, education, gender, access to climate information, credit, off-farm opportunities, and extension services, stakeholders can work towards promoting sustainable and resilient livelihoods in pastoralist and agro-pastoralist contexts.

Table 0.2: Description of demographic, socioeconomic and institutional variables

Variables	**Category**	**Mean/Percent**
Age of head (year)		44.40
Income (Birr)		1431.26
Market distance (Km)		10.19
Household size (adult equivalent)		6.51
Land size (hectare)		1.82
Life experience (year)		34.34
Sex of head	Male	51.80
	Female	48.20
Education level	No formal education	77.22
	Primary education	18.94
	High school & preparatory	2.88
	Above diploma	0.96
Access to climate change training	Yes	45.32
	No	54.68
Access to weather information	Yes	75.30
	No	24.70
Credit access	Yes	32.61
	No	67.39
Off- farm/non-farm	Yes	63.07
	No	36.93
Extension services	Yes	42.21
	No	57.79

Source: own computation (2023)

Table 5.3 shows that in the risk sharing model; age, household size, monthly income, and climate change training significantly affect risk sharing adaptation response on food security. Household size shows a negative relationship, implying that larger household sizes are associated with lower adaptation successfulness in addressing food insecurity ($p<.05$). Monthly income has positive coefficients, suggesting that higher income levels and access to climate change training are associated with greater adaptation successfulness ($p<.05$).

Whereas in the weather information model; education level, credit association membership, climate change training, and weather information have positive coefficients, indicating that higher education levels, membership to credit association, access to climate change training, and weather information are associated with higher adaptation successfulness while market distance, shows a negative relationship, suggesting that increased distance to markets is associated with lower adaptation successfulness.

Table 0.3: Results of Multivariate Probit model (MVP) of adaptation successfulness for food insecurity, Borena Zone

Variables	Risk sharing	Weather information
Age	0.01^{*}(0.01)	0.01(0.01)
Sex of household head	0.29(0.18)	-0.20(0.15)
Household size	-0.09^{**}(0.05)	0.05(0.04)
Education level	0.01(0.08)	0.36^{***}(0.08)
Monthly income	0.001^{***}(0.00)	0.001^{*}(0.00)
Credit access	0.06(0.18)	0.09(0.16)
Credit ass. membership	0.30(0.18)	0.64^{***}(0.16)
Access to extension services	-0.13(0.18)	-0.08(0.15)
Market distance	0.02(0.02)	-0.03^{**}(0.01)
Life experience in the area	-0.01(0.01)	-0.00(0.01)
Climate change training	0.23(0.18)	0.32^{**}(0.15)
Access to weather information	0.15(0.19)	0.32^{*}(0.18)

Constant	-0.18(0.64)	-1.57^{***}(0.57)

Source: Authors calculation (2023)

***, **, * are significant at 1 %, 5 %, and 10 %, respectively.

The multivariate Probit model results provide insights into the factors associated with different strategies related to food insecurity adaptation (table 5.4). These strategies include variables such as veterinary service, water harvesting, feed conservation, seasonal migration, modern forecast information precision, and extended search for feed, destocking, and receiving aid from the government.

For the veterinary service adaption strategy, the analysis shows that household size has positive significant association while membership to credit association and climate change training have negative significant association. This suggests that household size significantly influence successfulness rating of veterinary services while credit association and climate change training negatively affect successfulness rating. This shows the trainings given did not emphasize about the veterinary service to their livestock. On the other hand, the money they get from the credit union is used for other purposes or they have lost most of their livestock due to drought.

On the other hand, the water harvesting adaptation strategy is influenced by several variables. The age, monthly income, credit association membership, access to extension services, and climate change training have varying degrees of significance. Specifically, variables such as credit association membership and access to extension services more likely to rate water harvesting as a successful adaptation strategy.

Similarly, for the feed conservation strategy, age, education level, monthly income, access to extension services, market distance, life experience in the area, and climate change training have influence on adoption of feed conservation. Notably, variables such as age, education level, monthly income, market distance, and climate change training have significant positive associations with feed conservation. Life experience in the area, on the other hand, has negative associations with this strategy.

The seasonal migration adaptation strategy is significantly associated with the sex of the household head, education level, monthly income, credit association membership, market distance, and life experience in the area. Variables such as the sex of the household head, monthly income, market distance, and life experience in the area positive associations with seasonal migration while education level and credit association membership have negative association with seasonal migration. This suggests that pastoralist households with certain characteristics (male, high monthly income, far from market, and longer stay in the area) are more likely to rate seasonal migration as a successful adaptation strategy.

Regarding modern forecast information as an adaptation strategy, variables such as age, education level, monthly income, credit association membership, life experience in the area, and climate change training, have varying degrees of significance. Education level, monthly income, credit association membership, life experience and climate change training show positive associations with modern forecast information precision, indicating that better education and training increase the likelihood of rating of modern forecast information as a successful adaptation strategy.

Regarding extended search for feed, variables such as sex, household size, monthly income, market distance, and life experience in the area have varying degrees of significance. Sex, household size, monthly income, and market distance has positive associations with extended search for feed, indicating that household heads with characteristics such as male, large household size, better monthly income, and far from market increase the likelihood of rating of extended search for feed as a successful adaptation strategy while staying in the area longer associated with extended search for feed as unsuccessful adaptation strategy.

Regarding destocking, variables such as monthly income, credit association membership, and life experience in the area have varying degrees of significance. Monthly income, credit association membership, and life experience in the area have positive associations with destocking indicating that household heads with better monthly income, members of credit association and staying longer in the area are likely to rate destocking as a successful adaptation strategy.

Regarding receiving government aid as adaptation strategy is significantly associated with the age, sex of the household head, education level, monthly income, credit association membership, life experience in the area, and access to weather information. Variables such as age, education level, monthly income, and access to weather information have positive associations with receiving government aid indicating that household heads with old age, relatively educated, better monthly income, better access to weather information are likely to rate receiving government aid as a successful adaptation strategy. On the other hand, sex, credit association membership, and life experience in the area have negative association with receiving government aid indicating that male household heads, not member credit association, and staying longer in the area are likely to rate receiving government aid as an unsuccessful adaptation strategy.

Table 0.4: Multivariate Probit model result of adaptation successfulness for climate variability, Borena Zone

Variables	**Veterinary service**	**Water harvesting**	**Feed conservation**	**Seasonal migration**	**Modern weather forecast for precise info**	**Extended search for feed**	**Destocking**	**Receiving government aid**
Age	0.00(0.01)	0.01^{*}(0.01)	0.02^{***}(0.01)	-0.01(0.01)	-0.02^{***}(0.01)	0.01(0.01)	-0.01(0.01)	0.01^{**}(0.01)
Sex of household head	-0.03(0.14)	0.20(0.14)	-0.20(0.15)	0.49^{***}(0.15)	0.04(0.14)	0.32^{**}(0.16)	-0.03(0.15)	-0.40^{***}(0.14)
Household size	0.06^{*}(0.04)	0.01(0.04)	0.05(0.04)	0.02(0.04)	0.01(0.04)	0.07^{*}(0.04)	0.01(0.04)	0.05(0.04)
Education level	0.02(0.06)	0.08(0.06)	0.15^{**}(0.06)	-0.13^{**}(0.06)	0.10^{*}(0.06)	-0.08(0.06)	0.08(0.06)	0.16^{***}(0.06)
Monthly income	0.001 (0.01)	0.001^{*}(0.001)	0.001^{***}(0.00)	0.001^{**} (0.001)	0.001(0.001)	0.001^{**}(0.001)	0.001^{***}(0.001)	0.001^{*}(0.001)
Credit access	-0.08(0.14)	-0.08(0.15)	-0.16(0.15)	0.09(0.15)	0.09(0.14)	0.07(0.16)	0.09(0.15)	0.07(0.14)
Credit ass. Membership	-0.79^{***}(0.14)	0.81^{***}(0.14)	0.16(0.16)	-0.51^{***}(0.15)	0.58^{***}(0.14)	-0.15(0.17)	0.40^{***}(0.15)	-0.65^{***}(0.15)
Access to extn. Services	-0.02(0.14)	0.45^{***}(0.14)	0.42^{***}(0.16)	-0.03(0.14)	0.07(0.14)	0.00(0.16)	0.19(0.14)	0.11(0.14)
Market distance	0.02(0.01)	0.02(0.01)	0.03^{**}(0.01)	0.04^{***}(0.01)	-0.00(0.01)	0.05^{***}(0.01)	-0.02(0.01)	0.00(0.01)
Life experience in the area	-0.00(0.00)	-0.00(0.00)	-0.01^{***}(0.01)	0.01^{***}(0.00)	0.03^{***}(0.01)	-0.01^{**}(0.01)	0.02^{***}(0.00)	-0.02^{***}(0.00)
Climate change training	-0.24^{*}(0.13)	0.35^{**}(0.14)	0.41^{***}(0.15)	-0.19(0.14)	0.23^{*}(0.14)	-0.00(0.15)	-0.03(0.14)	0.08(0.13)
Access to weather info	0.19(0.15)	0.23(0.16)	-0.00(0.17)	0.21(0.16)	-0.11(0.15)	0.08(0.17)	0.01(0.17)	0.28^{*}(0.14)
Constant	1.06^{**}(0.51)	-3.63^{***}(0.56)	-2.48^{***}(0.58)	0.25(0.53)	-2.37^{***}(0.52)	-0.30(0.55)	-2.45^{***}(0.55)	0.01(0.49)

Source: Authors calculation (2023)

***, **, * are significant at 1 %, 5 %, and 10 %, respectively

5.5. Discussions

The findings from the multivariate probit model emphasize the importance of considering multiple factors that influence perceived climate variability adaptation successfulness of different adaptation strategies.

