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Pastoralist Household Vulnerability to Climate Change and Variability-Induced Shock: Adaptation Mechanisms in the Rayitu district, Southeastern Ethiopia

PhD Dissertation

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ABBREVIATIONS

ADB	African Development Bank
AU	African Union
CELEP	Coalition of European Lobbies for Eastern African Pastoralism
CRED	Centre for Research on the Epidemiology of Disasters
DFID	Department for International Development
DRSLP	Drought Resilience and Sustainable Livelihoods Programme
FAO	Food and Agriculture Organization of the United Nations
FDRE	Federal Democratic Republic of Ethiopia
GTP	Growth and Transformation Plan
IBM	International Business Machines Corporation
ICPALD	IGAD Centre for Pastoral Areas and Livestock Development
IGAD	Intergovernmental Authority on Development
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
MoA	Ministry of Agriculture
MoFED	Ministry of Finance and Economic Development
MPD	Ministry of Planning and Development
NPC	National Planning Commission
OPEDC	Oromia Planning and Economic Development Commission
PDC	Planning and Development Commission
PTC	Pastoral Training Centers
UNDRR	United Nations Office for Disaster Risk Reduction
UN-OCHA	United Nations Office for the Coordination of Humanitarian Affairs
VIF	Variance of inflation
WBG	World Bank Group

1. INTRODUCTION

1.1 Research background

Pastoralism is an ancient practice, dating back to the Neolithic period, and it is found on all continents (except Antarctica), although geography and culture shape the different regions (Barrow, 2022). By 2019, between 200 and 500 million people worldwide are engaged in pastoralism, and 75 percent of all countries have pastoralist communities (Mbow et al., 2019). Pastoral farming covers about 25 percent of the Earth's surface, mainly in the developing world, including dry forests in Africa, the Arabian Peninsula, Asia, and Latin America (Dong, 2016), and 61 percent of this, 13 million km², is in Africa (Barrow, 2022).

The FAO (2018) estimates that Africa has a population of some 268 million people, accounting for around 20.37 percent of the continent's total population. Pastoral agriculture covers 36 countries in Africa, covering 43 percent of the continent's surface. The pastoralist system supports 38 million people in Africa, 13.4 million of whom are living in extreme poverty in sub-Saharan Africa (de Leeuw et al., 2019). Pastoral farming is the dominant activity in East Africa, the Horn of Africa, and semi-arid countries, accounting for about 75 percent of the region's total area (Bacsi et al., 2023). In many African countries, livestock accounts for a high share of agricultural GDP and up to one-third of total GDP while providing jobs to pastoralists, traders, truck drivers, butchers, processors, artisans, and tourists (AU, 2010; Hesse and Catley, 2023; Setrana and Adzande, 2022).

In addition to its direct economic benefits, pastoralism plays an important role in ecology and conservation. Extensive grazing helps to maintain habitats, to regulate the structure of vegetation, to disperse seeds, and to recycle nutrients (Manzano et al., 2021; Perley, 2021). In several African countries, a large proportion of protected areas and wildlife reserves overlap with pastoralist areas, where traditional land-use practices and customary institutions have historically coexisted with wildlife (CELEP, 2017; Leitner et al., 2023). Iconic landscapes such as the East African savannas, including Maasai Mara, Serengeti, and Ngorongoro, show how mobile pastoralist systems can preserve biodiversity while also providing revenue for tourism and local livelihoods (Bollig et al., 2013; Bacsi et al., 2023).

Similarly, Ethiopia is one of the main pastoralist countries in East Africa, along with Kenya, Tanzania, and Uganda, and is home to over 20 ethnic groups, including Afar, Somali, Borana, Hamer, Dasenachi, Mursi, Guji, Kerayu, and Nuer. Pastoral areas cover

approximately 61 percent of Ethiopia's 1.1 million km² of total land area and stretch along the borders with Somalia, Kenya, Sudan, and Djibouti. Most pastoralists are concentrated in Somalia, Afar, and Oromia and are predominantly located in lowland areas bordering peripheral regions (Gebremeskel et al., 2019 and Mohamed, 2019).

In Ethiopia, pastoralist households rely heavily on livestock and related activities for their livelihood. The main types of livestock in pastoralist areas are cattle, camels, goats, sheep, and donkeys, which are reared for their meat, milk, wool, transport, and manure. In 2019, agro-pastoral and pastoralist systems accounted for 28 percent of the national livestock population, including 100 percent of cattle and camels, 70 percent of goats, and 50 percent of sheep (ICPALD, 2020). In pastoralist areas, livestock are not only economic assets but also storehouses of wealth, savings, social position, and cultural identity (Muhammad et al., 2019; Scoone, 2022).

Pastoralism in Ethiopia offers many advantages, including employment, income generation, food security, climate variability resilience, cultural importance, and export earnings (Adhiambo Onyango, 2023). It accounts for 10-40 percent of Ethiopia's GDP (Guye et al., 2023), 30-35 percent of its agricultural GDP (MoA, 2012), and 90 percent of Ethiopia's livestock exports (ICPALD, 2020). The pastoral and agro-pastoral sector, in particular the lowland grazing sector, contributes significantly to the national and export markets, producing 34 percent of the national red meat, 38 percent of total milk, 21 percent of cow's milk (Shapiro et al., 2017), and 80 percent of the yearly milk intake (Abduletif, 2019).

Pastoral rangelands provide unique ecological and cultural landscapes, many of which are important for ecotourism and conservation, e.g., lowland wildlife reserves and dry forests producing gum and resin (Alemu and Worku, 2017; CELEP, 2017; ICPALD, 2020). Indigenous knowledge of keeping animal health and herbal medicine continues to be central to local health systems and management of resources in pastoral area (Feyera et al., 2017).

Despite their important contribution, pastoralist area in Ethiopia and across Africa remain largely isolated, and infrastructural gaps remain, with limited access to basic services such as education, health, water, markets, and electricity (AU, 2010; ICPALD, 2020).Persistent political discourse has portrayed pastoralism as backward, unproductive, and environmentally harmful, justifying the sedentary sector, the expansion of crops, and extensive investment in grassland (Gebremeskel et al., 2019; Mohamed, 2019). In Ethiopia,

pastoralists have been formally recognized since the 1990s, and development plans have prioritized settlements, irrigation, and the provision of basic services as the main means of modernization. Meanwhile, implementation gaps, large land acquisitions, and restrictions on cross-border trade have eroded communal property rights, reduced mobility, and undermined the main institutions of pastoralism (FDRE, 1995; MoFED, 2002, 2003, 2006; NPC, 2016; Teka et al., 2022).

In Ethiopia's pastoralist belt, long-term structural constraints are being confronted by a rapidly changing climate: increasing temperatures, increased precipitation variability, and frequent and worsening droughts and floods are causing acute water and grazing shortages and increasing mortality (FDRE, 2021; Mera, 2018; Tesfamariam et al., 2019; WBG, 2021; Kimutai et al., 2025; Tofu, 2023). These lowlands, which are largely dependent on rainwater and lack services, are under further pressure from the degradation of the environment, rapid population growth, chronic poverty, unstable markets, and recurrent land-water disputes. All these factors increase vulnerability and turn climate shocks into cascading and chronic livelihood crises (Addis et al., 2021; Ewalo and Vedeld, 2023; Hordofa and Yazew, 2023; Tesfamariam et al., 2019; Worku, 2024; Gebremeskel et al., 2025).

Pastoral and agropastoral households are not passive victims that arise from climate change. They use various adaptation and management strategies, including the adoption of drought-tolerant livestock, herd diversification, fodder production, soil and water management, small-scale irrigation, pasture fencing, diversification of livelihoods, and new instruments such as livestock insurance indices (Berhanu and Beyene, 2015; Duba et al., 2021; Kemal et al., 2022; Gebbisa and Bacsi, 2025). Household characteristics, access to services and institutions, and the local biophysical context shape the uptake and effectiveness of these strategies (Belay et al., 2017; Zeleke et al., 2023; Sintayehu et al., 2025).

Based on the above broader context, this study examines pastoralist households' vulnerability to climate change and variability-induced shocks and adaptation strategies in the Rayitu district, Southeast Ethiopia, at local and micro levels.

1.2 Problem statement

Policy and statistics in Ethiopia systematically underestimate and misinterpret pastoralism, despite its proven economic, social, and environmental value (Gebremeskel et al.,2019; Mohamed, 2019). National accounts and agricultural surveys typically do not provide

aggregated data on pastoral production, and the country lacks a comprehensive database on pastoral activity. This lack of clear data obscures the true contribution of pastoral production to GDP, exports, employment, nutrition, and ecosystem services (IUCN, 2006).

Although awareness of the policy is gradually improving, a considerable gap still exists between policy commitments and implementation. Since the mid-1990s, Ethiopian development policies and strategies have officially recognized the land rights of pastoralists and promised better services in dry and semi-dry areas (FDRE, 1995; MoFED, 2002, 2003, 2006, 2010; NPC, 2016). In practice, however, public investments continue to prioritize settlement expansions, irrigation schemes, and livestock commercialization. As a result, a policy paradox emerges pastoralism is recognized in policy documents but constrained in practice through little investment in services, infrastructure, and markets that support mobility, exchange, and risk-sharing (MoFED, 2003, 2010; NPC, 2016; Gebremeskel et al., 2019; Teka et al., 2022).

Climate change exacerbates these policy challenges, imposing significant impact on pastoral and agro pastoral groups through rising temperatures, increased unpredictability in rainfall patterns, and frequent droughts. These climate-related stressors make securing pasture and water difficult, leading to increased livestock mortality and deepening food insecurity (FDRE, 2021; WBG, 2021). Pastoralists highly rely on climate-sensitive natural resources, particularly water and pasture, to sustain their livestock-based economies. Consequently, changes in temperature and rainfall patterns render them far more vulnerable and destabilize pastoral production systems (Mera, 2018; Gatew and Guyo, 2024; Kimutai et al., 2025; Worku, 2024).

In 2022, pastoral areas of Ethiopia faced significant challenges due to climate change, especially drought. In the southern and southeastern parts of the country, more than 8 million people are affected by drought; 56% of households reduce their meals to one or two per day during and after drought conditions; 1.5 million livestock have died, and 10 million livestock are at risk during this year; 514,018 children have dropped out of school; and 286,000 people have migrated to different areas in search of water and pasture, leaving behind their elderly and sick relatives, who are increasingly vulnerable (UN-OCHA, 2022). In the same way, declining milk yields and limited access to cereals heighten vulnerability. Rising cereal prices and falling livestock values further strain pastoralist trade, endangering the sustainability of pastoralism (Gebremeskel et al., 2019; FDRE, 2019).

Despite the growing awareness of climate risks, empirical research on adaptation in pastoralist societies still faces considerable methodological limitations. Many studies analyze, first and foremost, the perception and response of pastoralist and agro-pastoralist communities to climate change through household surveys, often without integrating long-term weather data or remote-sensing evidence to support these perceptions (Debela et al., 2015; Tesfahunegn et al., 2016; Mekuyie & Mulu, 2021). Additionally, although short-term management responses are frequently examined in conjunction with long-term adaptation strategies, comprehensive monitoring of their effects on milk production, herd dynamics, survival rates, and resilience is still inadequate. This hinders drawing comprehensive conclusions about the effectiveness of such strategies (Wario et al., 2016; Gebeyehu et al., 2021; Lelamo et al., 2022).

Similarly, understanding the determinants of perception, vulnerability, coping, and adaptation in pastoralist systems remains inadequate. Many econometric studies apply analytical frameworks originally designed for mixed farming systems, focusing on general socioeconomic variables while neglecting key pastoral-specific factors such as livestock composition, migration patterns, access to grazing and water sources, conflict history, participation in PSNP and IBLI, and the role of pastoralist institutions (Debela et al., 2015; Megersa et al., 2014). Excluding these variables risk overlooking the real drivers of household decision-making and underestimating the critical role of mobility, herd management, and social institutions in shaping vulnerability and adaptive responses (Zeleke et al., 2021).

Another methodological limitation relates to the analytical models used to study adaptation strategies. Most empirical studies on Ethiopian pastoralists employ multinomial logistic models that assume households adopt only a single strategy (Mengistu & Haji, 2015; Duba et al., 2021; Kemal et al., 2022; Tamene et al., 2023; Cherinet et al., 2025). However, pastoralists typically combine multiple, interrelated strategies, such as herd mobility, livelihood diversification, fodder storage, drought-resistant livestock, water harvesting, and irrigation. Treating this decision as interdependent can generate estimation bias and lead to inefficient policy recommendations. Multivariate probit models, which account for correlated decision-making, offer a more appropriate approach but remain rarely applied in Ethiopian pastoralist research (Ndiritu, 2021; Gebbisa and Bacsi, 2025; Feyissa et al., 2025; Regasa, 2025).

Beyond methodological gaps, a knowledge integration gap exists between scientific and local perspectives on climate risks and adaptation. Scientific research typically relies on climate models, drought indices, and national statistics (Gebbisa and Bacsi, 2025), whereas pastoralist communities draw upon long-term experience, local environmental indicators, and indigenous institutional systems (Debela et al., 2015; Tesfahunegn et al., 2016; Destaw & Fenta, 2021). If these knowledge systems are not systematically integrated, climate interventions could be technically sound but socially unacceptable, or they could be based on local knowledge but lack credible climate evidence. Therefore, connecting these perspectives is essential for designing scientifically sound yet socially acceptable adaptation and risk management strategies (Habte Mariam et al., 2016; Habte et al., 2020; Duba, 2022).

Moreover, the geographical distribution of research on climate change, drought, perception, vulnerability, and adaptation strategies in Ethiopia is uneven. While most studies concentrate on high-altitude areas or accessible mixed-farming regions, several lowland pastoralist areas remain understudied due to security concerns, logistical difficulties, and limited data availability (Gebremeskel et al., 2019). Similarly, the highland area of the Eastern Bale zone has received more attention than the pastoral area (Gebbisa and Bacsi, 2025). This spatial imbalance limits the evidence base available to local planners and authorities responsible for climate adaptation planning (NPC, 2016; PDC, 2020).

Taken together, these policies, methodological, knowledge, and spatial gaps collectively make the need for more comprehensive research on pastoral livelihoods under climate change apparent. Therefore, this study aims to fill these gaps by offering strong evidence and practical suggestions to improve climate adaptation policies for pastoralist communities in Ethiopia.

1.3 Objectives of the study

The general objective of this study is to examine pastoralist households' vulnerability to climate change and variability-induced shocks: Adaptation strategies in the Rayitu district, Southeast Ethiopia**.** The specific objectives of the study were defined as follows:

1. To analyses the long-term variability and trends in precipitation and temperature and their correlation between them in the study area
2. To quantify the inter-annual precipitation distribution and the dominance of mild drought in the study area.

3. To analyse the indicators of perceptions and to identify the key determinants that influence household perceptions of climate change
4. To measure pastoralists' vulnerability to climate change at the household level and identify its determinants in the study area.
5. To examine local pastoral household coping and adaptation mechanisms towards climate change and identify its determinants in the study area.