Regarding veterinary service as an adaptation strategy, previous research has highlighted the importance of access to veterinary care and its impact on livestock health and productivity while this study focuses on the perceived successfulness of veterinary service in pastoralist areas. The current study's findings suggest that the perceived success of veterinary services is influenced by household size, credit association membership, and climate change training. A study conducted by Gizaw et al., (2021) concluded that use of and satisfaction with animal health services significantly varied across livestock production systems, geographic locations, socioeconomic strata, and service providers. Specifically, satisfaction with veterinary services is determined by availability and accessibility of the services.

Water harvesting has been recognized as an important adaptation strategy to cope with water scarcity in arid and semi-arid regions. The current study's results align with previous research that highlights the significance of factors such as income, access to extension services, and credit association membership in promoting the successful implementation of water harvesting practices. For instance, a study by Muriu-Ng'ang'a et al., (2017) conducted in Kenya found that age, household size, farm size, farming history, training, and formal education were important factors which influenced successfulness of rainwater harvesting. Water harvesting systems offer technical and institutional options for climate change adaptation in agriculture. Water harvesting technologies have also been explored as a means of enhancing water availability for agricultural purposes (Balderama, 2015).

Feed conservation is another critical strategy for addressing food insecurity among the pastoralist communities. Previous study by Tegegne et al. (2016) have shown that factors such as education, income, and access to extension services play a vital role in the adoption of feed conservation practices. The current study's findings are consistent with this literature, indicating that age, education level, income, market distance, and climate change training positively influence the adoption and perceived success of feed conservation strategies. These results suggest that targeted educational programs, improved income opportunities, and better access to extension services can enhance the effectiveness of feed conservation practices.

Seasonal migration is a common adaptation strategy employed by pastoralist communities to cope with resource fluctuations. Previous studies have examined the factors associated with seasonal migration decisions and success. Pastoralists rely on the movement of their livestock to access grazing lands and water sources that vary in availability throughout the year. This strategy allows them to optimize resource utilization and ensure the survival and well-being of their herds. Seasonal migration is crucial for pastoralists as it enables them to access fresh grazing lands and water sources during different seasons. This strategy helps them cope with resource fluctuations, such as changes in rainfall patterns and the availability of forage (Tugjamba et al., 2023).

Moreover, the key informant interview suggests that gender-sensitive policies, educational opportunities, peaceful environment, and improved market infrastructure can support successful seasonal migration strategies.

Precision of modern weather forecast has gained attention as a valuable tool for climate change adaptation. There is strong need for improved forecast accuracy, capacity building, and effective communication to enhance adaptation efforts in Ethiopia (Belay et al., 2021). Focus group discussion revealed, most of the community members rely on traditional weather forecasting methods which needs to further integrate with the modern forecasting methods to further increase the precision of the system. These findings highlight the need for targeted capacity-building on integration of the modern and traditional weather forecasting, use of media, and improved access to accurate and timely weather information.

The extended search for feed is a strategy employed by pastoralist communities to mitigate the impacts of resource scarcity. Pastoralist communities often employ extended search for feed as a strategy to mitigate the impacts of resource scarcity. This strategy involves actively seeking out alternative sources of forage for their livestock when their usual grazing areas become depleted or inaccessible. By expanding their search for feed, pastoralists aim to ensure the survival and well-being of their livestock during periods of resource scarcity.

Changes in climate patterns, including prolonged droughts and erratic rainfall, have a significant impact on forage availability. Pastoralists are forced to search for extended forage options to cope with the changing climate conditions. Limited access to markets and low prices for livestock products can discourage pastoralists from selling their animals. This can lead to extended forage search as they try to maintain their livestock's condition and productivity (Mohamed et al., 2020).

Destocking is an adaptation strategy employed during periods of resource scarcity to reduce the burden on livestock and manage available resources more efficiently. Previous studies have examined the factors influencing destocking decisions and outcomes. The current study's findings align with existing literature, which indicated that various socioeconomic factors influence destocking decisions. These include the influence of different factors such as drought severity, socioeconomic characteristics, household size, cattle loss, and market price on destocking decisions (Nketiah& Ntuli, 2024).

According to a study by Catley et al., (2013), government support through social protection programs, safety nets, and livestock-related interventions can enhance the resilience of pastoralists and help them cope with shocks such as droughts or conflicts. These programs provide essential resources, such as food assistance, cash transfers, veterinary services, and livestock insurance, which help protect pastoralists' assets and support their livelihoods during challenging times. According to the discussion with the key informants, it is important to emphasize that perceived success could not always align with actual success in receiving government aid. Factors such as the eligibility criteria, documentation requirements, availability of resources, and the overall efficiency and transparency of the aid system can significantly influence an individual's ability to receive assistance.

5.6. Conclusion and implication

The analysis reveals that the adoption of specific strategies is influenced by a combination of demographic, socio-economic, and environmental factors.The findings indicate that variables such as education level, credit association membership, access to extension services, and climate change training consistently show significant associations with multiple adaptation strategies. This suggests that knowledge, access to resources, and skills development play a crucial role in enabling households to implement effective adaptation measures.Additionally, the results highlight the importance of gender in shaping adaptation strategies. The sex of the household head emerges as a significant factor for certain strategies, indicating that gender dynamics and social norms can influence decision-making processes related to food insecurity adaptation.Market distance and life experience in the area also demonstrate notable associations with some strategies. These findings suggest that proximity to markets and knowledge of local conditions can impact the feasibility and effectiveness of certain adaptation measures.It is worth noting that the significance and direction of associations vary across different strategies, indicating the contextual nature of food insecurity and adaptation. Therefore, tailored sustainable interventions and policies that consider the specific circumstances and needs of different regions and communities are crucial for promoting effective and sustainable adaptation.Overall, the multivariate probit model provides valuable insights into the complex factors that shape food insecurity adaptation strategies. By understanding these associations, policymakers, practitioners, and stakeholders can develop targeted interventions, programs, and policies to enhance resilience and reduce food insecurity in vulnerable populations. Further research and monitoring are essential to continually refine and improve our understanding of the dynamics of food insecurity and adaptation in a changing world.

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CHAPTER 6: SYNTHESIS, CONTRIBUTIONS TO NEW KNOWLEDGE AND FUTURE RESEARCH AREAS

6.1. Synthesis

The dissertation is divided into six main sections. The first chapter is the general introduction which includes the background, statement of the problem, objectives, description of the research area, methodology, theoretical underpinnings, and other topics. The final one deals with synthesis and suggestions for future areas of research. The subsequent four chapters contain the four manuscripts that were developed to better understand the meteorological hazards in Borena pastoralists, Ethiopia: causes and impacts on food Security, and disaster risk management strategy. The first piece discusses the variability of rainfall across space and time, how it relates to large-scale climate oscillations, and how it affects the food security of pastoral households. The impact of perceived climate variability on household food security and coping strategies is covered in the second manuscript. The perceptions of climate variability and the adaptation strategy to ensure household food security are covered in the third manuscript. The fourth manuscript examines the factors and perceived effectiveness of pastoral and agropastoral households' adaptation to climatic variability. Overall, the four manuscripts provide insights into the impact of climate variability on household food security, the coping responses employed by households, and the determinants and effectiveness of adaptive measures. Besides, the manuscripts alsofocus on the perceptions of climate change, the adaptive measures taken by the community, and the resulting impact on food security.

The study employed a dual-pronged theoretical approach, leveraging both the Psychological Dimensions of Climate Change model and the Sustainable Livelihoods framework, to examine the multifaceted impacts of climate change.

The Psychological Dimensions of Climate Change model was used to delve into the psychological aspects of climate change, providing insights into how individuals and communities perceive, relate to, and respond to the causes and effects of climate variability. This helped to guide and enhance existing adaptation strategies by acknowledging the important role of human psychology in shaping climate change responses.

Concurrently, the researcher applied a sustainable livelihoods modeling approach to investigate the potential effects of climate variability on pastoralist communities. This involved exploring the perspectives, experiences, and adaptation strategies developed by pastoralists to maintain food security amidst a changing climate.

By integrating these complementary theoretical lenses, the study was able to generate a more holistic understanding of the complex interplay between the psychological, social, and livelihood dimensions of climate change. This multidimensional approach enabled the researcher to uncover insights that can inform the design and implementation of more effective, context-appropriate climate change adaptation and mitigation initiatives.

Herein, a concise synopsis of the principal discoveries of this investigation is provided, delineating the four research inquiries identified during the study.

The first manuscript assesses the geographical and temporal trends of extremes in temperature and precipitation in the Borena zone between 1981 and 2020. The findings show a marked increase in extreme temperatures over time, except for cool days and nights, which worsen the local warming scenario. Furthermore, the research indicates a marginal increase in certain extreme indices, such days with no rain, but a decline in others. Regional climates can be influenced by large-scale climate indices, according to an analysis of the relationship between daily extreme rainfall and global climate indices. Negative correlations with consecutive wet days (CWD) imply a decline in the frequency of wet days, but positive correlations with sea surface temperature (SST), sea-level pressure (SLP) groups, and continuous dry days indicate an increase in prolonged dry periods. These results emphasize how crucial it is to comprehend the connections between large-scale climate indices and regional climate variables. The research highlights how these climate phenomena have a major impact on reduced agricultural yields, protracted droughts, infrastructural problems, and the shortage of water resources. It also highlights the necessity for effective adaptation methods. The observed data support the region's severe temperature rise and irregular rainfall patterns, which are consistent with previous research in the field. To completely understand the scope of these catastrophic events in relation to the climate variability, more research is necessary.

These changes in temperature extremes are consistent with the broader literature on climate change impacts across the Horn of Africa, which project an increase in the frequency and intensity of heatwaves (Osima et al., 2018; Gebrechorkos et al., 2019). In terms of precipitation extremes, the findings demonstrate a mixed picture, with a marginal increase in extreme dry days but a decline in other indices like consecutive wet days. This reflects the complex and uncertain nature of precipitation patterns under climate change in the region (Omondi et al., 2014). The analysis of the relationship between daily extreme rainfall and large-scale climate indices provides important insights into the drivers of regional climate variability. The negative correlations with consecutive wet days and positive correlations with prolonged dry periods underscore the influence of factors like sea surface temperatures and sea-level pressure on the local precipitation regime (Osman &Sauerborn, 2002). These climate-driven changes have far-reaching implications for the Borena zone, including reduced agricultural yields, protracted droughts, infrastructure challenges, and water scarcity (Adem&Bewket, 2011; Ayana et al., 2016).

The second manuscript highlights the challenges faced by households in Borena, including climate variability and food insecurity. A significant proportion of households perceive the negative effects of temperature increase and decreased annual rainfall on crop and livestock production. The high level of perception indicates the urgent need to address these climate-related challenges. Food security emerged as a major concern, with a substantial percentage of households (95%) experiencing varying levels of food insecurity. Coping strategies adopted by households to deal with climate variability and food insecurity include receiving humanitarian aid, out-migration, borrowing, expense reduction, daily labor, and selling charcoal and fuel wood. The study emphasizes the importance of specific coping responses that enhance resilience and well-being in the community. Traditional knowledge and resource management practices have been developed by Borena pastoralists and agro pastoralists to navigate climate variability and food insecurity. These coping strategies play a vital role in mitigating the impacts of climate variability and ensuring livelihood sustainability. The findings suggest the need for integrated interventions that address multiple aspects, including poverty, climate change, and access to a nutritious diet. Behavioral change communication advocacy can raise awareness about climate change risk management and promote better dietary practices to reduce malnutrition. Furthermore, a shift towards inclusive, community-oriented approaches, incorporating indigenous knowledge and climate change adaptive capacities, is crucial. Policies focusing on food and nutrition should prioritize the participation and needs of local communities.

The high level of perceived impacts on crop and livestock production, coupled with widespread food insecurity, highlights the vulnerability of local communities to these interlinked challenges (Tegegne et al., 2013; Abate et al., 2010). Households have adopted a range of coping strategies, including receiving humanitarian aid, out-migration, borrowing, expense reduction, and engaging in alternative livelihood activities (Ambaw & Getachew, 2019). These findings align with the broader literature on climate (Megersa et al., 2014). Importantly, the study emphasized the critical role of traditional knowledge and resource management practices developed by the Borena pastoralists and agro pastoralists to navigate climate variability and food insecurity (Ayana et al., 2013). These community-based coping strategies are an essential component of building resilience and ensuring livelihood sustainability in the face of climatic changes (Megersa et al., 2014). The findings underscore the need for integrated interventions that address the multifaceted challenges of poverty, climate change, and food and nutrition security, with a focus on community-oriented approaches that incorporate indigenous knowledge and adaptive capacities (Ayana et al., 2016; Habtemariam et al., 2016).

The third manuscript examined how pastoral households in the Borena Zone of southern Ethiopia perceive climate unpredictability, how they adapt to it, and how that affects household food security. The results show that the area's pastoralists and agropastoral have a significant perception of climate variability, which includes rising temperatures, falling precipitation, and more frequent droughts. Households use a variety of livestock adaptation techniques to address these issues, including growing livestock feed, destocking techniques, rainwater collection, haymaking or dirkosh, feed storage, and index-based livestock insurance. They also use agricultural adaptation techniques, such as selecting drought-tolerant varieties, modifying the dates of planting, and harvesting, and conserving water and soil. Additionally, households utilize other adaptation responses such as consuming stored food, borrowing from credit unions, using media for information, saving crop seed or money, receiving free support, and engaging in livelihood diversification activities like petty trade or daily labor. The study also finds that the perception of increasing temperatures has a positive and statistically significant impact on the adoption of growing livestock feed, saving crop seed and money, and receiving free support from NGOs and government. Similarly, a perception of decreasing rainfall among pastoralist communities increases the adoption of adaptation responses such as feed storage, destocking practices, rainwater harvesting, haymaking or dirkosh, drought-resistant varieties, early maturing varieties, media usage, and livelihood diversification. Furthermore, an increased perception of drought frequency among pastoralists enhances the adoption of growing livestock feed, index-based livestock insurance, borrowing from credit unions, and saving crop seed and money. Compared to households who have not embraced these tactics, those that have typically experienced greater food security outcomes. These households include those that have grown livestock feed, stored feed, conserved soil and water, saved crop seed, received free support, and used media. These results highlight the significance of putting these adaptation strategies into practice and supporting them to improve food security in pastoral communities dealing with climate variability-related issues.

The literature confirms that pastoralist and agropastoral households in the Borena Zone have a strong perception of climate variability and change. Several studies have documented their observations of rising temperatures, declining precipitation, and more frequent and severe droughts in the region (Debela et al., 2015; Abrha &Simane, 2016; Admassu et al., 2020). These subjective perceptions align with the observed climate trends analyzed in the scientific literature (Haile et al., 2019; Gebrechorkos et al., 2019).

The fourth manuscript examines the factors influencing the adoption of food insecurity adaptation strategies. The findings highlight the importance of demographic, socio-economic, and environmental factors in shaping households' decisions regarding adaptation measures. Education level, membership in credit associations, access to extension services, and climate change training consistently show significant associations with multiple adaptation strategies. This emphasizes the role of knowledge, resources, and skills development in enabling households to implement effective adaptation measures. Gender dynamics and social norms also play a significant role in shaping adaptation strategies. The sex of the household head emerges as a significant factor for certain strategies, indicating that gender considerations influence decision-making processes related to food insecurity adaptation.The literature stresses several key factors that influence the adoption of specific adaptation strategies. Education, access to extension services, membership in credit associations, and participation in climate change training programs emerge as important enablers (Deressa et al., 2011; Admassu et al., 2020). Gender dynamics and market access also shape the choice of adaptation measures, with women often facing greater constraints (Megersa et al., 2014; Debela et al., 2019).

Market distance and life experience in the area demonstrate notable associations with specific strategies. Proximity to markets and knowledge of local conditions can affect the feasibility and effectiveness of certain adaptation measures. It is important to note that the significance and direction of associations vary across different strategies, highlighting the contextual nature of food insecurity and adaptation. Tailored interventions and policies that consider the specific circumstances and needs of different regions and communities are crucial for promoting effective and sustainable adaptation. The findings from the multivariate probit model provide valuable insights into the complex factors that shape food insecurity adaptation strategies. Policymakers, practitioners, and stakeholders can utilize this knowledge to develop targeted interventions, programs, and policies to enhance resilience and reduce food insecurity in vulnerable populations. Continued research and monitoring are necessary to further refine our understanding of the dynamics of food insecurity and adaptation in a changing world. By staying informed and adapting approaches based on evolving circumstances, stakeholders can better address the challenges of food insecurity and promote sustainable adaptation strategies.