1.4 Research hypotheses

The following hypotheses guided the study:

1. The monthly precipitation varies by seasons without an annual precipitation trend
2. Annual and seasonal temperatures show a positive trend and temperatures are negatively correlated to precipitation.
3. Annual precipitation is concentrated in specific months, and the occurrence of mild drought is dominant
4. A higher proportion of pastoralist households perceive direct (meteorological) climate impacts than indirect (livelihood-related) climate change indicators.
5. Economic and environmental/physical capital endowments have stronger magnitude effects on household perception than socio-demographic and institutional factors.
6. The combined effects of human and financial capital are expected to have a stronger influence on household vulnerability than natural and physical capital.
7. Higher human capital endowments (education, training, livelihood experience, health status) reduces the probability of high vulnerability of pastoralist household.
8. Human, social, financial, natural, and physical capital have significantly different effects on pastoral households' coping and adaptation strategies.

1.5 Significance of the study

The research findings could have a significant impact on various stakeholders and help Ethiopia to achieve its sustainable development goals. The study provided context-specific evidence concerning the impacts of climate change, droughts, precipitation, and vulnerability on pastoral livelihoods in Ethiopia. The study measures the vulnerability of households, linking it to their lifestyle, their approach to challenges, and their resilience. This research filled an important gap and helped global efforts to reduce poverty, improve food security, support sustainable communities, and enhance climate action (SDGs 1, 2, 11,

and 13). By separating short-term strategies that can use up resources from long-term strategies that help build resilience, the study will offer practical advice for creating better drought risk management, livelihood support, and social protection that fit local needs. The findings can guide targeted investments in infrastructure, services, early warning systems, and livelihood support for vulnerable households and contribute to Ethiopia's broader agenda for climate change adaptation and pastoralism. The study strengthens the knowledge concerning climate vulnerability by applying a rigorous framework to show how the five livelihood capitals together shape the vulnerability and resilience of pastoralist households.

1.6 Structure of the Study

The research is structured into seven chapters. Chapter one presents the introduction, the study outlining background, the research problem, the general and specific objectives, and the research's relevance. Chapter 2 provides a comprehensive review of the literature, analyzing the theoretical foundations of the study, the empirical investigations of prior research, and the research gap. Chapter 3 gives a full description of the research methodology, including the design and approach, the target population, the sampling methods, the sample sizes, the conceptual frameworks, and method of data analysis. Chapter 4 presents and analyzes the findings of the study, supported by relevant evidence, while Chapter 5 discusses the conclusions, the policy implications, and the recommendations for stakeholders. Chapter 6 highlights the new scientific contributions of the study and provides a synthesis of the research. The last chapter deals with the summary of the study.

1.7 Operational Definitions

- **Adaptation Strategies:** Longer-term, deliberate adjustments made by households or communities intended to reduce future vulnerability and build resilience to climate change and variability, involving changes in livelihood strategy or resource use.
- **Climate Change:** A long-term (typically ≥30 years) statistically significant shift in the mean or variability of temperature and rainfall patterns in a specific area, attributable directly or indirectly to human activity, alongside natural climate variability observed over comparable time periods.
- **Climate Variability:** Short-term (seasonal, annual, or interannual) fluctuations in climate parameters (such as rainfall and temperature) around a long-term average, occurring within a normal range without necessarily indicating a long-term trend.

- **Coping Strategies:** Short-term, immediate responses employed by households to survive an ongoing or recent climate shock (e.g., drought), without necessarily altering their long-term livelihood system.
- **Drought:** A prolonged period of below-normal rainfall that results in decreased pasture and water availability, negatively impacting livestock and household welfare, as recorded through meteorological data or community/key informant recall.
- **Household Perception (of Climate Change/Variability):** The extent to which household heads or members report observing and interpreting changes in climate-related parameters (such as rainfall onset and cessation, amount, temperature, and frequency of drought) over a recalled reference period
- **Pastoral Household:** household whose members derive the majority (typically ≥50%) of their income, food, or livelihood from livestock production and related activities, practicing either full or partial mobility in search of pasture and water for their animals.
- **Pastoralism:** A livelihood and production system founded on extensive, mobile livestock rearing on natural rangelands, where herd mobility serves as the primary strategy to access seasonally and spatially variable pasture and water resources.
- **Pastoralist Area:** A geographic region characterized by arid and semi-arid agro-ecological conditions, marked by low and erratic rainfall, where land use is primarily dominated by extensive livestock grazing as the main economic activity.
- **Perception:** An individual's or household's subjective awareness, understanding, and interpretation of a phenomenon (e.g., climate change), shaped by personal experience, observation, and knowledge
- **Vulnerable Area:** An administrative or agro-ecological zone that experiences high exposure to climate-induced shocks (such as drought or flooding) and possesses limited institutional, infrastructural, or economic capacity to withstand or recover from these shocks.
- **Vulnerable Household:** A household characterized by a combination of high exposure to climate shocks, heightened sensitivity, and low adaptive capacity, placing it at a greater risk of livelihood loss compared to other households in the same area.

2. LITERATURE OVERVIEW

2.1 Theoretical Review

2.1.1 Definition of Pastoralism and Vulnerability

2.1.1.1 Pastoralism

Different scholars define pastoralism differently, depending on production systems, the type of land used, ethnicity, and cultural characteristics.

Pastoral production systems are characterized by households that earn at least 50 percent of their gross income from pastoralism or related activities, which include both market production and consumption for subsistence. Alternatively, a system is considered pastoral if it generates more than 15 percent of the household's consumption of milk or milk products. These systems rely mainly on livestock production through grazing, with more than 90 percent of the feed for livestock composed of dry matter and less than 10 percent of the total production coming from non-livestock activities. On the other hand, agricultural pastoralists receive between 25 and 50 percent of their income from livestock and the rest from crops (Swift, 1988).

Pastoralism is any production system that is mainly dedicated to livestock, characterized by extensive practices and the use of various forms of mobile stock (Hatfield and Davies, 2006). In Africa, pastoralism is both a way of life and a system of production adapted to arid and semi-arid areas. The term implies a significant dependence on livestock for economic and social welfare and uses strategic mobility to access water and grazing resources in areas with high rainfall variability (AU, 2010).

Pastoralism is both an economic activity and a cultural identity, although the former does not necessarily imply the latter. From an economic perspective, it is an animal production system that thrives on the stability of the pastoralist environment, where basic resources such as nutrients and water are often available in unpredictable concentrations. Pastoralists are focused on understanding the complex dynamics between humans, animals, and the environment, the strategic movement of animals, and the satisfaction of their nutritional needs. They also introduce adaptive resource management systems, including communal land management institutions and shared rights over water resources (Republic Kenya, 2012).

Pastoralism is a holistic livestock-and-land management system built on herd mobility, through which pastoralists sustain their livelihoods, protect natural resources, and preserve a culture deeply tied to environmental stewardship, applying extensive grazing methods on rangelands worldwide to address environmental challenges (Davies et al., 2016). It typically develops in remote areas marked by poor soil or water quality, extreme temperatures, steep terrain, or isolation, enabling communities to sustainably, independently, and adaptively manage common resources, shared values, and ecosystem services (Jenet et al., 2016).

More recently, scholars have proposed a comprehensive definition of pastoralism that covers all aspects of production systems, soil types, and cultural factors. According to this definition, pastoralism is both a means of livelihood and a method of production, which involves the rearing of domestic animals in communal grassland areas by means of herds and the mobility of households. These areas are often characterized by problems such as limited water resources, poor soil quality, extreme temperatures, difficult terrain, or isolation. Despite these difficulties, pastoralism allows communities to manage resources in a sustainable way, with independence and flexibility. It represents the rights to common resources, to common values, and to ecosystem services (Homewood et al., 2019).

2.1.1.2 Vulnerability

The concept of vulnerability occupies a central position in climate change research, yet it remains one of the most contested and variably defined terms in the field. Its meaning has evolved considerably across successive assessment cycles of the Intergovernmental Panel on Climate Change (IPCC) and has been shaped by contributions from scholars working within biophysical, social-ecological, and political-economy traditions. This study identifies the definition related to climate change only as follows:

Vulnerability is a property of coupled human–environment systems that emerges from the interaction of exposure, sensitivity, and resilience and cannot be assessed by examining climatic hazards in isolation. Turner and colleagues argue that these three elements must be understood as properties of an integrated social-ecological system rather than as separate technical variables (Turner et al., 2003).

Another scholar, Adger (2006), also defines “vulnerability” as a state in which individuals are highly likely to suffer harm due to exposure to stressors related to environmental and social changes or are at risk of harm due to a lack of adaptive capacity (Adger, 2006).

Vulnerability is a function of three interacting components that are exposure, sensitivity, and adaptive capacity and expressed as “vulnerability = f (exposure, sensitivity, adaptive capacity).” This formula treats vulnerability as a collective and outcome-oriented characteristic of a system, meaning that vulnerability is the result arising from the interaction between exposure and the system’s internal characteristics (IPCC, 2007).

According to Cardona et al. (2012), vulnerability is the propensity of exposed elements such as people, infrastructure, livelihoods, and ecosystems to suffer adverse effects when impacted by hazard events, a propensity shaped by their inherent susceptibility or fragility and their lack of resilience or capacity to cope an

Vulnerability is "the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2014).

According to the IPCC (2022), vulnerability refers to the propensity or predisposition of a system, community, or population to be adversely affected by climate-related hazards. It encompasses both sensitivity or susceptibility to harm and limited capacity to cope with, adapt to, and recover from impacts. Vulnerability is unevenly distributed across social groups, geographic contexts, and time, reflecting underlying social, economic, political, and institutional conditions. This definition is both scientifically rigorous and directly applicable to adaptation policy and planning. It cleanly separates vulnerability from exposure, allowing for more precise and comparable risk assessments.

2.1.2 Pastoralism in Africa

2.1.2.1 Historical origin of pastoralism in Africa

There is evidence of domestic rearing of cattle in the Horn of Africa and the Northern Sahara from 11,000 BP to 7,500 BP. It is believed that Saharan communities along the middle Nile were the first to domesticate cattle around 9500 BC, which predates by at least 1,000 years the earliest domestication of cattle in Southeast Asia. Around 11,000 BC, sheep and goats were first domesticated in what is now Syria and Palestine and then spread south to Northeastern Africa (Homewood, 2008).

Pastoral culture probably spread from the Nile Valley to North Africa, probably facilitated by the ancestors of the Berber people. By 7,000-6,000 BC, the descendants of the Cape people (the ancestors of the Berbers) were engaged in Mediterranean agropastoralism

throughout the whole of North Africa. This included the rearing of cattle, sheep, and goats, as well as the growing of domesticated varieties of Middle Eastern wheat and barley (Homestead, 2008).

Pastoralism, based on domestic cattle, sheep, and goats, spread southwards from about 7000 BC, leaving a series of striking rock art images throughout the central and southern regions of the Sahara. As the Sahara's climate gradually dries up and becomes increasingly inhospitable, populations have once again migrated south and east. Researchers estimate that the Sahara lost its bovine suitability between 5,000 and 4,000 BP. Researchers believe that during this time, pastoralists from the north migrated to East Africa and combined pastoralism with other activities such as cultivation, hunting, and fishing. Moreover, between 4500 and 3500 BP, the Horn of Africa welcomed cattle, the last of the animals to be reared for African pastoralism (Homewood, 2008).

Currently, pastoralism supports about 268 million people across Africa's arid and semi-arid regions, from the Sahel to East and Southern Africa (FAO, 2018). Pastoral areas cover approximately 43% of the continent, or 13 million km², and pastoralism is practiced in 36 African countries (FAO, 2018). Pastoralist populations are also growing by about 2.5–3.5% annually (AU, 2010).

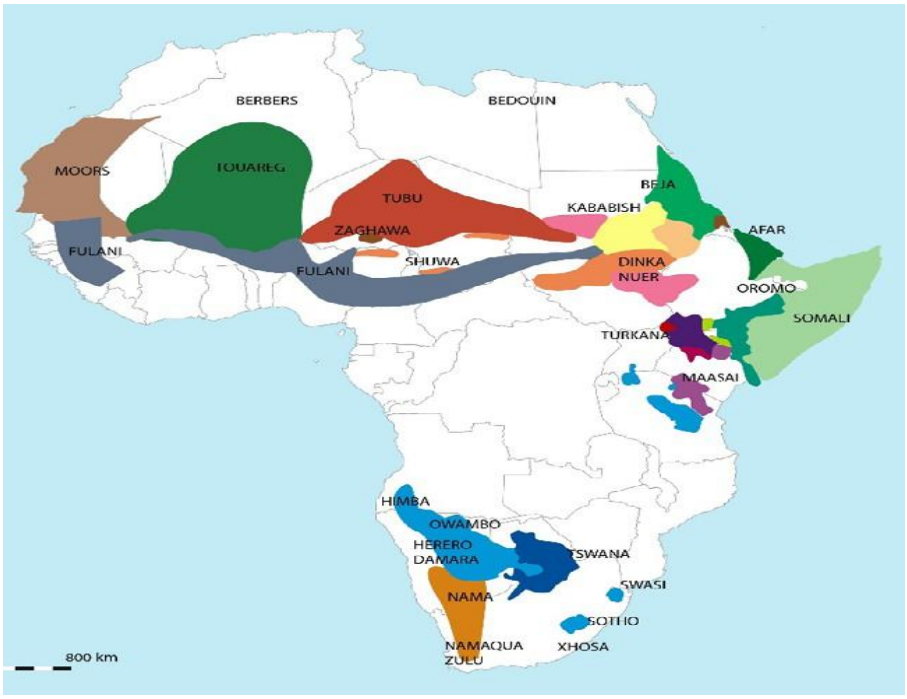
The geographic location of most pastoralist communities in Africa is typically in isolated, remote, and undeveloped areas, which are often vulnerable to climate change, conflict, and food insecurity, leading to high vulnerability levels. In general, services in these areas are less developed than in other regions, and health and education indicators are below national averages (AU, 2010).

According to Nori (2022), more than 29 African pastoralist groups inhabit vast grasslands, creating culturally distinct regions. across extensive grasslands, forming culturally distinct regions. Some groups also live in nearby areas, creating social clusters shaped by historical interactions and coexistence. These groups reflect Africa's rich diversity in culture, language, and traditional pastoral practices and can be classified as follows:

- North Africa & Sahara: Moors (Hassaniya Arabs), Berbers including Tuareg (Kel Tamasheq), Bedouin, Tubu, and Zaghawa.
- West & Central Sahel: Fulani/Peul, plus overlaps of Tuareg, Tubu, Zaghawa, and Shuwa/Arab (around Lake Chad).

- Eastern Africa drylands: Dinka, Nuer, Kababish (Arab camel pastoralists), Beja, Somali, Afar, Oromo (incl. Borana), Turkana, and Maasai.
- Southern Africa (Southwest & South): Himba, Herero, Damara, Ovambo (Owambo), and Nama/Namaqua; and mainly agro-pastoral pockets among Tswana, Sotho, Zulu, Xhosa, and Swazi.

Figure 1: Ethnic group distribution and diversity of pastoral group in Africa



Source**:** Nori, 2022.

Pastoral areas in Africa are shared by arid and semi-arid rangelands, mobile livestock production (nomadism and transhumance), traditional institutions regulating access to water and grazing under high rainfall, and family-based networks (FAO, 2018; AU, 2010; Homewood et al., 2019).

2.1.2.2 The socioeconomic contribution of pastoralism in Africa

Livestock plays a key role in boosting rural incomes, ensuring nutrition and food security, and building resilience among smallholder farmers in much of Africa, especially in mixed-crop, livestock, and pastoral systems. In many African countries, 60–80 percent of rural households keep livestock, which are used as movable and liquid assets, as a source of income, and as a source of food security and nutrition for households. In addition, livestock

products make an indirect and significant contribution to crop production through the provision of organic fertilizer (manure) and animal feed (AU, 2015).