Figure 6.1 gives a graphic summary and encapsulates the essence of the manuscript, focusing on the drivers of climate change, perceptions of climate change, the coping mechanisms and adaptive measures taken by the community, and the resulting impact on food security. It also highlights the required capacity to improve the livelihood of Borena pastoralists and agro pastoralists. For a more detailed discussion, the full manuscript should be consulted.

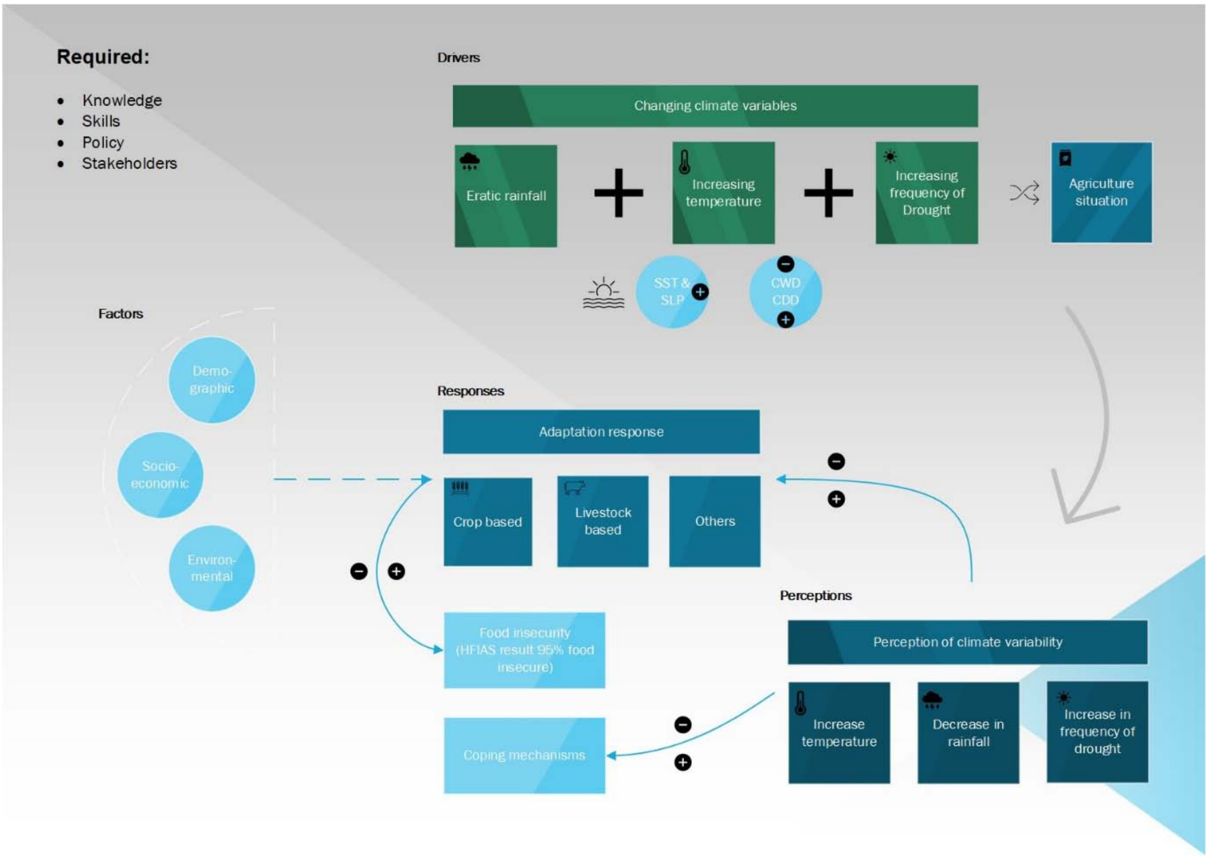

Figure 0.1: Synthesis: Visual representation of the main findings.

6.2. Recommendations

The study on the impacts of meteorological hazards in the Borena Zone of Ethiopia highlights the pressing need for comprehensive adaptation strategies to address the challenges faced by pastoralist and agro-pastoralist communities. As these communities heavily rely on rainfed agriculture and livestock production, they are particularly vulnerable to the effects of climate variability, such as droughts and floods, which directly threaten their food security.

To enhance the resilience of these communities, a multifaceted approach is recommended. Firstly, it is crucial to strengthen livestock management and feed conservation strategies. Promoting the adoption of livestock feed storage and conservation practices has been shown to significantly improve household food security. Additionally, supporting the development and use of improved livestock breeds, as well as enhancing access to veterinary services, can help increase the resilience of pastoralist herds. Effective destocking strategies should also be encouraged to manage livestock numbers during periods of feed scarcity and drought.

Secondly, improving water resource management and soil conservation is paramount. Investing in water harvesting and storage infrastructure can increase the availability of water resources during dry periods. Simultaneously, promoting sustainable soil and water conservation practices, such as terracing and tree planting, can enhance the productivity of rainfed agriculture. Providing extension services and training to help pastoralist and agro-pastoralist communities adopt these measures is crucial.

Thirdly, enhancing climate information and early warning systems is essential. Improving the availability and accessibility of accurate, localized climate information and weather forecasts can support informed decision-making by these communities. Strengthening early warning systems to enable timely preparedness and response to climate-related hazards, such as droughts and floods, can also significantly reduce their impact. Ensuring the effective dissemination of climate information and early warning messages through multiple channels, including mass media and community-based platforms, is key.

Lastly, it is imperative to integrate adaptation strategies and strengthen institutional support. Developing and implementing comprehensive, multi-sectoral adaptation strategies that address the interlinked challenges of food security, water resource management, and livestock production can deliver more effective and sustainable solutions. Strengthening the capacity of local institutions, such as extension services and community-based organizations, to support the adoption of climate change adaptation strategies is also essential. Facilitating coordination and collaboration among various stakeholders, including government agencies, research institutions, and development partners, can further enhance the delivery of integrated and effective support to pastoralist and agro-pastoralist communities.

By implementing these holistic recommendations, policymakers and stakeholders can enhance the resilience of pastoralist and agro-pastoralist communities in the Borena Zone and similar arid and semi-arid regions of Ethiopia, ultimately improving food security and reducing their vulnerability to the impacts of climate variability and change.

6.3. Contribution to new knowledge

The contributions to new knowledge in this dissertation are as follows:

Geographical and Temporal Trends of Extremes: The first manuscript provides insights into the geographical and temporal trends of temperature and precipitation extremes in the Borena zone. It identifies the increase in extreme temperatures over time and the complex relationship between daily extreme rainfall and global climate indices. These findings contribute to understanding the regional climate dynamics and highlight the need for effective adaptation strategies.

Climate Variability, Food Insecurity, and Coping Strategies: The second manuscript examines the challenges faced by households in Borena, including climate variability and food insecurity. It highlights the high perception of climate-related negative effects on crop and livestock production and the various coping strategies employed by households. The study emphasizes the importance of specific coping responses that enhance resilience and well-being in the community, providing insights into the adaptation practices of pastoralists and agropastoral.

Perceptions of Climate Variability and Adaptive Measures: The third manuscript explores how pastoral households in the Borena Zone perceive climate unpredictability, adapt to it, and its impact on household food security. It identifies the range of livestock and agricultural adaptation techniques employed by households and examines the influence of climate perceptions on the adoption of adaptive measures. The findings contribute to understanding the link between climate perception, adaptation strategies, and food security outcomes in pastoral communities.

Factors Influencing Food Insecurity Adaptation: The fourth manuscript investigates the factors influencing the adoption of food insecurity adaptation strategies. It highlights the significance of demographic, socio-economic, and environmental factors in shaping households' decisions regarding adaptation measures. The study emphasizes the role of knowledge, resources, gender dynamics, and local conditions in determining the feasibility and effectiveness of adaptation strategies. These findings contribute to designing tailored interventions and policies for promoting effective and sustainable adaptation in vulnerable populations.

Overall, this dissertation contributes to the understanding of climate variability, food insecurity, and adaptation strategies in the Borena pastoralist community. It provides insights into the drivers of climate change, perceptions of climate variability, coping mechanisms, adaptive measures, and their impact on food security. The research findings have implications for decision-making, management strategies, and the development of targeted interventions to enhance resilience and improve the livelihoods of pastoral communities.

6.4. Possiblefutureresearchareas

Based on the findings and contributions of the dissertation, the following are possible future research areas:

Long-Term Climate Projections: Further research can focus on developing long-term climate projections for the Borena Zone. This would involve analysing climate models and historical data to understand future trends in temperature, precipitation, and extreme weather events. These projections would provide valuable information for decision-making and the development of climate change adaptation strategies.