Pastoralism is an important contribution to Africa's economies. The economic value of pastoralism in Africa is US$1.3 trillion, or 30 percent of the continent's GDP. In many African countries, the livestock sector accounts for as much as 80 percent of agricultural GDP (Hesse and Catley, 2023).

The average pastoralist household uses at least 50 percent of the total value of marketed and subsistence livestock production (AU, 2010). In Uganda, pastoralists own about 90 percent of the total livestock in the country, which is a source of meat, hides, leather, and milk for local and world markets. The agro-pastoral and pastoralist systems account for 70 percent of total milk production in Tanzania, at 1.18 billion liters. Pastoral production accounts for an estimated 80 percent of Ethiopia's annual milk intake (CELEP, 2017).

Pastoralism also has a significant impact on the local economy, as illustrated by the thriving industry processing and marketing animal by-products. It is often recognized that the husbandry of pastoral animals plays a key role in the supply of fresh milk, yogurt, butter, traditional cheeses, and other goods to the cities. Pastoral women are active in the market for animal by-products because they own and sell the milk produced by their family cows. Women in pastoralist families use the income from these sales to support themselves and to contribute to family expenditures such as childcare (AU, 2022).

Parks and protected areas in pastoralist areas in Africa are vital conservation assets for biodiversity, integrating traditional land management practices (Leitner et al., 2023). These areas also attract tourists, increasing income for local communities and underlining the sustainable coexistence of humans and nature on African savannas (Bacsi et al., 2023). In Tanzania, more than a third of protected areas are historically pastoralist-owned; in Kenya, 92 percent of protected areas are pastoralist-owned, a pattern that is similar in other African countries (CELEP, 2017). Iconic sites such as Maasai Mara National Reserve, Serengeti National Park, Amboseli National Park, Ngorongoro National Park, Virunga National Park, and Tsavo National Park are examples of a balanced approach between conservation and traditional livelihoods (Bollig et al., 2013).

In addition to its economic benefits, African pastoralism is also important for the conservation of ecosystems. Livestock grazing is beneficial in preventing forest fires,

controlling invasive species, and promoting soil fertility, among other benefits. Climate change recognizes these systems for their resilience. The use of the countryside as an ecological and political space has fostered a growing appreciation of its economic value, with large pastoralist economies emerging as the only systems able to manage such large areas efficiently (Ploch, 2010).

2.1.3 Pastoralism in Ethiopia

2.1.3.1 The Potential and Contribution of Pastoralism in Ethiopia

The livestock population in the pastoral and agro-pastoral systems of Ethiopia is considerable. Estimates of the population up to 2019 are 14.1 million bovine animals, 4.5 million camels, 20.4 million goats, and 15.7 million sheep. These figures correspond to 23, 100, 62, and 50 percent of the national livestock population for cattle, camels, goats, and sheep, respectively. At the national level, 65 percent of the livestock population is in pastoralist areas and 35 percent in agro-pastoral systems (ICPALD, 2020).

Pastoralism is an essential for its economic, environmental, and socio-cultural value. Economically, it supports livelihoods and regional economies and promotes environmental sustainability. From an ecological point of view, it maintains basic ecosystem functions such as seed dispersal and nutrient distribution. From a socio-cultural point of view, pastoralism is deeply linked to community identity and traditions and reflects a moral economy based on a subsistence ethic. Overall, pastoralism supports a diverse and resilient population and ecosystem (Muhammad et al., 2019).

In terms of economic value, livestock production in Ethiopia's pastoral and agro-pastoral areas generates huge wealth and income for households as well as for the national economy (IPAD, 2020). Pastoralism is an important economic driver, accounting for 10-40 percent of GDP (Guy et al., 2023) and 30-35 percent of agricultural GDP (MoA, 2012). Ethiopia has the highest livestock population in Africa and the fifth largest in the world, with pastoralists accounting for 20 percent of national exports and 90 percent of live exports (Mohamed, 2019).

The pastoral and agro-pastoral sectors produce 34 percent of the national red meat, 38 percent of total milk, 21 percent of milk from cows (Shapiro et al., 2017), and 80 percent of the annual milk intake (Abduletif, 2019). These high-quality, nutritious animal products are essential for impoverished, marginalized, and undernourished populations, for young

children and pregnant women (Scoones, 2022). The leather industry, which is an important source of foreign currency for Ethiopia, is highly dependent on the raw materials of pastoralism. In addition, pastoral livestock provide transport services, serve as household property, and provide a safety net in the event of food or cash shortages (Gebremedhn et al., 2023).

On the social side, Ethiopian communities have deeply integrated pastoralism into their cultural heritage, promoting highland cultures and attracting tourists (Salachna et al., 2022). Livestock represent wealth and social status in pastoralist societies. More than 70 percent of the wildlife reserves and parks of Ethiopia are in pastoralist areas (ICPARD, 2017), making them ideal places for ecotourism initiatives. The unique culture and lifestyle of pastoralist communities is a great source of inspiration for tourism (ICPALD, 2020).

In these communities, native knowledge and ethnoregional practices are widespread, based on traditional methods and locally available herbal medicinal products (Feyera et al., 2017). Women and adolescents play an important role in managing natural resources, although the authority and control of these resources is usually vested in older men (ICPALD, 2017).

From an ecological point of view, pastoralism plays a key role in maintaining biodiversity, creating habitats, and managing vegetation (Manzano et al., 2021). It provides basic ecosystem services such as grazing, which is an effective tool to maintain and restore biodiversity (Perley, 2021). The lowland regions of Ethiopia, home to many ecological and historical sites, are important tourist attractions. These include the Afar archaeological site, which is registered by UNESCO, and other spectacular and unique landscapes (ICPALD, 2020).

Agro-pastoral and pastoral areas cover about 1.2 million hectares of dry forest, which produces 31,850 tonnes of gum and resin per year (Alemu and Worku, 2017). These areas help to maintain the nutrient balance of the soil and to support the biodiversity of the flora of the lowland grasslands (Gazheng, 2016). Pastoral farming is essential to maintain biodiversity in the rangelands, to act as a carbon sink, and to promote ecological balance and sustainable tourism (Gebremedhn et al., 2023). Indigenous knowledge of pastoralist communities contributes to the management of landscapes, the sustainable use of natural resources, and the conservation of ecological diversity.

2.1.3.2 Pastoral Development Policy and Strategy in Ethiopia (1995 to 2025)

Over the last three decades, Ethiopia's pastoral development agenda has been guided by successive national policies and strategies, which have been subsequently adapted by the region in a context of continuing tension between recognizing pastoralist rights and promoting modernization and sedentarisation (FDRE, 1995; MoFED, 2002, 2003, 2006; NPC, 2016; PDC, 2020).

The 1995 Federal Constitution recognizes the rights of pastoralists to land and natural resources and sets out broad social and economic objectives for fair development, including access to unoccupied pasture and a fair price for the benefit of the population and a fair share of national prosperity (FDRE, 1995). However, implementation gaps remain: large-scale investment, land conversion, and restrictive cross-border trade regimes have weakened communal ownership and reduced market access, undermining the transformative promise of the constitution (Gebremeskel et al., 2019).

The 2001 Rural Development Strategy and Instruments called for immediate support for pastoralist livelihoods while pursuing a long-term strategy of irrigation and planned settlements, together with participatory water management to prevent rangeland degradation (MoFED, 2003). Building on this, the 2002-2005 Programme for Sustainable Development and Poverty Reduction proposed a differentiated approach: voluntary sedentarisation where river irrigation is possible; improved basic services for settled and semi-settled groups; and integrated, mobile social services, health and education packages for households with mobility (MoFED, 2002). The SDPRP also recognized the institutional ambiguities and infrastructure deficiencies in pastoralist areas and directed resources to pro-poor investments such as agriculture, roads, schools, health, and drinking water systems to reduce spatial disparities (MoFED, 2006).

The medium-term plan for accelerated and sustainable development to end poverty (PASDEP, 2005-2010) sought to reduce poverty by increasing agricultural productivity and strengthening links between the rural and the industrial sectors. It also included a dedicated pillar for pastoralist regions, with priority given to asset-building, water development, environmental protection, education, health, and institutional capacity for broadening access to basic services (MoFED 2006; Dagne et al., 2022). However, the impact has been limited by the continuing mobility constraints, the weak market integration, and the limited

availability of services in the dry regions, which highlights the difficulty of aligning national growth strategies with the ecological diversity and livelihood flexibility characterizing pastoralist systems (MoFED, 2006).

The Growth and Transformation Plan I (GTP I, 2010-2015) aimed at modernizing the economy and specifically identified smallholder farmers, pastoralists, and private investors as actors for development. The interventions prioritized water and transport infrastructure, genetic improvement and veterinary services, the development of market systems, and voluntary resettlement in areas with irrigation systems (MFFED, 2010). Yet pastoral areas continue to be affected by recurrent droughts, conflict, and resource scarcity, while climate variability, poverty, and uneven service delivery continue to constrain social progress; even flagship social protection initiatives have achieved only marginal poverty reduction in many pastoral areas (Mohamed, 2019; Teka et al., 2022).

The Growth and Transformation Plan II (2016-2020) has intensified the focus on infrastructure and service provision in the drylands, with emphasis on potable water for households and livestock, small-scale irrigation from surface and groundwater, grazing extension schemes, interconnections, and institutional strengthening to address implementation bottlenecks in the construction of water and roads (NPC, 2016). While these measures have increased physical access and created opportunities for local markets and services, unresolved issues of communal land ownership, rangeland management, and the inclusion of mobile groups continue to shape results, highlighting the value of policies that internalize mobility, reciprocity, and risk sharing as core elements of pastoralism rather than barriers to overcome (NPC, 2016).

The ten-year development plan (2021-30) builds on the comprehensive pastoral program linking livestock development to regional trade and urban interfaces, aiming at the expansion of infrastructure and social services in pastoral and border areas, and emphasizing cooperation with neighbouring countries (PDC 2020). The complementary pillars are livelihood diversification, environmental protection, institutional capacity building, and social inclusion to promote a more resilient and diversified pastoralist economy integrated into the national development framework (PDC 2020). The cumulative policy trend thus reflects iterative learning about the expansion of services and infrastructure but also reveals a continuing normative bias towards sedentarisation as a presumed path to social improvement, often in contradiction with evidence of the environmental and economic

rationality of mobility in a changing dry environment (Gebremeskel et al., 2019; Mohamed, 2019).

Conclusively, the Ethiopian government's strategies for the period 1995-2025 formally recognize pastoralists while often favouring the model of settled production and services. This focus is based on persistent misconceptions that characterize pastoralism as economically marginal and environmentally degrading, which in turn justify interventions that favour crop-based agriculture and urban development over mobile livestock systems (Gebremeskel et al., 2019; Mohamed, 2019; Abebe et al., 2022). A theoretical analysis of this policy trajectory suggests that more effective and equitable results require refocusing pastoral development on mobility-friendly services, community-based tenure, risk management, and market arrangements that reward livestock mobility and cross-border trade, along with safety nets that are increasingly aligned with the principles of climate change resilience and dryland development (Teka et al., 2022).

2.2 Climate Change and Variability in Ethiopia

2.2.1 Historical trends of temperature and precipitation

Climate variability involves short- to multi-decadal fluctuations in temperature and rainfall driven by natural processes and human influences that alter atmospheric composition, often manifesting as prolonged droughts and intense floods. Climate change, in contrast, is a statistically significant, long-term shift in the climate system’s mean state or variability over decades or longer times (Koroso et al., 2023).

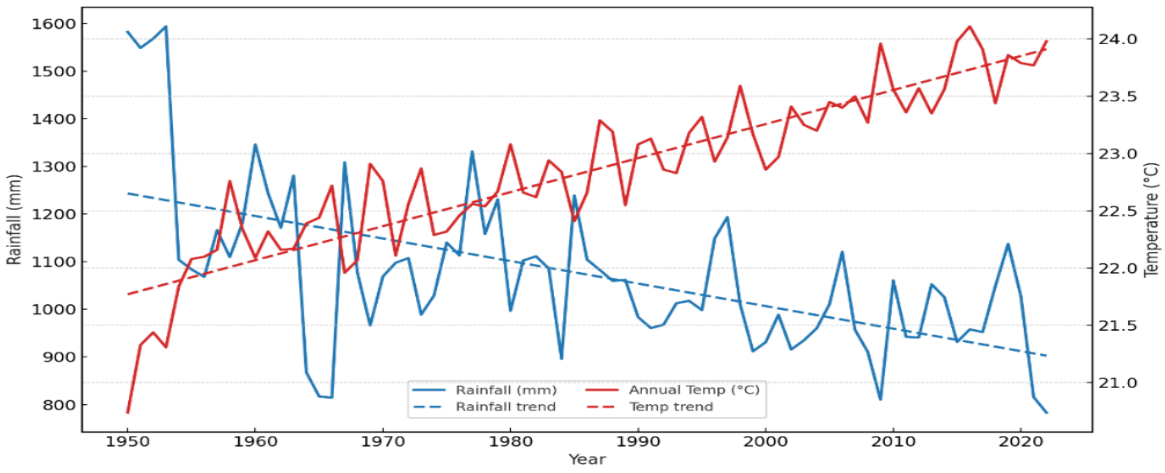
Against this global backdrop, Ethiopia’s contribution to global greenhouse gas emissions is negligible, about 0.04% (Crippa et al., 2019), yet the country is highly vulnerable to climate change because of its heavy reliance on rain-fed agriculture and natural resources and its relatively low adaptive capacity. Over the past 60 years, the climate signal has become clear: national mean temperatures have risen by roughly 1 °C since the 1960s, while rainfall remains highly variable across years, seasons, and regions, with interannual deviations around the mean of about 25% and up to 50% in some areas. Evidence also points to a 20% decline in rainfall in south-central Ethiopia, compounding risks to agriculture, water resources, and livelihoods (FDRE, 2021).

Consistent with these patterns, Ethiopia’s temperature showed a strong, steady warming across the record period of 1950–2022. A simple linear fit indicates an increase of about

+0.30°C per decade (approximately +0.03°C per year), equivalent to roughly +2.1°C from 1950 to 2022. Decadal averages rise almost monotonically from 21.81 °C in the 1950s to 23.67 °C in the 2010s and 23.85 °C for the partial 2020s (2020–2022). The lowest annual value is 1950 (20.74 °C); the highest cluster occurs in the mid-2010s, peaking at 2016 (24.11 °C) with similarly high values in 2015 and 2022 (both 23.98 °C). In summary, there has been a persistent warming temperature without any long-term reversals (WBG, 2023).

Complementing the temperature signal, annual rainfall is highly variable year-to-year but exhibits a downward long-term trend. A linear fit indicates a decline of about 47 mm per decade (–4.7 mm per year), implying a net drop of roughly 340 mm over 1950–2022. Based on data from 2020 to 2022, decadal means were about 1,301 mm in the 1950s, about 1,005 mm in the 2010s, and about 875 mm in the 2020s. Extremes also move lower on the dry side; the wettest year is 1953 (1,593.9 mm), while very dry years include 2009 (810.4 mm) and 2022 (783.3 mm). In short marked interannual variability superimposed on a gradual long-term decline (WBG, 2023). Figure 3 indicates the trend of rainfall and temperature over the past 72 years in Ethiopia, starting from 1950 to 2022.

Figure 2: Historical trend of rainfall and temperature in Ethiopia (1950-2022)



Source: Author's own computation and data organized from (WBG,2023)

Based on the status, Ethiopia is experiencing high temperatures and warming, characterized by increasingly frequent hot conditions and greater heat stress in the future. The projection indicated that mean temperatures would rise by about +1.8°C by the 2050s and +3.7°C by the 2080s–2090s under a high-emissions pathway. The share of “hot” days is expected to grow sharply to roughly 19–40% of days by the 2060s and 26–69% by the 2090s, with the

fastest increases during July–September. These hotter conditions will accelerate evapotranspiration, compounding risks for people, livestock, crops, water resources, and ecosystems (FDRE, 2021; MPD, 2025).

In the same way, rainfall is highly variable across years and seasons in Ethiopia, and long-term signals remain uncertain; however, multi-model projections suggest as much as a 20% decline in spring and summer rainfall in southern and central regions, increases in parts of the southwest and southeast, and a general decrease toward the north. Even in areas where rainfall totals increase, warmer temperatures are expected to accelerate evapotranspiration, which offsets these gains and contributes to greater water stress, drought, and flood risks that challenge agriculture, ecosystems, and hydropower (FDRE, 2021; MPD, 2025).

For a long period, Ethiopia and its nations have experienced expensive natural disasters due to climate change. Droughts, floods, diseases of people and animals, pests and diseases of crops, hailstorms, landslides, volcanic eruptions, and wildfires, which are peculiar to certain regions, are major climate-related hazards in the nation that significantly impact the livelihoods of many people (WBG, 2021; FDER, 2019). From 1900 to 2020, there were 16 droughts, 2 earthquakes, 19 epidemics, 41 floods, 5 landslides, and 3 volcanic events in Ethiopia (WBG, 2021).

Agriculture accounted for 37.6% of Ethiopia's GDP in 2022. The strong link between economic performance and rainfall stems from low irrigation coverage (only 2% of arable land), making the sector highly vulnerable to climate variability (WBG, 2021). In 2015/16, droughts led to a 1–4% decline in GDP, while estimates suggest that soil erosion from rainfall reduces GDP by 2–3% annually (Singh, 2019). Between 2013 and 2020, about 2.65 million hectares of cropland (7.08% of the total) were damaged due to climate-related factors such as floods, high temperatures, and infestations (UNDRR, 2020). Between 2016 and 2021, climate-related factors caused the death of approximately 108 million livestock (11.5%) and 259 million poultry (70%), which affected the livelihood of smallholder farmers and pastoralists in the vicious circle of poverty (WBG, 2021).

2.2.2 Drought in Ethiopia and its impacts on the pastoral system

Ethiopia's history of drought has shifted from episodic crises to a permanent seasonal risk since the 1970s. During the Wollo famine (1972-1975), a further 13.3 million people were affected by successive droughts, and a decade later, the famine of 1983-1985, triggered by

severe drought, conflict, market failures, and political failings, affected a further 23.75 million people, making droughts a national risk (Mera, 2018). During the 1990s and 2000s, severe events recurred as seasonality became more pronounced: autumn rains (March-May) in many regions were weakened by spring (June-August) rains, while summer rains (June-August) showed mixed or localized increases, which made planning and recovery difficult (Tesfamariam et al., 2019). The two back-to-back national crises in 2002 and 2003 affected 14.0 and 12.6 million people, respectively, signing the shift to chronic, broad-based impacts (CRED, 2025; Mera, 2018).

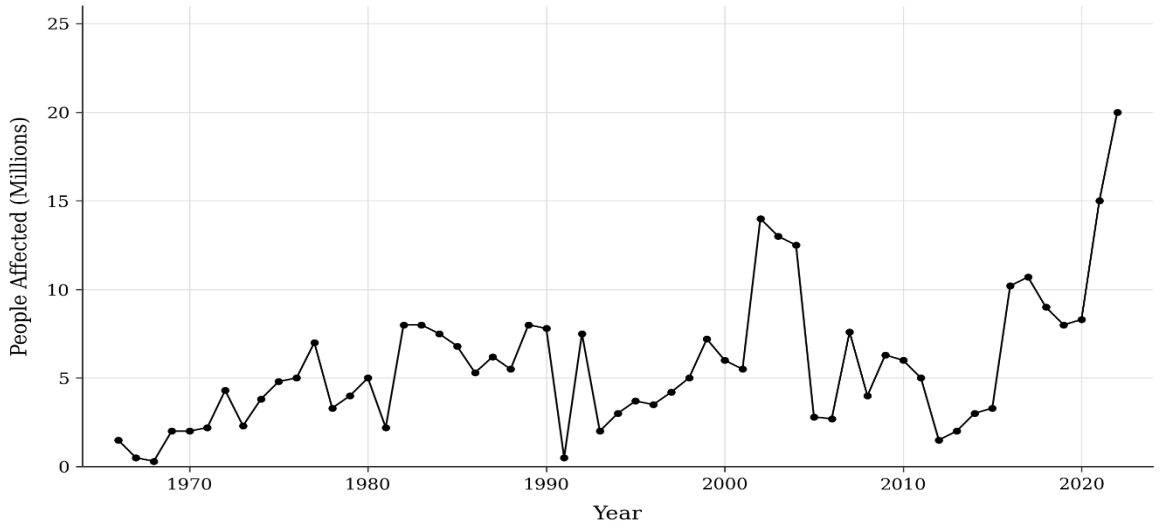
Since 2015, the extremes have intensified and have spread over different seasons. The severe El Niño of 2015 and 2016 (Tesfamariam et al., 2019; Kourouma et al., 2022) caused 10.2 million people to be affected in 2015 and 10.7 million in 2016 (CRED, 2025; Mera, 2018). The sequence of La Niña-dominated rainy seasons between 2020 and 2023 brought the worst multi-seasonal drought in almost 50 years (Kimutai et al., 2025), with a peak of 24.1 million in 2022, followed by 20.0 million in 2021 (CRED, 2025). Taken together, this pattern points to a warming-induced drought, increasingly unreliable autumn and Belgian rain, and increasing droughts, with pastoral lowlands hit hardest and food systems and rangelands gradually restored (Worku, 2024; Duba, 2022).

The pastoralist regions of Ethiopia lie at the borderline between climate stress and structural vulnerability. Increasingly erratic rainfall and rising temperatures are straining water and pasture, degraded rangelands are amplifying biophysical shocks, and poverty and food insecurity are narrowing the choices of households. Because production is largely rain-fed, seasonal shocks are rarely isolated; they cascade through livelihoods, markets, mobility, and social welfare (Tesfamariam et al., 2019).

Climatic variability, particularly erratic rainfall, aggravated by warming, is now above the regional average in East Africa, increasing extremes and reducing recovery time (Shibru et al., 2023). In Southern Ethiopia, the drop in the long-rainfall season is depressing agricultural production and reducing water availability for people and livestock, which directly undermines pastoralism (Worku, 2024; Duba, 2022; Habte et al., 2022). On this climate basis, the condition of the rangelands is largely determined by whether shocks are temporary setbacks or permanent losses (Tesfamariam et al., 2019).

Environmental degradation, such as desertification, overgrazing, and unsustainable land management, is reducing the carrying capacity of water reserves and weakening the ecological resilience to droughts (Ewalo & Vedeld, 2023). As vegetation shrinks and soils degrade, droughts deepen and recovery slows, closing the biophysical barrier that every household must cross (Tesfamariam et al., 2019).

Figure 3: Historical trend of drought affected people of Ethiopia (1966-2022)



Source: Author's own construction and the data organized from (CRED, 2025; UNDRR, 2020; Mera,2018)

Socio-economic stresses such as rapid population growth, high poverty, and chronic food insecurity increase the exposure and further limit the options for coping (Mera, 2018; Kimutai et al., 2025). In this context, drought interacts synergistically with land use and changes in soil cover, resulting in losses exceeding the sum of the individual pressures. The broader dynamics of the climate system then set the pace of how often and how strongly these shocks occur (Gebremeskel et al., 2025; Kourouma et al., 2022).

The heavy reliance on rain-fed agriculture and limited irrigation makes the population particularly vulnerable to seasonal droughts (Hordofa and Yazew, 2023). Repeated failed rains in parts of Ethiopia, Kenya, and Somalia show how climate variability can turn stress into crisis (Kimutai et al., 2025), with Ethiopia showing where climate and structural forces are most converging (Tesfamariam et al., 2019).

The impacts unfold in a clear cascade. The first is acute pasture and water shortages, which drive disease and mortality in livestock and undermine the basis for wealth and production

in pastoralism (Dejene et al.,2023). As herds shrink, household incomes decline, food insecurity increases, and dependence on aid increases; this immediately compounds the risks within the country itself (Worku, 2024).

The succession of dry spells accelerates soil degradation, water quality degradation, and biodiversity loss, reducing the ability of rangelands to regenerate and slowing recovery between events. If ecosystems cannot recover, households will struggle to replenish and restart production, and this environmental drag will soon be felt as food stress (Tofu et al., 2023).

As production and access decline, the availability of and quality of household food are deteriorating, increasing the risk of morbidity and mortality, particularly in children and other vulnerable groups (Lelamo et al.,2022). Price spikes during feed shortages further undermine purchasing power and nutritional quality, turning a health problem into an economic squeeze (Alulu et al., 2024).

Lack of commodities and higher distribution costs are leading to high staple prices, while livestock incomes are falling. With scarce credit and few alternative income options, diversification is stalling, and liquidity is drying up, pushing the shift from strategic adaptation to risky necessity (Alulu et al., 2024).

In search of pasture and water, households have expanded or moved migration routes to unknown locations, increasing competition and the likelihood of conflict with neighbouring communities. As the episodes become longer, the displacement of people in distress becomes more frequent, which burdens host regions and strains local governments (Kimutai et al., 2025). These pressures are deepening inside households. Longer trips for water and food increase the workload of women and children, while school breaks are interrupted by migrations and subsistence work, eroding human capital and slowing down recovery (Mera, 2018; Worku, 2024). In short, climate-driven shocks, filtered through degraded ecosystems and constrained economies, are reshaping pastoralist systems and increasing vulnerability, making it harder to escape each successive event (Tesfamariam et al., 2019).

2.3 Bibliometric mapping of climate vulnerability and adaptation in Ethiopia

The analysed documents used in this study have been extracted from the Web of Science with advanced research using the keyword TS= ("pastoralist" OR "herder" OR "livestock" OR "nomad") AND ("household" OR "family" OR "domestic" OR "community") AND

("vulnerability" OR "susceptibility" OR "risk" OR "exposure") AND ("climate change" OR "climate variability" OR "global warming" OR "environmental change") AND ("Ethiopia" OR "Rayitu" OR "East Africa" OR "Horn of Africa"). The input data consists of publication downloaded from the Web of Science on December 29, 2025. Only research published in English during 2014 to 2025 in all field of discipline were considered. Using relevant keywords, 259 research papers were downloaded from Web of Science and categorized; of these, 99 were Ethiopia-based research papers. VOS Viewer software was employed for the bibliometric analysis in this study. The research findings are presented in this section as follows.

Over the past decade (2014–2025), Ethiopia saw a total of 99 annual scientific papers on climate variability, drought, vulnerability, and adaptation. While annual fluctuations occurred, with 2 to 17 publications per year, a clear long-term upward trend was evident. This data indicates that the subject has transitioned from an emerging phase to an active and growing research field. Publication output was moderate and highly variable during the initial phase (around 2014–2018), but increased sharply from 2019 onwards, peaking around 2023 before moderating somewhat in 2024–25. Overall, the growth rate has been robust (approximately +1.2 papers per year), with the rapidly growing field exhibiting alternating peaks and troughs.

Research on climate variability, drought, vulnerability, and adaptation in Ethiopia over the past decade (2014–2025) has accumulated 3,124 citations from 99 publications. All databases indicate citations exhibited a strong initial effect, followed by a stated peak and a recent marked decline.

Regarding regional distribution from 2014 to 2025, most of the 99 publications on climate variability, drought, vulnerability, and adaptation in Ethiopia were concentrated in Oromia (32 publications; 30.77%) and Amhara (28 publications; 26.92%), with these two regions accounting for 57.69% of the evidence base. This dominance is mainly due to better research conditions in these areas, such as more diverse agricultural ecosystems and livelihoods, closer ties to universities and institutions, easier access and infrastructure, more available data, and established research sites. Southern Ethiopia (8 studies, 7.69%) and Tigray (7 studies, 6.73%) exhibit the second-smallest scale, indicating their recognition as highly vulnerable regions. National-level research (10 studies, 9.62%) provides important broad insights but cannot fully replace detailed, regionally based studies (Table 1).

Table 1: Summary of Regional distribution of Publication (2014-2025) in Ethiopia

SN	Region	Pastoral area	Highland area	Total publication	% Share
1	Afar	3	0	3	2.88
2	Amhara	0	28	28	26.92
3	Central Ethiopia	0	4	4	3.85
4	Central Ethiopia and Amhara	0	1	1	0.96
5	Gambela	1	0	1	0.96
6	Oromia	20	12	32	30.77
7	Oromia and Benishangul-Gumuz	0	1	1	0.96
8	Oromia and Central Ethiopia	0	1	1	0.96
9	Somalia	2	0	2	1.92
10	Southwest Ethiopia	1	0	1	0.96
11	Southern Ethiopia	0	8	8	7.69
12	Tigray	0	7	7	6.73
13	At national (Country) level	0	10	10	9.62
		27	72	99	100

Source: Author's own construction based on the bibliometric analysis

Most of the research was concentrated in the Highlands agricultural area, with 72 studies (about 73%), while 27 studies (about 27%) were carried out in pastoral and agropastoral areas. This imbalance is mainly due to the highlands having a higher availability and database, while pastoral lowlands face isolation, security issues, and logistical and data constraints. As a result, pastoral areas that are particularly vulnerable to climate change, such as Afar (2.88), Somali (1.92), Gambela (0.96), and other pastoral areas, are still poorly understood.

A keyword co-occurrence analysis of 99 academic journal articles on Ethiopia (2014–2025) indicates that fundamental research domains, focused on climate change, adaptation, vulnerability, and drought, are significantly interconnected and intricately associated with rainfall variability, impacts, and determining factors. This structure suggests the literature is organized around consistent analytical pathways linking climate risks (particularly drought and rainfall variability) to livelihood and agricultural impacts, vulnerability assessments, and household or community responses. Several distinct thematic clusters are observed.

- The first cluster indicates vulnerability assessment and adaptive capacity. It uses words like "exposure," "vulnerability index," "institutions," and "dynamics."

- The second cluster reflects perspectives defining climate stress as a development and welfare challenge, emphasizing livelihoods, food security, resilience, and assets/capital.
- The third cluster focuses on adaptation and coping strategies at the household level, particularly centred on smallholder farms, frequently incorporating perceptions and risk factors when explaining adaptation choices.
- The fourth cluster demonstrates how climate information integrates with decision-making and agricultural practices by linking drought/precipitation variability with meteorological data and risk perception.