Impact of Climate Variability on Ecosystem Services: Future research can explore the impact of climate variability on ecosystem services in the Borena pastoralist area. This would involve assessing how changes in temperature and precipitation patterns affect grazing lands, water availability, and biodiversity. Understanding these impacts can help in designing sustainable land management practices and conservation strategies.

Assessment of Climate Change Communication and Awareness: Research can investigate the effectiveness of climate change communication and awareness programs in the Borena community. This would involve evaluating the knowledge, attitudes, and behaviours of community members towards climate change and adaptation. Such research can guide the development of targeted communication strategies to enhance climate change literacy and promote adaptive behaviours.

Evaluation of Adaptation Interventions: Further research can focus on evaluating the effectiveness of specific adaptation interventions implemented in the Borena Zone. This would involve assessing the outcomes and impacts of interventions such as drought-resistant crop varieties, livestock insurance schemes, or water resource management strategies.

Evaluating these interventions can provide insights into their success, challenges, and potential for upscaling or replication in similar contexts.

Socio-economic Dynamics of Adaptation: Future research can delve deeper into the socio-economic dynamics of adaptation in the Borena pastoralist community. This would involve examining the social and economic factors that influence households' decision-making processes related to adaptation strategies. Understanding the barriers and enablers of adaptation can inform the design of context-specific policies and interventions that support vulnerable communities.

Climate Change and Health: Research can explore the intersection between climate change, food security, and health outcomes in the Borena Zone. This would involve investigating the impacts of climate variability on nutrition, waterborne diseases, and other health-related issues. Understanding these linkages can contribute to the development of integrated approaches that address both food security and health challenges in the face of climate change.

Participatory Approaches for Adaptation: Future research can focus on participatory approaches for climate change adaptation in the Borena community. This would involve engaging community members and stakeholders in the co-design and implementation of adaptation strategies. Participatory approaches can enhance local ownership, knowledge sharing, and the effectiveness of adaptation measures.

These future research areas can further deepen our understanding of climate change impacts, adaptation strategies, and the well-being of pastoral communities in the Borena Zone. By addressing these research gaps, we can develop more context-specific and effective interventions to build resilience and promote sustainable development in the face of climate variability.

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CHAPTER 7: ANNEXES

Informed consent

Dear respondents, this study is conducted entitled on ‘Meteorological Hazard: Causes, Impact on Food Security and Disaster Risk Management Strategy in Borena Pastoralists, Ethiopia’ at the Center for Food Security, College of Development Studies, Addis Ababa University, Ethiopia. This questionnaire is designed for the academic purpose of fulfilment of Doctoral Degree in Development and Food Security. The objective of the research is to assess the effect of climate variability on household food security status and their food coping responses,
Examine pastoral household’s climate variability perceptions and adaptation response to ensure their food security and identify climate change adaptation response determinants and examine perceived adaptation successfulness among pastoral households.

This research at the end would come up with recommendations that could help in planning sustainable food security through disaster risk management and adaptation strategies to diminish the negative effects of climate change and variability and sustain the communities’ livelihood and household food security in the study area.

Therefore, we kindly request your cooperation in responding to the questionnaire, while assuring you that all furnished information would be treated with utmost confidentiality and strictly for academic purpose. The information is used purely for research purposes; your answers will not affect any benefits or subsidies you may receive now or in the future. Do you consent to be part of this study? If there are questions that you would prefer not to answer, then we respect your right not to answer them.

Please sign and date here indicating that you agree to participate:

______________________	______________________	______________________
Name	Signature	Date

Questionnaire

I	**General Information**	Description
1	Enumerator's name	
2	District	
3	Kebele	
4	Village	
5	HH ID	
6	Date	
II	**Demographic Characteristics**	
1	Is the respondent HH head?	
2	Age of the respondent (years)	____________
3	Gender of HH head	1. Male 2. Female
4	Marital status of HH head	1. Single 2. Married 3. Divorced 4. Separated 5. Widowed 6. Polygamy
5	Education level of HH head	1. Cannot read & write 2. Grade 1 – 4 3. Grade 5 – 8 4. Grade 9 – 12 5. Level/ Diploma 6. Degree (BSc/BA) 7. Above degree (BSc/BA)
6	Religion of HH head	1. Orthodox 2. Muslim 3. Christian 4. Protestant 5. Wakefata 6. Others__________
7	Household size (in number)	__________________
8	Household size by age (years) (in number) Fill all options	1. < 7 ________________ 2. 7-14 ________________ 3. 15-64 ________________ 4. Above 65________________
III	**Socioeconomic Characteristics**	
1	Monthly income of the household (ET. Birr)	_______________
2	Access to credit services	1. Yes 2. No
3	Credit Association Member	1. Yes 2. No

4	Farm activities involved	1. Crop farming 2. Livestock farming 3. Fish farming 4. Mixed farming 5. Other specify__________
5	Access to agricultural extension services for crop and livestock production	6. Yes 7. No
6	Annual crop production in quintal/s	______________________
7	Do your household engage in income generating activities other than agriculture? /Off-farm income/?	1. Yes 2. No
8	If yes, what is/are your major income generating activities?	1. Pity trade 2. Weaving 3. Carpeting 4. Pottery 5. Selling of fuel wood 6. Daily work 7. Sewing clothes 8. Others Specify______________
9	Land size (hectares)	__________________
10	Cultivated land size (hectares)	_____________________
11	Grassland size (hectares)	____________________
12	Distance to the market (km)	_____________________
13	Duration of the stay in study area (years)	____________________
14	Access to training on climate change	1. Yes 2. No
15	Access to weather related information from stations	1. Yes 2. No
16	Agricultural extension services	1. Yes 2. No
IV	**Climate Change and Variability Perception and Knowledge**	
1	How do you understand climate change?	
2	Have you ever noticed some particular changes in climate and weather variability in the last 30 years?	1. Yes 2. No
3	In your view is climate change taking place?	1. Strongly agree 2. Strongly disagree 3. Agree somewhat 4. Disagree somewhat 5. Neutral 6. I don’t know
4	If you agree, please indicate from the list below what you have observed for the last 20 years that makes you conclude climate change is occurring?	1. Increase in temperature 2. Increase in rainfall 3. Decrease in rainfall

		4. Change in rainfall patterns 5. Increased frequency and intensity in floods 6. Increased frequency and intensity in droughts 7. Other, specify________________
	Are you concerned about these changes in climate?	1. Yes 2. No
5	If yes, why?	1. Unable to plan faming activities 2. Livestock/crop production have declined 3. Crops destroyed and livestock died 4. Insufficient pasture for my animals 5. Any other reason, specify______
6	Would you agree that the changes you mentioned, have negatively affected your agricultural activities?	1. Strongly agree 2. Agree somewhat 3. Neutral 4. Disagree somewhat 5. Strongly disagree 6. I don't know
7	Do you have access to climate change information	1. Yes 2. No
8	Do you have access to climate variability information	1. Yes 2. No
9	Do you have access to information on weather forecasting	1. Yes 2. No
10	What are the major sources of information for climate change and variability?	1. Relatives or friends 2. Television 3. Radio 4. Newspapers 5. Personal involvement in environmental protection activities 6. Environmental protection campaign 7. Others, specify______________

V. Pastoralists' perception on temperature

1. Strongly disagree, 2. Disagree, 3. Neutral (undecided), 4. Agree, 5. Strongly agree

No.	Statements	1	2	3	4	5
1.	I understand the temperature in this area increases from time to time					
2.	I am aware that the rise of temperature can negatively affects crop and livestock production					
3.	When temperature is high the incidence of crop pests and diseases and livestock diseases would increase					
4.	In my opinion the temperature is highest during *belg*, are lower in *bega*,					

	tsedey and *kiremt* in this order					
5.	I believe the frequency of drought occurrence increases with an increase in temperature					
6.	I am of the opinion that land use patterns change due to increasing temperature					
7.	I think a rise of temperature would decrease the water reservoirs in our locality					
8.	I am well aware that when temperature increases not only scarcity but the quality of grazing land would decrease in my locality					
9.	I know that changes in temperature could result in a change in my cropping pattern, livestock size and variety					
10.	I do not think that changes temperature would cause changes in livelihood strategies					
11.	I am aware that there is direct association between temperature and amount of crop &livestock production					
12.	I am of the opinion that the changes in temperature can predicted					
13.	The rise of temperature results in a shortage of food in our locality					