Pastoralists are positioned relatively peripherally, suggesting that pastoral systems are less represented or integrated into mainstream adaptation discourse focused on smallholder farming. Overall, this map demonstrates that Ethiopia's evidence base is predominantly drought-centric and adaptation-focused, with a strong emphasis on vulnerability measurement, livelihood outcomes, and determinants of adaptation decisions.

2.4 Empirical literature on the climate-related vulnerability of pastoral households

2.4.1 Perception of households in climate change

This subsection synthesizes prior studies on how pastoralists and smallholders perceive climate change and the factors shaping those perceptions. Common indicators include hotter temperatures, erratic or declining rainfall (with shifted onset/cessation), more frequent droughts and floods, worsening water scarcity, crop failure/yield decline, and rangeland degradation; details follow.

Pastoral and farming households across Ethiopia perceived increasing temperatures as a consistent suite of climate signals that unfold in everyday life: hotter days and warmer nights, longer heat spells, faster drying of ponds and wells, and routine livestock heat stress (panting, shade seeking, curtailed midday grazing, and a shift toward night grazing). Linked to these heat signals, most households also perceived declining rainfall coupled with irregular within-season distribution that shortens effective planting and grazing seasons (Destaw & Fenta, 2021; Megabia et al., 2022; Habte et al., 2022; Gashure & Wana, 2023).

Timing shifts of rainfall, such as later starts and earlier endings, are repeatedly perceived as the most consequential change because they compress the growing season and leave too little time for pasture growth and grain filling (Mekuyie and Mulu, 2021; Tesfahunegn et

al., 2016; Destaw & Fenta, 2021; Teshome et al., 2021; Habte et al., 2022). Households further perceived rains as erratic/short, intense bursts separated by long dry spells, undermining crop establishment and pasture recovery even when seasonal totals appear normal (Tesfahunegn et al., 2016, 2022; Destaw & Fenta, 2021; Teshome et al., 2021; Megabia et al., 2022).

These distributional shifts cascade into more frequent and severe droughts that are visible as earlier well and pond failure, faster grazing collapse, and shorter recovery (Tesfahunegn et al., 2016; Destaw & Fenta, 2021; Mekuyie and Mulu, 2021; Habte et al.,2022; Gashure & Wana, 2023; Alhassan et al.,2025).

Agro-pastoralists consistently perceived crop failure and yield decline as the clearest signals of climate change, symptoms that converge with heat stress, erratic intra-seasonal rainfall, and shortened growing periods to produce substantial harvest losses (Tesfaye & Seifu, 2015; Tesfahunegn et al., 2016; Teshome et al., 2021; Gashure & Wana, 2023). On rangelands, the same drivers that manifest as feed scarcity and degradation become primary signals of climate change because of hotter conditions, delayed/short rainy seasons, and more frequent droughts directly suppress grass growth, alter species composition, and shrink carrying capacity (Destaw & Fenta, 2021).

Finally, pastoralist and farming households increasingly perceive a suite of climate-related signals, including pest/parasite and disease upsurges, soil fertility decline and erosion, heightened heat stress on people and livestock, and shifts in rangeland composition as evidence of climate change (Megabia et al., 2022; Tesfahunegn et al., 2016; Destaw & Fenta, 2021; Habte et al., 2022).

Previous studies (see Table 1) point to a common set of factors shaping how households perceive climate change. These include socio-demographics, household and farm attributes (family size, farm size, income, and livestock holdings in TLU); access to services and resources (extension, early warning and other media, credit, irrigation); market connectivity (market access and distance); biophysical context (agro-ecological zone or location); and social capital (cooperative membership).

Table 2: Previous studies on determinants of household perception

	Determinants	Key finding	Evidence
1	Sex/gender	Female-headed households are less likely to perceive climate	Asfaw et al.,2021a, Gashure and Wana,2023
2	Age	Age as a proxy of accumulated experience with irregularity and shocks of climate change	Debela et al.,2015, Amare et al.,2017, Asfaw et al.,2021a, Gashure and Wana,2023
3	Education	Education persistently raises perceptions of climate change	Debela et al.,2015, Tesfahunegn et al.,2016
4	Family size	Larger families perceive climate more due to their social network	Teshome et al.,2021
5	Experience	More experience perceives the impacts of climate change easily.	Tesfahunegn et al.,2016, Amare et al.,2017
6	Farm size/plots	Larger farms expose households to micro-climatic variations	Saguye,2017
7	Income	Higher income eases access to get information about climate change.	Amare et al.,2017,
8	Livestock ownership	Higher livestock ownership raises the perception of climate change.	Debela et al.,2015
9	Access to extension service	Access to extension services raises perceptions of climate change	Debela et al.,2015, Gashure and Wana,2023
10	Early warning system information	Households that receive seasonal forecasts from radio/TV/DAs perceive climate change more.	Debela et al.,2015, Tesfahunegn et al.,2016, Teshome et al.,2021
11	Access to credit/ finance	Access to credit have better financial capital to use technology that visualizes climate signals.	Habtemariam et al.,2016
12	Irrigation	Accessing irrigation are less likely to perceive climate change	Gashure and Wana,2023
13	Market access/distance	Proximity to markets increases exposure to information flows	Saguye,2017

	Determinants	Key finding	Evidence
14	Agro ecology / location	Households in the lowland are less likely to perceive climate	Saguye, 2017; Gashure and Wana,2023
15	Membership in a cooperative	Members of a cooperative group have better information	Tesfahunegn et al.,2016
16	Number of relatives	The greater the number of relatives, the more likely to have access to weather information.	Amare et al.,2017; Gashure and Wana,2023

Source: Author's own construction based on reviewed literature

2.4.2. Vulnerability of pastoral households to climate change

Previous studies on climate vulnerability in Ethiopia found that exposure is high, sensitivity is acute, and adaptive capacity is low. Common determinants fall into four clusters: socio-economic conditions, services and access. Location and agro-ecology also matter; remoteness, ecological zone, and shifting rainfall–temperature regimes shape shock intensity and response options (Zeleke et al., 2021; Gatew & Guyo, 2024). Table 2 presents a summary of these determinants, offering concise conclusions supported by representative evidence.

Table 3: Common determinants of vulnerability

	Determinants	Key finding	Evidence
1	Sex/Gender	Female-headed households have higher odds of falling into a more vulnerable category	Addis et al. (2021)
2	Education	Low education/illiteracy limits adaptive choices; associated with higher vulnerability.	Tofu & Dedefa (2018); Addis et al. (2021); Tefera et al. (2025)
3	Climate/early-warning info	Lack of climate/early-warning information raises exposure and delays response.	Addis et al. (2021); Zeleke et al. (2021); Gatew & Guyo (2024)
4	Extension/veterinary contact	Limited extension contact weakens the technical options of livelihood and planning.	Tofu & Dedefa (2018); Zeleke et al. (2021); Tefera et al. (2025)

	Determinants	Key finding	Evidence
5	Access to credit	Poor access to credit constrains the purchase of feed/water	Addis et al. (2021); Zeleke et al. (2021)
6	Land size/soil fertility	Less/low-quality land pushes households into vulnerability	Tofu & Dedefa (2018); Tofu et al. (2023)
7	Market access/distance	Remoteness raises costs and reduces options that increases vulnerability.	Zeleke et al., 2021; Addis et al., 2021
8	Agro ecology	Arid/lowland agro ecology affected by frequent drought increases vulnerability on average.	Gatew & Guyo (2024); Addis et al. (2021)
9	Temperature	Rising temperature pushes to higher levels of vulnerability	Gatew & Guyo (2024)
10	Rainfall	Rainfed cropping heightens weather dependence, thereby elevating household vulnerability.	Tofu & Dedefa (2018); Tofu et al. (2023)
11	Irrigation	Irrigation/water development reduces rainfall dependence	Addis et al. (2021)
12	Livestock ownership and non-farm income	Larger managed herds & non-farm income buffers reduce vulnerability	Zeleke et al. (2021); Bogale & Erena (2022)
13	Dependency ratio	A high dependency ratio increases sensitivity and vulnerability.	Dejene, 2020; Gatew & Guyo, 2024
14	Health status/access to family planning & services	Poor health and limited family-planning/service access increase vulnerability (lower AC).	Dejene, 2020
15	Infrastructure (roads, electricity, vet clinics)	Better infrastructure lowers vulnerability by enabling services, markets & info flow.	Addis et al., 2021; Gatew & Guyo, 2024

Source: Author's own construction based on reviewed literature

2.4.3 Adaptation and coping strategies

Coping strategies involve immediate, short-term responses to mitigate the effects of climate variability, whereas adaptation strategies entail longer-term, more permanent shifts in livelihood approaches aimed at building resilience and reducing vulnerability to future climate impacts (Opiyo et al., 2015). While coping mechanisms address urgent needs, they often involve a depletion of resources, potentially eroding livelihoods over time, whereas adaptation seeks to enhance capital and capabilities for sustainable futures (Schie et al., 2024).

2.4.3.1 Adaptation strategies

Empirical studies show six adaptation fronts in Ethiopia's rangelands: securing feed and water, rebalancing herds with strong animal health, rule-guided herd mobility, livelihood diversification, rangeland recovery, and anticipatory finance/insurance working together to sustain milk, survival, and assets under recurrent drought (Tolera and Senbeta, 2020; Duba et al.,2021; Gebeyehu et al.,2021; Kemal et al.,2022; Tamene et al.,2023; Feyissa et al.,2025).

- *Securing feed at its source through fodder cropping and conservation.* Converting idle plots to forage grasses/legumes smooths seasonal nutrition and improves body condition and milk yield; hay/silage and fodder banks bridge lean seasons and reduce risky treks/purchases, with soil/pasture co-benefits (Berhanu and Beyene,2015; Mengistu & Haji,2015; Kemal et al.,2022; Feyissa et al.,2025).
- *Water security and governance.* Soil and water conservation, rainwater harvesting, and rehabilitated ponds/boreholes increase soil moisture and steady domestic/livestock supplies during dry spells; when embedded in access rules aligned with customary institutions, they lower conflict and support mobility (Belay et al.,2017; Destaw & Fenta, 2021; Cherinet et al.,2025).
- *Rebalancing the herd portfolio & animal health*. Shifting toward camels/goats while maintaining smaller cattle cores matches hotter, woodier rangelands and stabilizes milk/survival; community-based breeding and community animal health workers led vaccination/deworming further reduce drought-period mortality (Mihiretu et al.,2019; Tolera & Senbeta, 2020; Duba et al.,2021; Gebeyehu et al.,2021).

- *Rule-guided herd mobility* uses customary corridors, seasonal timing, and watering-interval limits to align herds with shifting pasture and water while easing localized grazing pressure. When reinforced by conflict-resolution institutions and inter-clan/district agreements, it consistently functions as a dependable adaptation under climate variability (Mekuryie and Mulu,2021; Tolera and Senbeta, 2020; Kemal et al.,2022; Tamene et al.,2023; Sintayehu et al., 2025; Regasa,2025).
- *Livelihood diversification* into field crops, petty trade/services, wage work, and small processing add income less correlated with rainfall, financing water/feed/vet inputs; crop–herd synergies (residues, manure) and improved market access/savings/credit enable proactive off-take over distress sales (Mengistu and Haji,2015; Duba,2021; Gebeyehu et al.,2021; Lelamo et al.,2022; Feyissa et al., 2025).
- *Rangeland recovery* (enclosures) and active rehabilitation (targeted enclosures and integrated restoration, including enrichment tree planting, woody control, and hay supplementation) rebuild forage, raise soil organic carbon, and serve as strategic fodder reserves. This practice of participatory rules in Ethiopia among Borana pastoralist areas outperforms passive fallowing (Tolera and Senbeta,2020; Lemalo and Shenkute,2022; Aboye et al.,2023; Ewalo and Vedeld, 2023).
- *Anticipatory finance & risk transfer.* Forecast-based financing and insurance-based livestock index (IBLI) use rainfall/Normalized difference Vegetation Index (NDVI) triggers to fund pre-shock feed/water and strategic off-take, lowering mortality, boosting income/milk, and reducing distress responses while complementing on-farm and mobility strategies (Jensen et al., 2015; Feyissa et al.,2025).

Pastoral and agro-pastoral households in Ethiopia use several complementary adaptation strategies: investing in education to expand future livelihood options (Lelamo et al., 2022); building financial buffers through saving schemes (Gebeyehu et al.,2021; Kemal et al., 2022); deploying small-scale irrigation to stabilize food/feed during dry spells (Asfaw et al., 2019; Gebayehu et al.,2021; Ewalo & Vedeld, 2023; Molla et al., 2023; Zeleke et al.,2023; Cherinet et al., 2025); diversifying into cereals for income and food security (Birhanu & Beyene, 2015; Tolera & Senbeta, 2020; Destaw & Fenta, 2021; Feyissa et al., 2025); and adjusting planting calendars to track shifting rains in agro-pastoral zones (Alemayehu & Bewket, 2017; Belay et al., 2017; Asfaw et al., 2019; Destaw & Fenta, 2021).

2.4.3.2 Coping strategies

Empirical work in Ethiopia's pastoral areas shows a layered progression of coping: households begin with consumption smoothing, then use cash stopgaps and labor/market pivots, draw on social protection, and deploy rapid herd–range tactics; when necessary, early destocking tied to early warnings averts collapse and speeds recovery (Wario et al., 2016; Gebeyehu et al.,2021; Gebre et al., 2021; Lelamao and Shenkute,2022; Wako et al., 2023)

- *Immediate consumption smoothing:* In early shock weeks, households cut meal frequency/size and substitute cheaper staples; wild-food foraging buffers intake but raises undernutrition risks for children, pregnant and lactating women, and elders (Gebeyehu et al., 2021; Mekuryie and Mulu,2021; Gebre et al., 2021). Earlier droughts show rationing/ substitution/foraging as first-line responses in agropastoral and pastoral areas (Gebre et al., 2021).
- *Cashing out the landscape, fast liquidity with long-run costs:* To meet food/water needs, families sell firewood/charcoal and sometimes non-essential assets, gaining quick cash but accelerating bush loss and degrading rangelands (Gebeyehu et al.,2021; Lelamao and Shenkute,2022; Girma et al.,2024; Sintayehu et al.,2025).
- *Labor and markets as short-run shock absorbers:* Households pivot to petty trade, casual labor, services, or short urban stints to stabilize consumption without culling breeders, off-farm income, and transfer smooth shocks in Ethiopia, with parallels from Kenya's heat waves (Gebeyehu et al.,2021; Sintayehu et al.,2025).
- *Social protection from below and above:* Customary gifts/loans bridge individual shocks but weaken under covariate droughts (Gebeyehu et al.,2021; Mekuryie and Mulu,.2021; Wako, 2023). Productive Safety Net Program (PSNP) transfers reduce distress sales and fund water, fodder, and veterinary care with the strongest effects where public works align with pastoral ecologies and market links exist (Abay et al., 2022; Bahru et al., 2020; Gebbisa and Bacsi,2025).
- *Rapid herd and range management* through emergency herd splitting sustains milk and protects vulnerable stock (Gebeyehu et al.,2021; Lelamo et al., 2022; Sintayehu et al.,2025); households negotiate crop residues, purchase feed, truck water, and perform veterinary triage, complemented by short opportunistic mobility (Wario et al., 2016). In Borana, these tactics start early in the drought cycle and withdraw after rains (Girma et al., 2024).