VI. Pastoralists' Perception on Rainfall

No.	Statements	1	2	3	4	5
1.	I know that rainfall pattern affects the cropping and grazing calendar (cropping & site of grazing time)					
2.	I think that the amount of rainfall can decrease from time to time					
3.	I know that the amount of rainfall affects agricultural/livestock production					
4.	When rainfall variability increases, the incidence of crop pests and diseases as well as animal diseases also increases					
5.	I know that rainfall is highest in *kiremt* and becomes less during belg, *tsedey* and *bega* in that order					
6.	I am well aware that there is a shift in onset and cessation of rain					
7.	I know that rainfall is highest in July and lowest in January					
8.	I am of the opinion that the number of rainy days has decreased over the last 15 years					
9.	I have observed that the frequency of drought occurrence increases as rainfall amount decreases					
10.	I have observed that land use has changed due to variations in rainfall distribution					
11.	I understand that when rainfall decreases the availability of water for agricultural/livestock production and other uses in our locality also decreases					
12.	I am not of the opinion that when the rainfall decreases the quality of grazing land also decreases in our locality					
13.	I know that rainfall variability influences the cropping pattern, livestock					

	size and variety					
14.	I do not have enough knowledge to state that rainfall variability can cause changes in the livelihood strategies					
15.	I am aware that rainfall and agricultural/livestock production are directly associated to each other					
16.	I do not have enough knowledge to acknowledge that there is an inverse relationship between rainfall and the magnitude of drought severity					
17.	I think that rainfall variability is predictable					
18.	I am aware that rainfall variability contributes to food shortage in our locality					
19.	I am aware that high intensity of rainfall can aggravate soil erosion					
20.	I believe that the annual rains do not support the crop and livestock production as was the case in the past in my locality					

VII. Pastoralists' Perception on Accesses to basic services and infrastructures

No	Statements	1	2	3	4	5
1.	I am well aware of the various networks available to me to buy and sell my livestock and crops in my locality					
2.	I know where to obtain information on good market prices					
3.	I now have access to better and improved seeds for the planting of my crops					
4.	I have access to better and improved livestock breed					
5.	I am able to obtain enough fertilizers required for the crops I am cultivating for a specific season					
6.	I have better access to more modern agricultural technology					
7.	I have no access to modern livestock farming technology					
8.	I am of the opinion that I now have enough knowledge to improve the breeding of better livestock					
9.	I believe that I have acquired enough knowledge and skills on modern adaptation strategies from extension workers					
10.	I can easily access information on the local climate and issues related to climate					
11.	I do not trust the available source of information on climate and related issues					
12.	I am able to gain access to policies and strategies related to my activities through a variety of ways					
13.	I believe adaptation strategies introduced by the government are not efficient as local coping and adaptation strategies					
14.	I usually use my own coping and adaptation strategies to minimize climate related problems					
15.	I am aware that I can get institutional information whenever I have a need for this information					
16.	I have access to formal and informal credit					
17.	I believe government incentives have helped me adapt to climate related problems in my farming activities					

18.	I am aware that position in the kebele help to get easy access to institutions					

VIII. Livelihood Income and Expenditure Survey (Wellbeing assessment)

S/N	**Variables**	Description
1	What source of income do you have & how much do you earn in (Birr) yearly?	______________________________
2	On-farm income	1. From crops 2. From livestock 3. Other sources, specify
3	Off-farm income	1. Daily laborers 2. Wages 3. Investment 4. Other sources, specify
4	Do you make a pool of incomes of all earning members?	1. Yes 2. No
5	If no, do you take share from each earning member to make a pool?	1. Yes 2. No
6	If yes, how much is the share in Birr?	__________________
7	What types of animals do you own?	1. Cattle 2. Sheep 3. Goat 4. Chicken 5. Pig 6. Equine 7. Others, specify
8	On average how many of the above livestock do you have now?	____________________
9	How many more have you acquired this year?	______________________
10	On average how many did earn from selling (Birr)	________________________
11	Do you seek for veterinary services for them?	1. Yes 2. No
12	Which of the following asset is available at your home?	1. Cutlass 2. Hoe 3. Knapsack 4. Radio 5. Irrigation pump 6. Mobile 7. Television 8. Bicycle 9. Motorcycle 10. Car 11. Tractor 12. House

		13. Other, specify_______________
13	Price of above assets if you were to sell it now (ETB)	_________________
14	If you suddenly need money, where do you turn to?	___________________
15	What is the average amount of money you can get from this source?	_________________
16	What is the average amount of money you can get from this source?	______________________
17	Do you source credit to finance your farm operations?	1. Yes 2. No
18	Did you buy any input for credit during the 2020 season?	1. Yes 2. No
19	If yes, what were the terms of the credit?	1. Repay in cash 2. Repay with farm produce 3. Repay with cash and farm produce 4. Other, specify_________________
20	Did you repay with interest?	1. Yes 2. No
21	If yes what was the interest rate?	______________________%
21	What is/are your HH expenditures look like (Birr)?	1. Food 2. Health 3. Clothing 4. Education 5. Weddings (Son, Daughter) 6. Funerals 7. Taxes 8. Weddings of relatives 9. Expenditures on legal matters like courts police station etc. 10. Other major exp., specify______

IX	The possible cause of food insecurity in the study area	Yes	No
1	Recurrent drought and lack of adequate rainfall		
2	High family size or population pressure		
3	Use of traditional agricultural tool		
4	Poor post-harvest management and handling of product		
5	Failure of livestock/crop production due to bad environment		
6	Poor soil condition		
7	Unavailability and expensive of agricultural inputs		
8	Inadequate water and water harvesting scheme		
9	Deforestation		
10	Inadequate agricultural extension system		

11	Inadequate of alternative income generating activities		
12	Inadequate of information and training how to produce		
13	Inadequate of credit and microfinances		
14	Low livestock population and disease		
15	Shortage of cultivated land		
16	Lack of oxen to plow		
17	Poor health situation of the farmers		
18	Others, specify________		
X	**Coping and adaptation strategies in the livestock sector**	**Yes**	**No**
1	Feed storage		
2	Destocking		
3	Keeping drought resistant species		
4	Veterinary service		
5	Enclosure/protected farmland		
6	Extended search of water and pasture		
7	Bush clearing		
8	Growing feeder		
9	Cut and carry		
XI	**Coping and adaptation strategies to climate variability in crop sector**		
1	Grow different crop variety		
2	Varying planting and harvesting dates		
3	Use fast growing varieties		
4	Use drought resistant varieties		
5	Intercropping		
6	Using fertilizer		
7	Using pesticides		
8	Using herbicides		
9	Mulching		
10	Increased use of irrigation		
11	Water and soil conservation		
12	Others, specify___________		
XII	**Non-farm coping and adaptation strategies to climate variability**		
1	Land contracting (renting, share cropping)		
2	Borrowing from credit union		
3	Borrowing from friends and or families		
4	Selling of wood and tree		
5	Selling of charcoal		
6	Saving (crop seed, money etc.)		

7	Free support (money, labor, material) from the clan or relatives and friends		
8	Remittance from family elsewhere		
9	Migration		
10	Aid from government and NGOs		
11	Avoidance, postponement or reduction of expenses during religious and public holidays or family occasions for example, dowry, wedding, mourning feasts, etc.		
12	Using media (TV, radio etc.) forecasting		
13	Water harvesting technology		
14	Diversification of livelihoods through non-farm activities: petty trading, hand craft		
15	Using indigenous forecasting and or own experiences		
16	Reduce food intake		
17	Look for daily work		
18	Sell assets (livestock, etc.)		
19	Others, specify___		
XIII	**Challenges that devisal of coping and adaptation strategies to climate variability**	Yes	No
1	Financial constraints		
2	Poor infrastructure		
3	Lack of information		
4	Lack of relevant skills		
5	Lack of technology		
6	Others___________________________		
	The major shocks in the study area		
1	Recurrent drought		
2	Resource-based conflict		
3	Bush encroachment		
4	Livestock disease		
5	Rangeland degradation		
6	Others___________________________		

XIV. Perception Respondents on the Impact of Climate Variability on Food Security (Tick)

1. Strongly agree, 2. Agree, 3. Neutral, 4. Disagree, 5. Strongly disagree

No	Items	1	2	3	4	5
1	Do you understand what is climate change					
2	How much do you understand about climate change					
3	Do you believe that climate change is taking place					
4	Do you believe that climate change has reduced livestock/crop production in your area					
5	Do you believe that all people should know something about climate change					
6	Do you believe that food security is changing from better to worse due					

	to rainfall and temperature changes					
7	Do you participate in any activity to adapt to climate change on food security in your area					
8	Do you associate climate change and food shortage					
9	Do you believe that problems related to climate change and food security will be reduced if early warning measures were communicated in time					
10	Do you believe that Government Policy covers issues of global warming?					
11	Do you believe that if climate change impacts are not solved now, the future generations will suffer					
12	Do you believe that a degraded and devastated environment is not as a result of climate change					
13	Do you believe that climate change has not reduced livestock/crop production in your area					
14	Do you believe that only the old people should know something about climate change					
15	Do you believe that food security has improved in your area overtime					
16	Do you belief in the early warning measures to be Accurate					
17	Do your belief that the early warnings are useful to you					
18	Do your belief that land use/land cover changes is as a result of climate change					
19	Do you agree that the meteorological department always makes timely the early warnings					

XV. Pastoralists' perception on their adaptation and coping practices successfulness on the livestock sector

This section aims to measure farmers' successfulness perceptions of adaptation and coping practice to climate variability in the livestock sector. To this end, some possible adaptation and coping strategies are listed below. Please read each item separately and indicate your opinion by putting a tick (√) mark under one of these alternatives. Your response could range from not at all (1) to always (5).

1. Not at all, 2. Rarely, 3. Sometimes, 4. Usually, 5. Always

No.	Statements: how do you rate your adaptation and coping success	1	2	3	4	5
1.	Increased use of veterinary services					
2.	Employing water harvesting technology					
3.	Diversifying household economy by engage in non–farming activities					
4.	Shift from livestock to agro-pastoral production					
5.	Feed conservation and storing					
6.	Extended search for better pasture in more distance and less affected area					
7.	Destocking					
8.	Receiving remittance outside household members					
9.	Seasonal migration of household heads					

10.	Receiving aid from government and NGOs for months of food insecurity					

XVI. Indigenous Knowledge Practices and Climate Change Adaptation Strategies Adopted at Household Level (What has Been Done to Adapt with Climate Change?)

S/N	**Characteristics**	**Yes**	**No**
1	Please mention different sources of knowledge concerning climate change adaptation? (multiple response is possible!)		
	1. Personal experience		
	2. Parents/Family		
	3. Friends/Neighbors		
	4. Social groups		
	5. Church/mosques		
	6. Community gathering		
	7. Village leaders		
	8. Media		
	9. Extension staffs		
	10. NGOs		
	11. Others, specify_____________		
2	Do you have any traditional weather prediction methods?		
3	Has climate change and variability created any good opportunities for you?		
4	If Yes, please support your answer with explanation __________________		
5	Are there any adaptation strategies you made for the change in climate (precipitation and temperature)?		
6	If yes, what drives you to take measure against the change? ___________		
7	Which of the following strategies have you/ your family adopted to reduce the loss / or adapt to climatic events or change over the last 20 years?		
	1. Planting trees		
	2. Soil and water conservation		
	3. Integrated agriculture		
	4. Agroforestry		
	5. Livelihood diversification		
	6. Others, specify___________		
8	How did the government, GOs and NGO's responded to reduce the impact? _______________		
9	Which type of climatic shock is your main concern? __________________		
10	What are the major constraints you have that hinders your coping mechanisms? ________________		

11	Indigenous knowledge and practices		
	1. Planned transhumance migration		
	2. Herd splitting		
	3. Increasing herd size during rainy seasons		
	4. Altering grazers and browsers composition		
	5. Stocking female dominated herds		
	6. Night grazing		
	7. Traditional pasture conservation		
	8. Use of browse trees		
	9. Use of wild herbs to treat livestock diseases		
	10. Postharvest use of fields		
	11. Planting drought tolerant varieties		
	12. Use of natural occurring salt		
	13. Traditional bee keeping		
	14. Rotational grazing		
	15. Partitioning grazing land into enclosures		

XVII. Disaster Risk Management

S/N	Characteristics	
	Disaster Risk Knowledge	
1	How much of a concern are disasters to you?	1. Great concern 2. Little concern 3. No concern
2	What types of natural disasters threaten your community? Multiple Responses Allowed DO NOT READ RESPONSES	1. Rains 2. Tropical cyclone/hurricane 3. Wildfires 4. Severe storms 5. Extreme temperature 6. Volcanic eruption 7. High waves/swells 8. Floods 9. Drought 10. Earthquake 11. Tsunami 12. Landslides 13. Other: ____________ 14. None 15. Don't know
3	What other types of disaster threaten your community?	

4	Could your community experience a natural disaster in the next 5 years?	1. Yes 2. No 3. Don't know
	Hazards Exposure	
1	Are disasters becoming increasingly common?	1. Yes 2. No 3. Don't know
2	In the past 5 years, was your community affected by a disaster or emergency?	1. Yes 2. No
3	If yes, how many disasters or emergencies occurred in this time?	______________________________
4	What types of disasters/emergencies? Multiple Responses Allowed DO NOT READ RESPONSES	1. Rains 2. Tropical cyclone/hurricane Wildfires 3. Landslides 4. Severe storms 5. Extreme temperature 6. Volcanic eruption 7. High waves/swells 8. Floods 9. Drought 10. Earthquake 11. Tsunami 12. Other_______________
5	In the past 5 years, has your family been affected by a disaster or emergency?	1. Yes 2. No
6	If yes, how was your family affected? Multiple Responses Allowed DO NOT READ RESPONSES	1. Evacuation 2. Serious injury (required medical attention) 3. Death 4. Property damage 5. Minor injury (did not seek medical attention) 6. Disruption or loss of income 7. Other_________________
	Household Preparedness	
1	Will being prepared help your family in a disaster or emergency?	1. Yes 2. No 3. Don't know
2	How prepared is your family to handle a disaster or emergency?	1. Very prepared 2. Somewhat prepared 3. Not prepared 4. Don't know
3	Compared to a year ago, is your family more or less able to handle a disaster or emergency?	1. More able 2. No change 3. Less able 4. Don't know

4	If less able, why is your family less able to handle a disaster or emergency? DO NOT READ RESPONSES	1. Lost job or income source 2. Reduced earnings (same job/income earning activities) 3. Family member died or moved away (includes resulting loss of income) 4. Family member became sick, disabled, or couldn't work for health reasons 5. Family is worse off financially than before because cost of living has increased 6. Other_______________
5	Which of the following statements best describes your family? READ RESPONSES	1. We have not done anything to prepare for a disaster or emergency and we do not plan to 2. We have not done anything to prepare for a disaster or emergency but we plan to in the coming months 3. We just recently began preparing for a disaster or emergency 4. We are prepared for a disaster or emergency
6	Do you have supplies or other things in your home that could be used in a disaster or emergency?	1. Yes 2. No 3. Don't know
7	If yes, what supplies do you have? DO NOT READ RESPONSES Multiple Responses Allowed	1. Packaged food 2. First Aid kit 3. Eyeglasses or medicine 4. Bottled water 5. Flashlight 6. Important documents 7. Radio 8. Cash 9. Other:________________________ 10. Nothing
8	Have you and your family members ever spoken about or planned what you would do if a disaster or emergency occurs?	1. Yes 2. No 3. Don't know
9	If yes, what did you discuss? DO NOT READ RESPONSES Multiple Responses Allowed	1. Planned meeting place for family members List of important phone numbers or contacts 2. Activities to strengthen your home or reduce risk or damage to your property 3. Emergency supplies or a planned list of items to take in case the family leaves home 4. Evacuation plan

		5. Going to a shelter/place to stay 6. Other: ______________________ 7. Nothing		
	Public Awareness			
1	In the past year, have you or your family members done any of the following activities?	Yes	No	Don't know
	i. Attended a meeting on how to be better prepared for a disaster?			
	ii. Attended a First Aid training?			
	iii. Participated in a disaster or evacuation drill?			
	iv. Participated in a community or volunteer activity related to disaster preparedness or prevention?			
	v. You were given a pamphlet or flyer about disasters or a person visited you to discuss disasters?			
2	Does your community have an early warning system?			
3	Does your community have a disaster response or emergency plan?			
4	Does your community have a committee or organized group that decides what to do in disasters or emergencies?			
5	Have community members been trained to assist others in the event of a disaster?			
6	Does your community have evacuation routes?			
7	Does your community have a shelter identified where people can go in the event of a disaster?			
	Governance			
1	Are your community members involved in planning or coordinating with local government?			
2	Can your community access government resources or programs for disaster response and/or recovery?			
3	In the past year, has the government been involved in any projects or activities related to reducing risk or vulnerability in the event of disaster in your			
4	In the event of a disaster, what people or organizations do you have confidence in to	1. The government 2. Community members/organizations		

	respond and provide assistance? DO NOT READ RESPONSES Multiple Responses Allowed	3. NGOs or other civil service groups that work in the community 4. The Red Cross 5. Religious groups 6. My family 7. Other_____________ 8. Nobody / No organization

XVIII. AVAILABILITY DIMENSION OF FOOD SECURITY SURVEY

Household Food Insecurity Access Scale (HFIAS) Measurement Tool

No	Question	Response Options	CODE
1.	In the past four weeks, did you worry that your household would not have enough food?	0 = No (skip to Q2) 1=Yes	....|___|
1.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	....|___|
2.	In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	0 = No (skip to Q3) 1=Yes	....|___|
2.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	....|___|
3.	In the past four weeks, did you or any household member have to eat a limited variety of foods due to a lack of resources?	0 = No (skip to Q4) 1 = Yes	....|___|
3.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	....|___|
4.	In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	0 = No (skip to Q5) 1 = Yes	....|___|
4.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	....|___|