- *Liquidity under stress and the step toward proactive response:* Shop credit/trader advances and temporary peri-urban relocation maintain food intake and access to services during prolonged shocks (Camfield et al., 2020). Early, well-coordinated destocking triggered by early warnings improves prices, cuts mortality and feed demand, protects breeders, and speeds recovery; Ethiopian cases show markedly higher revenues than late crisis sales, especially when commercial/slaughter programs link traders and local authorities (Tamene et al.,2023; Zeleke et al.,2023; Feyissa et al.,2025; Regasa,2025; Sintayehu et al., 2025).

2.4.3.3 Factors influencing coping and adaptation strategies

Empirical studies indicate that interconnected socio-economic, institutional, informational, and infrastructural factors influence the coping and adaptation strategies of households in Ethiopia's pastoral area. Table 3 provides detailed information on previous studies examining factors influencing adaptation and coping strategies.

Table 4: Previous studies on factors influencing adaptation and coping strategies

(Notation: HH: household; ↑: increase; ↓: decrease; →: no change)

Sr	Factors	Effect on adaptation	Effect on Coping	Evidence
1	Sex / Gender	↑ Adaptation among male-headed HHs via asset control & mobility; women's groups enable diversification	↓ Erosive coping, where women access groups/PSNP; otherwise, ↑ burden on negative coping	Mengistu & Haji (2015); Berhanu & Beyene (2015); Belay et al. (2017); Duba et al. (2021); Kemal et al. (2022); Regasa (2025)
2	Age	Mixed: older HH heads ↑ indigenous knowledge & mobility norms; younger ↑ uptake of IBLI/fodder markets.	Older heads rely less on erosive short-term sales; very old may ↑ be aid-seeking	Berhanu & Beyene (2015); Belay et al. (2017); Duba et al. (2021); Kemal et al. (2022); Tamene et al (2023); Regasa (2025);
3	Family size	↑ Labor for split-herd, water hauling, haymaking, petty trade	If very large & poor, ↑ pressure → ↑ distress	Berhanu & Beyene (2015); Tolera & Senbeta (2020); Duba

Sr	Factors	Effect on adaptation	Effect on Coping	Evidence
			sales/consumption smoothing	et al. (2021); Kemal et al. (2022)
4	Education / Literacy	↑ Adaptation & bundling of strategies	↓ Erosive coping; ↑ informed short-term choices	Tolera & Senbeta (2020); Duba et al. (2021)
5	Access to training	↑ Probability of adopting multiple, proactive strategies	↓ Reliance on ad-hoc coping	Mengistu & Haji (2015); Zeleke et al (2023)
6	Extension / Veterinary service	↑ Protective, multi-strategy adoption	↓ Negative coping; ↑ productive short-run responses	Kemal et al. (2022); Feyissa et al (2025)
7	Access to weather & early-warning info	↑ Timely mobility, early off-take, forage planning, water staging	↓ Last-minute trekking & distress sales	Gebeyehu et al.,2021; Kemal et al. (2022); Feyissa et al (2025); Ragasa (2025)
8	Herd size & assets	↑ Split-herd mobility, early off-take, diversification	↓ Distress sales/charcoal	Tolera and Senbeta (2020); Feyissa et al (2025)
9	Income	↑ Investment in feed, water trucking, animal health, IBLI; ↑ diversification	↓ Need for erosive coping (meal cuts, distress sales)	Duba et al. (2021); Aboye et al. (2023); Ewalo & Vedeld (2023).
10	Access to credit/Saving	↑ Adoption (fodder banks, planned destocking, inputs)	↓ Negative coping via liquidity for shocks	Duba et al. (2021); Kemal et al. (2022); Ragas (2025)
11	Distance to water	Long-distance ↓ proactive adaptation; closer water enables planned mobility	Long distances ↑ emergency trekking & short-term rationing	Duba et al. (2021)

Sr	Factors	Effect on adaptation	Effect on Coping	Evidence
12	Distance to markets & roads	↑ Planned destocking, haymaking, and diversification	↓ Late sales at trough prices; remote HHs ↑ charcoal/firewood sales	Duba et al. (2021); Tamene et al. (2023); Zeleke et al (2023); Gebbisa &Bacsi (2025); Ragas (2025),
13	Access to Range land	↑ Coordinated mobility, rotational use, dry-season reserve management	↓ Extractive coping (charcoal/firewood); ↓ conflict-driven displacement	Gebbisa & Bacsi (2025)
14	Farmland size	↑ Fodder cropping, residue use, cereal support to herds; ↑ feed self-sufficiency	↓ Distress purchases/sales; ↓ meal cuts	Berhanu & Beyene (2015); Belay et al. (2017), Feyissa et al. (2025)

Source: Author's own construction based on reviewed literature

2.5 International support programmes in Ethiopian pastoral areas

Ethiopia's pastoral area is the focus of a diverse set of international support programmes addressing climate change, drought, vulnerability, and adaptation. These range from large-scale social protection schemes, such as the Productive Safety Net Programme (World Bank, 2026), to livestock- and market-based resilience initiatives (Smith et al., 2019; Mercy Corps, 2019; World Bank, 2024). Collectively, these programmes illustrate the breadth of institutional engagement in Ethiopia's Afar, Somali, Oromia, Amhara, SNNP, and Tigray regions, spanning cash transfers and infrastructure development to insurance, market access, and climate advisory services, and providing the policy for the government and donor. The major support programme in pastoral areas is listed in table 5.

Table 5: Major international support programmes in Ethiopian pastoral areas

Programme (Acronym)	Focus / Intervention	Source
Productive Safety Net Programme (PSNP)	Cash/food transfers, public works, social protection, and disaster-risk management for chronically food-insecure households.	(World Bank, 2026)

Programme (Acronym)	Focus / Intervention	Source
Pastoralist Areas Resilience Improvement and Market Expansion (PRIME)	Market-based resilience building, livestock value chains, livelihood diversification, and climate adaptation.	(Smith et al., 2019; Mercy Corps, 2019)
IGAD Drought Disaster Resilience and Sustainability Initiative (IDDRSI)	Regional drought-resilience framework supporting coordination, investment, and implementation of resilience programmes in drought-prone areas.	(IGAD, 2012)
Drought Resilience and Sustainable Livelihoods Programme (DRSLP)	Water and rangeland management, livestock-related services, infrastructure, value chains, and livelihood resilience.	(AfDB, 2014)
Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED) – Market Approaches to Resilience (MAR)	Market-based approaches to improve resilience, access to finance, livelihood diversification, and adaptation to climate shocks.	(Farm Africa, 2015)
De-Risking, Inclusion and Value Enhancement of Pastoral Economies (DRIVE)	Livestock insurance, financial inclusion, livelihood diversification, and climate-resilience financing.	(World Bank, 2024)
Borana Resilient Water Development for Improved Livelihoods Program (BRWDLP)	Climate-resilient water and sanitation infrastructure, livestock water access, watershed management, and drought adaptation.	(AfDB, 2024)

Source: Author's own construction based on reviewed literature

2.6 Summary of the empirical research gap

All existing policies and strategies of the Ethiopian government prioritize pastoralist sedentarisation as a long-term strategy to improve the welfare of populations in the arid and semi-arid lowlands (Gebremeskel *et al.,* 2019; Mohamed, 2019). These policies are based

on general misconceptions and inappropriate generalizations about pastoralism and pastoral lifestyles, with pastoralists often stereotyped as irrational and backward. Government interventions in pastoralist areas aim to rectify these characterizations. Additionally, there are no clear and long-term plans for developing pastoral areas at both regional and federal levels that match the African Union Pastoral Framework Policy, Intergovernmental authority on development (IGAD) instruments, Sustainable development goals (SDGs), and other important guidelines (Gebremeskel et al. 2019).

There is a lack of comprehensive statistical databases on pastoralism due to insufficient and irregular data collection, leading to an undervaluation of its significance. Research often relies on sporadic and estimated data (Bacsi et al.,2023), which undermines the ability to accurately assess the economic and social contributions of pastoralism in Ethiopia. Ethiopia lacks a national database on pastoralism activity, instead merging and recording it with the agriculture sector (IUNC, 2006), which complicates efforts to assess the true impact and needs of pastoral communities in the country.

There are also significant methodological constraints in the analysis of numerous studies concerning the perceptions and responses of pastoralist and agro-pastoralist communities to climate change. Most of the studies on perception of climate change were analyzed using household surveys of perception signals/indicators, frequently lacking triangulation with long-term weather data or remote-sensing evidence to substantiate these perceptions (Debela et al., 2015; Tesfahunegn et al., 2016; Mekuyie & Mulu, 2021). Additionally, although short-term management responses are frequently examined in conjunction with long-term adaptation strategies, comprehensive monitoring of their effects on milk production, herd dynamics, survival rates, and resilience is still inadequate. This hinders drawing comprehensive conclusions about the effectiveness of such strategies (Wario et al., 2016; Gebeyehu et al., 2021).

Most of the studies on the determinants of perception, vulnerability, coping, and adaptation in pastoralist systems incorporated inappropriate variables. The studies apply analytical frameworks originally designed for mixed farming systems, focusing on general socioeconomic variables while neglecting key pastoral-specific factors such as livestock composition, migration patterns, access to grazing and water sources, conflict history, participation in PSNP and IBLI, and the role of pastoralist institutions (Debela et al., 2015; Megersa et al., 2014). Excluding these variables risk overlooking the real drivers of

household decision-making and underestimating the critical role of mobility, herd management, and social institutions in shaping vulnerability and adaptive responses (Zeleke et al., 2021).

Empirical studies have shown that adaptation and coping strategies for climate change in Ethiopian pastoralist areas use multinomial logistic models that assume households only use one strategy (Mengistu & Haji, 2015; Duba et al., 2021; Kemal et al., 2022; Tamene et al., 2023; Cherinet et al., 2025). In practice, pastoralists generally employ a combination of interconnected strategies, including herd mobility, livelihood diversification, fodder storage, drought-resistant livestock, water harvesting, and irrigation. Treating this decision as interdependent can generate estimation bias and lead to inefficient policy recommendations. Multivariate probit models, which account for correlated decision-making, offer a more appropriate approach but remain rarely applied in Ethiopian pastoralist research (Ndiritu, 2021; Gebbisa and Bacsi, 2025; Feyissa et al., 2025; Regasa, 2025).

There exists a knowledge integration deficit between scientific and local viewpoints regarding climate risks and adaptation. Scientific research typically relies on climate models, drought indices, and national statistics (Gebbisa and Bacsi, 2025), whereas pastoralist communities draw upon long-term experience, local environmental indicators, and indigenous institutional systems (Debela et al., 2015; Tesfahunegn et al., 2016; Destaw & Fenta, 2021). If these knowledge systems are not systematically integrated, climate interventions could be technically sound but socially unacceptable, or they could be based on local knowledge but lack credible climate evidence. Therefore, connecting these perspectives is essential for designing scientifically sound yet socially acceptable adaptation and risk management strategies (Habte Mariam et al., 2016; Habte et al., 2020; Duba, 2022).

Research on climate change, drought, perception, vulnerability, and adaptation strategies in Ethiopia exhibits an uneven geographical distribution. Most of the studies concentrate on high-altitude areas or accessible mixed-farming regions; several lowland pastoralist areas remain understudied. This imbalance is mainly due to the highlands having a higher availability and database, while pastoral lowlands face isolation, security issues, and logistical and data constraints (Gebremeskel et al., 2019). This spatial imbalance limits the evidence base available to local planners and authorities responsible for climate adaptation planning (NPC, 2016; PDC, 2020).

3. MATERIALS AND METHODS

3.1 Research strategies

This study employed a cross-sectional research strategy with a mixed-methods approach, combining quantitative and qualitative techniques to capture the complex interactions between climate variability and pastoral livelihoods. The use of both approaches enhanced the depth, credibility, and reliability of findings through triangulation (Creswell, 2014; Johnson et al., 2007).

Primary data were collected from pastoral households using structured surveys, focus group discussions (FGDs), key informant interviews (KIIs), and direct observation, while secondary data included long-term rainfall and temperature records from 1984 to 2024, sourced from the Meteoblue database (Meteo,2025), to assess climate trends and drought situation over time. This combination ensured both contextual insights and measurable indicators of household characteristics, climate variability, drought, vulnerability, coping, and adaptation strategies.

Data analysis involved descriptive and inferential statistics, the Mann–Kendall test, Sen's slope estimator, the coefficient of variation, Principal Component Analysis (PCA), and econometric models such as binary logistic regression, ordered logit model, and the multivariate probit. Qualitative data were thematically analyzed to complement quantitative results. Analytical work was supported by DrinC (Drought Indices Calculator), SPSS (v29), STATA, and R Studio, ensuring robust and reproducible findings.

3.2 Data collection methods

This study employed both primary and secondary data collection methods. Primary data referred to information collected specifically for this research through household surveys, focus group discussions (FGDs), key informant interviews (KIIs), and direct observation.

A household survey was conducted among 351 pastoral households, as detailed in Section 3.3, to assess climate variability, drought, perception, vulnerabilities, and adaptation. The survey was carried out during the end of spring season (April -May), a period when pastoral households typically returned from their seasonal migration. The questionnaire gathered socio-demographic data such as family size, age, gender, education, marital status, primary source of income, and awareness of climate risks. In addition, the survey investigated the

perceived extent of exposure, vulnerability, drivers of vulnerability, coping and adaptation strategies, and their determinants.

To complement the survey, six focus group discussions (FGDs) were organized across selected kebeles, involving a total of 72 participants. The sessions were facilitated by local leaders and brought together elders, men, women, and youth, selected through quota sampling to ensure demographic and socio-economic representation. Discussions focused on climate-related experiences, community development, perceptions of climate variability and extremes, and adaptation strategies. These group sessions were conducted after completing household surveys and followed a structured discussion guide.

Furthermore, 36 key informant interviews were conducted with community experts, including local leaders, professionals, and residents, at locations convenient for the respondents. Using open-ended questions, these interviews explored local climate change trends, causes of vulnerability, pastoral livelihood options, coping and adaptation practices, and sustainability concerns.

The researcher also engaged in direct observation of pastoral livelihood strategies, household assets, resilience levels, and coping mechanisms in response to climate risks. Visits were made to pastoralist communities across the Rayitu district, where participant observation enabled close interaction with households and documentation of daily activities. Instead of relying solely on verbal reports, behaviors were observed directly and recorded using a checklist. Observations were carried out concurrently with household surveys and FGDs. Field notes and photographs were systematically used to capture significant events, patterns, and findings. The recorded information was later organized, coded, and analyzed to identify themes and relationships and cross-checked against survey, FGD, and KII data to ensure reliability.

In addition, secondary data were gathered from a global climate database called the Meteoblue database sources to supplement primary findings. The Meteoblue database provided monthly, seasonal, and annual rainfall and temperature data for the period 1980–2024, which supported trend and variability analysis and drought index. These sources enriched the understanding of climate impacts, allowed comparisons with primary data, and highlighted gaps requiring further exploration.

Finally, based on McDermaid and Barnstable (2001), the study triangulates data to identify shortcomings inherent in each data collection method, which can lead to more reliable and comprehensive findings in research studies. This process of triangulation addresses the limitations of individual methods and strengthens the overall research conclusions by integrating diverse perspectives and data sources. Cross-validation improves the validity of the data by using social triangulation to compare data from different methods. Relying on a combination of approaches ensures a more balanced outcome. Therefore, the study implemented data triangulation from diverse sources, including household surveys, focus group discussions, key informant interviews, direct observation, and secondary sources.

3.3 Research tools

3.3.1 Questionnaire design

The questionnaire was designed by adapting items from relevant published literature and modifying them to fit the local pastoral context. It was initially developed in English and then translated into the local language, called "Afan Oromo," to ensure clarity and accessibility for respondents. The instrument included a combination of semi-structured, open-ended, multiple-response, and dichotomous questions, enabling both quantitative measurement and qualitative insights. It covered socio-demographic characteristics, household livelihood capital asset variables, perceptions of climate change, vulnerability, and coping and adaptation strategies.

The structure of the questionnaire is categorized into four different sections. The first section begins with general information (respondent's gender, marital status, household size, and length of residence). Section 2 addresses the five capitals that shape perception, vulnerability, coping, and adaptation (human capital, financial capital, social capital, natural capital, and physical capital). Section 3 indicates climate perceptions and vulnerability indicators (observed changes in temperature/rainfall/drought/flooding/wind, and their social livelihood impacts). Section 4 documents long-term adaptation and short-term coping strategies, along with barriers to their adoption.

3.3.2 Data collection procedure

To ensure effective data collection, six enumerators with diploma-level qualifications were recruited and trained from each kebele (village) on the questionnaire's structure and content before fieldwork. The training emphasized clarity in administering questions, probing

techniques, and ethical considerations. During the household interviews, enumerators explained any complex questions to respondents, when necessary, while the researcher supervised and coordinated the process to maintain consistency.

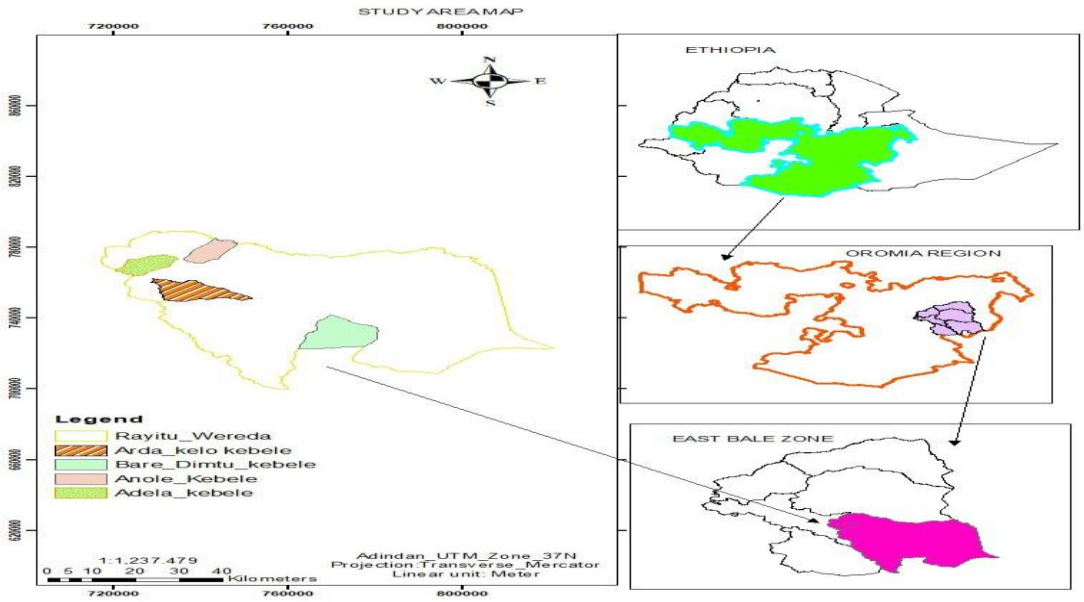
The questionnaire was pretested and reviewed by experts in the field to ensure reliability and validity. Feedback was incorporated into refining the instrument, particularly by reducing repetition and shortening lengthy items. This step enhanced the accuracy, cultural sensitivity, and overall quality of the survey tool.

3.3.3 Sample size and sampling procedure

For this study, the researcher used multi-stage sampling techniques that incorporate both purposive and random sampling techniques. Rayitu was purposively selected from the existing five pastoral districts of the Eastern Bale zone for this study because it is predominantly pastoral, highly vulnerable to recurrent droughts, and representative of the ecological and socio-economic characteristics of the wider zone. Furthermore, its accessibility and local institutional support made it feasible for intensive data collection within the resource and time constraints of this research.

Rayitu district has a total population of 111,235, organized into 21,927 households (OPEDC, 2025). From the 19 kebeles in Rayitu district, four kebeles i.e Arda Kalo, Adela, Anole, and Bara Dimtu were purposively selected. These sites were chosen because they represent predominantly pastoral and agro-pastoral communities, are highly vulnerable to recurrent drought, and were accessible for data collection. Their selection also reflected recommendations from the district pastoral and rural development office and ensured feasibility within the study's time and resource constraints.

Figure 4: Map of Study area



Source: Author's own construction

The study determined the sample size using the Kothari (2004) equation. The equation helps determine the sample size when the population size is finite. Let's break down the equation:

$$n = \frac{z^2.p.q.N}{e^2(N-1) + z^2.p.q} \qquad \text{(Eq.1)}$$

where,

z: values of standard variant at 95% confidence interval (Z = 1.96).

p: the estimated proportion of an attribute that is present in the population.

q: the estimated proportion of an attribute that is not present in the population.

e: margin of error considered is 5 % for this study

N: total population

$$n = \frac{(1.96)^2(0.5)(0.5)(4064)}{(.05)^2(4064-1) + (1.96)^2(0.5)(.5)} = 351$$

The four selected kebeles, Arda Kalo, Adela, Anole, and Bara Dimtu, have a combined total of 4,064 households (OPEDC, 2025). Based on the formula for determining sample size, the required sample consisted of 351 households. Accordingly, the sample respondents were proportionally distributed across the four kebeles in line with their respective household numbers, using Equation (2).

$$n_i = \frac{N_i}{N} * n \qquad \text{(Eq. 2)}$$

where the variables n_i, N_i, N, and n represent the sample households from kebele i, the total households in kebele i, the total households in all selected kebeles (4,064), and the total sample size (351), respectively.

Table 6: Household sample respondents at the kebeles level

S.N	Name of village	Number of total households	Number of sample households
1	Arda Kalo	954	81
2	Adela	990	84
3	Anole	960	83
4	Bara Dimtu	1160	103
Total		**4064**	**351**

Source: Author's own construction, based on OPEDC (2023*)*

Thus, the proportional allocation ensures that each kebele's sample size (n_i) is directly proportional to its household population share within the combined total of the four selected kebeles.

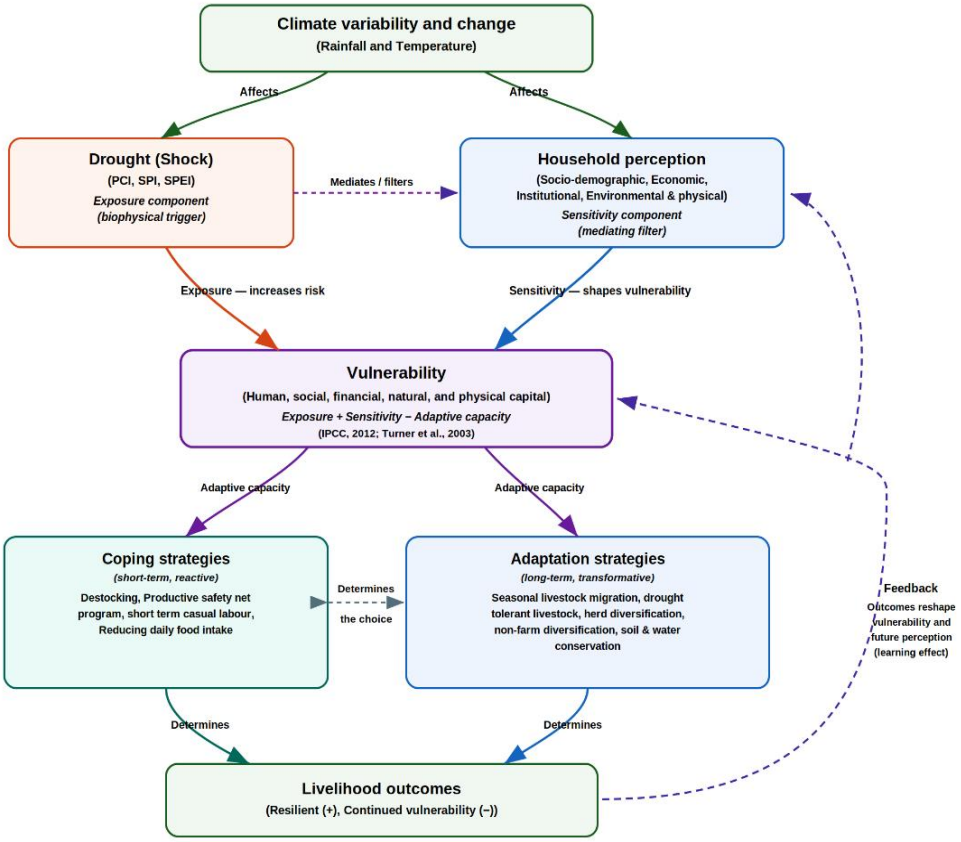
A total of 351 sample respondents from four selected kebeles (villages) of Rayitu district participated in the survey. In cases where the household head was absent, the spouse or another adult family member actively involved in pastoral livelihood activities completed the questionnaire. Although the household head was typically the main respondent, they were allowed to consult other family members when appropriate to provide accurate information.

3.4 Conceptual framework

Pastoral communities are highly dependent on rangeland resources, which exposes them to rainfall and temperature variability and climatic shocks. Understanding how these shocks translate into vulnerability of households and how they affect coping and adaptation requires a framework linking climate risks to household perceptions, livelihoods, response strategies and outcomes. Accordingly, this study integrates three complementary perspectives: the Vulnerability–Sensitivity–Resilience (VASS) framework (Turner et al., 2003), exposure–

sensitivity–adaptive capacity framework (Lavell et al., 2012) and the Sustainable Livelihoods Framework (SLF) (Scoones,1998; DFID,1999). Together, these perspectives provide a theoretical path from climate shocks to vulnerability, response strategies and the impact on livelihoods as explained in Figure 5.

Figure 5: Conceptual framework of the study



Source: Author's own construction

As illustrated in Figure 5, the framework shows the relationship between climate hazards, the exposure and vulnerability of households, coping and adaptation strategies, and livelihood outcomes. The following section explains these relationships and the mechanisms by which climate-related shocks shape the response and resilience of pastoral households.

Rainfall and temperature variability are part of the biophysical exposure component of vulnerability and can be measured by means of drought indicators such as Precipitation Concentration Index (PCI), Standardized Precipitation Index (SPI), and Standardized Precipitation Evapotranspiration Index (SPEI) (Turner et al., 2003). For pastoralist systems, drought is a major climatic shock, as it has a direct impact on rangeland and water

availability. Evidence from pastoralist communities, including Turkana households in Kenya, shows that drought severity and frequency have increased over the past few decades. Climate variability and droughts are therefore the initial trigger that sets in motion the process of vulnerability and response. (Opiyo et al., 2014).

Household perceptions act not only as a reflection of exposure to climate but also as a proxy filter through which households interpret and react to environmental risks. Perception is affected by socio-demographic, economic, institutional and environmental conditions. When household perceptions are closely matched to actual climatic conditions, adaptation responses are more likely to be adequate and effective. As a result, households facing similar drought conditions may have different degrees of vulnerability as they experience and interpret the risk in different ways (Angula and Kaundjua, 2016).

The vulnerability is grounded on the sustainable livelihood's framework, which identifies five forms of capital for livelihoods: human, social, financial, physical (Scoones 1998; DFID 1999). These assets determine the resources households have available to withstand shocks and react to changing circumstances. Thus, vulnerability is dynamic and asset-based: households with more access to livelihood capital tend to have greater capacity to adapt, while households with fewer assets tend to be more vulnerable. This aligns with the Lavell et al. (2012) perspective that adaptive capacity influences the extent to which exposure and vulnerability transform into vulnerability.

Vulnerability subsequently shapes households' choices between coping and adaptation strategies. Coping mechanisms are typically short-term and reactive, such as destocking, safety-net use, casual labor, and reducing food consumption, whereas adaptation strategies involve longer-term adjustments, including migration, livestock diversification, drought-tolerant herds, and soil and water conservation (Turner et al., 2003; Opiyo et al., 2014). Pastoral households often rely first on coping mechanisms after a drought, while long-term adaptation is dependent on their assets, institutions, and access to resources.

Adaptation and coping strategies produce livelihood outcomes that can either enhance resilience or contribute to continued vulnerability. These results are not definitive, but they feed back into the future vulnerability of households through changes in their livelihood assets and capacity to adapt. The results will also affect future perceptions among

households as they reassess climate risks based on experience and the effects of past shocks (Turner et al., 2003; Scoones, 1998).

Overall, the framework follows the sequence: climate variability and drought → exposure → household perception and sensitivity → capital-based vulnerability → coping and adaptation strategies → livelihood outcomes → feedback to future vulnerability and perception. This integrated framework combines the Vulnerability–Sensitivity–Resilience framework and Intergovernmental Panel on Climate Change (IPCC) perspectives on exposure, sensitivity, vulnerability, and adaptive capacity with the sustainable livelihood framework emphasis on livelihood capitals, strategies, and outcomes. It therefore provides an empirically testable framework for examining how climate-induced shocks affect pastoral households and how their perceptions and livelihood assets shape their coping and adaptation mechanisms.

3.5 Data analysis

This study achieved its objectives by analyzing secondary data and survey data through classification, editing, coding, systematization, summarization, descriptive statistics, inferential techniques, and econometric models. The researchers employed the Mann–Kendall statistical test, Sen's slope estimator, the coefficient of variation, and correlation coefficient models to analyze climate variability and change. Drought conditions were assessed using indices such as the Precipitation Concentration Index (PCI), Standardized Precipitation Index (SPI), and Standardized Precipitation Evapotranspiration Index (SPEI). Binary logit model to identify the determinants of household perception toward climate change. Principal component analysis (PCA) and ordinal logit (proportional odds) models were applied to investigate vulnerability and its determinants. Descriptive statistics and multivariate probit models were utilized to identify adaptation strategies and their determinants. To meet the research objectives, IBM SPSS version 29 (IBM Corp., 2023), Stata version 17 (StataCorp LLC, 2021), and XLSTAT Version 2025.x (Addinsoft, 2022), DrinC (Tigkas et al., 2015) software was used to calculate parameter estimates during the data analysis process. The various methods are described below in relation to the objectives and hypotheses for which the methods were applied.