No	Question	Response Options	CODE
5.	In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	0 = No (skip to Q6) 1 = Yes	....|___|
5.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	....|___|
6.	In the past four weeks, did you or any other household member have to eat fewer meals in a day because there was not enough food?	0 = No (skip to Q7) 1 = Yes	....|___|
6.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	....|___|
7.	In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food?	0 = No (skip to Q8) 1 = Yes	....|___|
7.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	....|___|
8.	In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?	0 = No (skip to Q9) 1 = Yes	....|___|
8.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	....|___|
9.	In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?	0 = No (questionnaire is finished) 1 = Yes	....|___|

No	Question	Response Options	CODE
9.a	How often did this happen?	1 = Rarely (once or twice in the past four weeks) 2 = Sometimes (three to ten times in the past four weeks) 3 = Often (more than ten times in the past four weeks)	....|___|

Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access

	QUESTIONS AND FILTERS	CODING CATEGORIES
1	Now I would like to ask you about the types of foods that you or anyone else in your household ate yesterday during the day and at night. READ THE LIST OF FOODS. PLACE A *ONE* IN THE BOX IF ANYONE IN THE HOUSEHOLD ATE THE FOOD IN QUESTION, PLACE A *ZERO* IN THE BOX IF NO ONE IN THE HOUSEHOLD ATE THE FOOD.	
A	Any [INSERT ANY LOCAL FOODS, E.G. UGALI, NSHIMA], bread, rice noodles, biscuits, or any other foods made from millet, sorghum, maize, rice, wheat, or [INSERT ANY OTHER LOCALLY AVAILABLE GRAIN]?	A.. |___|
B	Any potatoes, yams, manioc, cassava or any other foods made from roots or tubers?	B .... |___|
C	Any vegetables?	C .... |___|
D	Any fruits?	D.. |___|
E	Any beef, pork, lamb, goat, rabbit wild game, chicken, duck, or other birds, liver, kidney, heart, or other organ meats?	E .... |___|
F	Any eggs?	F .... |___|
G	Any fresh or dried fish or shellfish?	G.. |___|
H	Any foods made from beans, peas, lentils, or nuts?	H.. |___|
I	Any cheese, yogurt, milk or other milk products?	I .... |___|
J	Any foods made with oil, fat, or butter?	J .... |___|
K	Any sugar or honey?	K .... |___|
L	Any other foods, such as condiments, coffee, tea?	L... |___|

Food Consumption Score

This module will allow you to collect the information needed to compute the FCS

How many days over the last 7 days, did most members of your household (50% +) eat the following food items,inside or outside the home? And what was their source?*(Use codes below, write 0 if not consumed in the last 7 days)* ***Note for enumerator: Determine whether the consumption of fish, milk was only in small quantities.***				
	Foods	Number of days eaten in the past **7 days** *If 0 days, do not specify the main source.*	FCS	How was this food acquired? **Write the main source of food for the past 7 days**
1.	**Cereals, grains, roots and tubers, such as:** Rice, pasta, bread, sorghum, millet, maize, potato, yam, cassava, white sweet potato	|___|	FCSStap	|___|
2.	**Pulses/legumes/nuts, such as:**beans, cowpeas, peanuts, lentils, nuts, soy, pigeon pea and/or other nuts	|___|	FCSPulse	|___|
3.	**Milk and other dairy products, such as:** fresh milk / sour, yoghurt, cheese, and other dairy products (Exclude margarine/butter or small amounts of milk for tea/coffee)	|___|	FCSDairy	|___|
4.	**Meat, fish and eggs, such as:** goat, beef, chicken, pork, blood, fish, including canned tuna, escargot, and/or other seafood, eggs (meat and fish consumed in large quantities and not as a condiment)	|___|	FCSPr	|___|
5.	**Vegetables and leaves, such as:**spinach, onion, tomatoes, carrots, peppers, green beans, lettuce, etc	|___|	FCSVeg	|___|
6.	**Fruits, such as:**bananas, apples, lemon, mango, papaya, apricot, peach, etc	|___|	FCSFruit	|___|
7.	**Oil/fat/butter, such as:**vegetable oil, palm oil, shea butter, margarine, and other fats/oil	|___|	FCSFat	|___|
8.	**Sugar, or sweet, such as:**sugar, honey, jam, cakes, candy, cookies, pastries, cakes and other sweet (sugary drinks)	|___|	FCSSugar	|___|
9.	**Condiments / Spices, such as:**tea, coffee/cocoa, salt, garlic, spices, yeast/baking powder, lanwin, tomato/sauce, meat or fish as a condiment, condiments including a small amount of milk/tea coffee.	|___|	FCSCond	|___|

Codebook list name: SRf		**<u>Food acquisition codes</u>** 100 = Own production (crops, animal) 200 = Fishing / Hunting 300 = Gathering 400 = Loan 500 = market (purchase with cash) 600 = market (purchase on credit) 700 = begging for food 800 = exchange labor or items for food 900 = gift (food) from family relatives or friends 999 = Other 1000 = food aid from civil society, NGOs, government, WFP etc.		

Part Two: KEY INFORMANT INTERVIEW/FGD GUIDE

Code No: ________________________ Position__________________

Organization __________________________

Mobile Number __________________________ Date __________________

1. How did you experience climate change in the last two decades?

____

____

2. Which kind of manifestations of climate change do you experience?

____

____

4. What are the main climate change adaptation/coping mechanisms?

____

____

6. How can you adapt/cope to climate change?

____

____

8. What is your opinion about the current climate change status in your local area?

____

____

10. Who is more concerned about the impacts of climate change?

____

____

11. What are the major factors associated with the perception of pastoralists about the impacts of climate change on socioeconomic characteristics?

____

____

13. Were you affected by the past drought? If the answer is yes mention the impact of drought on your wealth (crop production, livestock, food security, health, and drinking water)

____

____

14. During a drought period, how people cope with the problem occurred?

15. Is there migration due to drought? If yes, where did you migrate?

16. How many family heads are under food insecure and get food aid from international donors generally in percentage?

16. What are the pastoralists' indigenous knowledge to climate related disasters and adaptability?

18. How prepared is your family to handle a disaster or emergency?

19. How prepared is the government to handle a disaster or emergency?

20. How prepared is NGO to handle a disaster or emergency?

21. Does your community have an early warning system, a disaster response or emergency plan?

22. Are your community members involved in planning or coordinating with local government?

23. Can your community access government resources or programs for disaster response and/or recovery?

24. In the past year, has the government been involved in any projects or activities related to reducing risk or vulnerability in the event of disaster in your

End of Questionnaire and Thank you for your time and cooperation.

AUTHOR BIOGRAPHY

Fikru Tarekegn was born on September 19, 1976, in western Shoa, Ethiopia. He holds a Bachelor of Science degree in Agricultural Extension from Alemaya University (2000), a Master of Science degree in Horticulture from Hawassa University (2005), a Master of Arts degree in leadership and management from EGST (2015), and a Master of Arts degree in Development Management from Ambo University (2018). Additionally, he obtained a TOT certificate in Community Based Conflict Management from Saint Francis University, Canada (2017), and in Project Evaluation from MDF, the Netherlands, in 2010. He has also participated in various training workshops and earned numerous certificates from North America, Europe, Asia, and African countries.

Following his graduation, Fikru gained extensive work experience in various international NGOs and as a consultant. He began his career as an Agriculture Program Facilitator at World Vision International Ethiopia, where he coordinated the USAID-funded PSNP program in SNNPR. He then worked as a full-time consultant, leading major studies in different parts of Ethiopia. Subsequently, he served as a Programs Manager for Dorcas regional office, providing support to Egypt, South Sudan, Sudan, and Ethiopia.

Since 2009, Fikru has been working as the Country Director for Dorcas Aid International Ethiopia. Throughout his career, he has accumulated over twenty years of experience in leadership, networking, fundraising, and managing diverse development programs. These programs encompass a wide range of areas, including early recovery and resilient livelihoods, disability inclusion, agriculture, food security/nutrition, SRHR (sexual and reproductive health and rights), WASH (water, sanitation, and hygiene), energy, housing, child development, business development, sustainable livelihoods, peacebuilding, youth employment/job creation, humanitarian aid, DRR (disaster risk reduction), women empowerment, capacity building, and others.

Fikru's exceptional leadership skills and hard work in the Ethiopian field office have resulted in significant growth year after year, both in terms of size and quality. The projects under his guidance have brought hope to many lives and serve as a model for other country offices. He excels in working with partners, leadership development, staff development, fundraising, research, communication, and networking. His passion lies in serving the most vulnerable communities, particularly pastoralist communities.

In the year 2020, Fikru enrolled in the PhD program at Addis Ababa University, College of Development Studies (CDS), Center for Food Security Studies (CFSS). His doctoral research focuses on Meteorological Hazard: Causes, Impact on Food Security and Disaster Risk Management Strategy in Borena Pastoralists, Ethiopia.