Table 7: The list of variables in the analysis

No	Variable name	Unit	Definition and ranges of value	Source
I	Climate data			
1	Temperature	°C	Area's long-term near-surface air temperature; continuous	Meteoblue database
2	Rainfall	Mm	Total precipitation over period; continuous	Meteoblue database
	Dependent variable			
3	Perception of the household	Binary (1/0)	Household perception that climate has changed:	Household survey
4	Vulnerability level	Scale	high, moderate, and low.	Household survey + constructed index
5	De stocking	Binary (1/0)	Practiced herd destocking in the last 12 months: 1=Yes, 0=No.	Household survey
6	Productive safety net program	Binary (1/0)	Participation in Productive Safety Net Program: 1=Yes, 0=No.	Household survey
7	Short-term casual labour	Binary (1/0)	Short-term casual labour undertaken as coping in the last 12 months: 1=Yes, 0=No.	Household survey
8	Reduction in daily food intake	Binary (1/0)	Reduced daily food intake as coping in the last 12 months: 1=Yes, 0=No.	Household survey
9	Seasonal livestock migration	Binary (1/0)	Seasonal livestock migration practiced in the last 12 months: 1=Yes, 0=No.	Household survey
10	Herd diversification	Binary (1/0)	Herd diversification (≥2 species or breed mix): 1=Yes, 0=No	Household survey
11	Drought-tolerant livestock	Binary (1/0)	Adoption of drought-tolerant livestock (e.g., camel/goat/resilient breeds): 1=Yes, 0=No.	Household survey
12	Nonfarm diversification	Binary (1/0)	Engagement in non-farm income sources: 1=Yes, 0=No	Household survey

No	Variable name	Unit	Definition and ranges of value	Source
13	Soil and water conservation	Binary (1/0)	Soil & water conservation practiced (terraces, bunds, micro-basins): 1=Yes, 0=No	Household survey
	Independent variables			
14	Sex	Binary (1/0)	Sex of the household head and it is a dummy variable assigned one if a head is male and 0 otherwise.	Household survey
15	Family size	Count (persons)	Total number of household members takes the value of (1, 2, 3, …). It is a continuous variable	Household survey
16	Education	Schooling year	Highest education attained by household head and it is a continuous variable measured in education level of household	Household survey
17	Age	Years	Age of household head in years and continuous variables (1, 2, 3...	Household survey
18	Training participation	Binary (1/0)	Household participation in training in last 12 months (1=Yes, 0=No)	Household survey
19	Access to health facility	Binary (1/0)	Households' perception level of health service quality. A dummy variable, which takes 1 if a household access 0 otherwise.	Household survey
20	Livelihood of household	Categorical	Primary livelihood activity of the household (Pastoral, farmers, trade, daily labour)	Household survey
21	Livelihood experience	Years	Household head years of experience in main livelihood and a continuous variable (1, 2, 3...	Household survey
22	Total income	ETB/year	It represents the annual average household income and a continuous variable expressed using values such as 1, 2, 3… in Ethiopian currency.	Household survey

No	Variable name	Unit	Definition and ranges of value	Source
23	Total Expenditure	ETB/year	It is an average household expenditure per annum and a continuous variable expressed using values such as 1, 2, 3 in Ethiopian currency	Household survey
24	Access to saving	Binary (1/0)	It represents household currently has savings. A dummy variable, which takes 1 if a household participate in saving 0 other wise	Household survey
25	Access to credit	Binary (1/0)	It represents household obtained any loan in last 12 months. A dummy variable, which takes 1 if a household access 0 other wise	Household survey
26	Received remittance	Binary (1/0)	Support received by a household from friends/relatives in the last 12 month, which takes 1 if a households received 0 other wise	Household survey
27	Access to insurance	Binary (1/0)	Household head enrolled in insurance. A dummy variable, which takes 1 if a household enrolled 0 otherwise	Household survey
28	Membership of Cooperative	Binary (1/0)	Any member belongs to a pastoral/co-op group. A dummy variable, which takes 1 if a household participate in cooperative 0 other wise	Household survey
29	Access to information	Binary (1/0)	Receives climate/weather information. A dummy variable, which takes 1 if a household access 0 otherwise	Household survey
30	Access to veterinary service	Binary (1/0)	It refers to extension agent contact with pastoralists. A dummy variable, which takes 1 if a household access 0 otherwise	Household survey
31	Tropical Livestock unit	TLU (index)	It is a continuous variable and measured by Tropical Livestock Unit (TLU Size of livestock owned by HHHs	Household survey
32	Range land	Hectares	Area of private pasture/enclosure owned or used by the household, and it is measured by hectares (1, 2, 3 …).	Household survey

No	Variable name	Unit	Definition and ranges of value	Source
33	Farmland	Hectares	Represents cultivated land area owned/used by the household in hectares value (1, 2, 3 …).	Household survey
34	Access of potable water	Binary (1/0)	Potable water accessible in locality of household. A dummy variable, which takes 1 if a household access 0 otherwise	Household survey
35	Grazing land condition	Binary (1/0)	Household assessment of rangeland condition. It is a dummy variable, which takes 1 if grazing condition good 0 otherwise	Household survey
36	Access to livestock water	Binary (1/0)	Livestock water points accessible. A dummy variable, which takes 1 if a household access 0 otherwise	Household survey
37	Distance to all-weather road	Kilometers	Distance from home to nearest all-weather road and it is a continuous variable	Household survey
38	Distance to nearest market	Kilometers	Distance from home to nearest market and it is a continuous variable.	Household survey
39	Access to Electricity	Binary (1/0)	Household has grid/solar electricity and a dummy variable, which takes 1 if a household access 0 otherwise	Household survey
40	Distance to nearest school	Kilometers	Distance from home to nearest school and it is a continuous variable	Household survey
41	Distance to nearest health center (km)	Kilometers	Distance from home to nearest health canter and it is a continuous variable	Household survey
42	Distance to pastoral training	Kilometers	Distance from home to nearest PTC and it is a continuous variable	Household survey
43	Distance to veterinary health post (km)	Kilometers	Distance from home to nearest vet post it is a continuous variable	Household survey

Source: Author's own construction

3.5.1. Objective one: To analyze the long-term variability and trends in precipitation and temperature and their correlation between them in the study area

In this study, the Mann–Kendall statistical test, Sen's slope estimator, the coefficient of variation, and correlation coefficients were applied to examine temporal patterns and trends in rainfall and temperature, as well as the relationships between them in the selected study area. Annual and seasonal rainfall and temperature were illustrated using line graphs to highlight observable trends over time. The analysis drew on data obtained from the Meteoblue database, spanning 40 years (1984–2024) and covering monthly, seasonal, and annual rainfall and temperature.

The Mann-Kendall test

The Mann-Kendall (MK) test is a robust non-parametric method for detecting monotonic trends in time series, proposed by Mann (1945) and developed by Kendall (1975), remaining reliable despite outliers and non-linearity without assuming normality (Roshani et al., 2023; Sanogo et al., 2023). It returns a standardized Z-statistic and p-value for trend significance (Isioma et al., 2018). MK assumes data are independent and identically distributed under the null of no trend, testing for monotonicity rather than a specific functional form. Serial correlation violates independence, so pre-whitening is recommended, though large sample size and trend magnitude reduce this sensitivity. Alternatives include the Seasonal Mann-Kendall test (removing seasonal confounding), Sen's slope, and Innovative Trend Analysis (Tan Kesgin, 2025).

In Ethiopia, the MK test has been widely applied to assess long-term rainfall and temperature variability, and climate extremes across pastoral and agro-pastoral systems (Alemayehu et al., 2024; Aytenfisu et al., 2024; Deresse et al., 2025; Duba, 2022; Gebbisa & Bacsi, 2025; Shigute et al., 2023; Tofu & Mengistu, 2023; Worku, 2024). These studies confirm that MK, often paired with Sen's slope, is a reliable tool for quantifying climate change impacts and guiding adaptation strategies in vulnerable pastoral areas.

Sneyers (1990) defines the MK test statistic (S) as the sum of positive differences minus negative differences, calculated as follows:

$$s = \sum_{j=1}^{n-1} * \sum_{i=j+1}^{n} sign(Zi - Zj) \quad \text{(Eq.3)}$$

Where n is the data series, j=1,2,3.....n, i=j+1,2, 3.....n, Zj = variable ranks from j^{th}, Zi variable ranks from $i^{th,}$ and mean and variance for statistics (S) were derived from sign (Zi-Zj)

$$Sign(Zi - Zj = \begin{cases} +1\ if\ (Zi - Zj) > 0 \\ 0\ if\ (Zi - Zj) = 0 \\ -1\ if\ (Zi - Zj)\ < 0 \end{cases} \quad \text{(Eq.4)}$$

Kendall (1975) utilised to estimate a normal approximation test for large datasets comprising over 10 values. This method utilizes a normal distribution with mean and variance to address non-monotonic trends in the data. The E(S) = 0, and the variance of Var (S) can be calculated as:

$$Var\ (S)\ = \frac{(n-1)(2n+5)-\sum_{p=1}^{k} t_p(t_p-1)(2t_p+5)}{18} \quad \text{(Eq.5)}$$

Where t_p is the number of tied groups of data in the p_{th} group, and k is the number of tied groups. If there are no tied groups, this summary process can be ignored (Kisi and Ay, 2014). A tied group is a collection of sample data with the same value. In cases where the sample size is > 10, the standard normal test statistic Z_S is computed as follows:

$$Zs\ = \begin{cases} \frac{S-1}{\sqrt{Var(s)}},\ if\ S > 0 \\ 0\ , \qquad\quad if\ S = 0 \\ \frac{S+1}{\sqrt{Var(s)}},\ if\ S < 0 \end{cases} \quad \text{(Eq.6)}$$

Positive Z_S values indicate increasing trends, whereas negative Z_S values show decreasing trends. The p-value determines the statistical significance of the trend. The lower the p-value, the more statistically significant the observed difference.

Sen's slope estimator

Sen's slope (Sen, 1968), building upon Theil's (1950) research, estimates the trend as the median of all pairwise slopes. This constitutes a robust nonparametric measure of the rate of change. When combined with the Mann-Kendall test, it simultaneously provides directionality and significance, with a positive slope indicating an increase and a negative slope indicating a decrease. Recent Ethiopian studies confirm its value, including applications in Eastern Bale (Gebbisa & Bacsi, 2025), Borana (Worku, 2024; Duba, 2022), Afar (Aytenfisu et al., 2024), Upper Genale (Shigute et al.,

2023), West Shewa (Tofu & Mengistu, 2023), and southern Ethiopia (Deresse et al., 2025). These works demonstrate that MK with Sen's slope is now the standard method for assessing climate variability and extremes in pastoral and farming systems. Calculate the slope (Ri) of all the data pairs as:

$$Ri = \frac{Zi - Zj}{i - j} \text{ For } i = 1, 2, 3, \ldots n \quad \text{(Eq.7)}$$

Here, *zi* and *zj* are considered as data values at *i* and j time (*i > j),* respectively. Sen's slope estimator is basically the median of these *n* values of *Ri,* ranked from smallest to largest, and the median of the slope, or Sen's slope estimator, is computed as*:*

$$R_{med=} \begin{cases} R\ \frac{(N+1)}{2} & if\ N\ is\ odd \\ \frac{R\frac{N}{2}\ R\frac{(N+2)}{2}}{2} & if\ N\ is\ even \end{cases} \quad \text{(Eq.8)}$$

The coefficient of variation (CV)

According to Pearson (1896), the coefficient of variation (CV) is a dimensionless measure of relative dispersion, calculated as the standard deviation divided by the mean. It is widely used in climate research to compare variability between time periods or regions. In this study, the CV is employed to quantify the temporal consistency and variability of rainfall and temperature in the study area, thereby allowing researchers to understand the extent of climatic fluctuations affecting pastoral livelihoods (Tofu & Mengistu, 2023; Deresse et al., 2025; Alemayehu et al., 2024; Akafu, 2025). The calculation is as follows:

$$CV = 1 + \frac{\sigma}{\mu} * 100 \quad \text{(Eq.9)}$$

CV stands for coefficient of variation, σ for standard deviation, and μ for mean precipitation and temperature. CV classifies climate variability as low (CV < 20), moderate (20 < CV < 30), or high (CV > 30) (Asfaw et al. 2018).

Hypothesis one is confirmed if the MK-test p-value is below 0.05, Sen's slope estimator is non-zero (positive or negative), and the coefficient of variation (CV) falls below 20, between 20 and 30, or surpasses 30. The assessment of significant changes in long-term trends depends on factors like

dataset characteristics, chosen significance level, and considerations such as data type and duration of the time series.

Coefficients of correlation

The correlation coefficient standardizes covariance into a dimensionless index within the range [–1, +1], which Pearson formalized based on Galton's pioneering research (Galton, 1888; Pearson, 1895, 1896). For rainfall (X) and temperature (Y), Pearson's r quantifies the strength and direction of their linear association and is widely used in pastoral studies to assess the impact of simultaneous variation on pasture, water, and livestock productivity. Several empirical studies have employed this approach to capture climate dynamics in dryland ecosystems (Sanogo et al., 2023; Worku, 2024; Alemayehu et al., 2024).). The formula for Pearson's correlation coefficient is expressed as:

$$r_{XY} = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}} \quad \text{(Eq.10)}$$

Where r_{XY} represents the correlation coefficient that indicates the strength and direction of the relationship between rainfall and temperature. Here, X_i and Y_i denote the rainfall and temperature values at time i, respectively, while $\bar{X}$ and $\bar{Y}$ indicate their corresponding means. The term n refers to the total number of paired observations considered in the analysis.

Based on the above, the following two hypotheses are formulated:

H1: The monthly precipitation varies by seasons without an annual precipitation trend. This hypothesis will be tested by evaluating the coefficient of variation of monthly precipitation, and the existence of an annual trend of long-term precipitation time series.

H2: Annual and seasonal temperatures show a positive trend and temperatures are negatively correlated to precipitation. The trend analysis of long-term mean, minimum, and maximum temperatures will be used, and correlations of annual precipitation values with minimum, maximum and mean annual temperatures, to justify or reject this hypothesis.

3.5.2. Objective two: To quantify the inter-annual precipitation distribution and the dominance of mild drought in the study area.

To identify the level and frequency of drought in the study area, this research applies four widely recognized indices: the Precipitation Concentration Index (PCI), the Standardized Precipitation Index (SPI), and the Standardized Precipitation Evapotranspiration Index (SPEI). These indices offer additional information about rainfall variability, distribution, and climate-driven water balance, enabling a comprehensive assessment of drought patterns across time and space.

Precipitation concentration index (PCI)

The Precipitation Concentration Index (PCI) is a statistical indicator developed by Oliver (1980) to assess the temporal distribution and concentration of rainfall over a given period (monthly, seasonal, or annual). The Precipitation Concentration Index (PCI) is widely recognized as a reliable measure of rainfall distribution and irregularity (Oliver, 1980). It has been increasingly applied in pastoral and semi-arid studies to assess rainfall seasonality and drought exposure (Ayugi et al., 2021; Mekuyie and Mulu,2021 Alemu et al., 2023; Shigutie,2023; Shibru et al., 2023; Deresse et.al.,2025; Akafu,2025; Abebe et.al.,2025). According to Oliver (1980), PCI is derived from the squared proportion of monthly rainfall relative to the annual total. The general formula is:

$$PCI = \frac{\sum_{i=1}^{12} {p_i}^2}{(\sum_{i=1}^{12} p_i)^2} \qquad (Eq.11)$$

Where P_i represents rainfall in month i(i=1,2,3……..12) and $\sum_{i=12}^{12} p_i$Total annual rainfall.

Standardised Precipitation Index (SPI)

The Standardized Precipitation Index (McKee et al., 1993) measures precipitation anomalies relative to the long-term mean in standard deviation units; positive values indicate wetter, negative values drier conditions. It assumes precipitation fits a parametric distribution (typically gamma), with reliability depending on distribution fit and record length (~30 years recommended). SPEI (adding evapotranspiration) is the main alternative, while Bayesian hurdle models address non-stationarity (Vergni et al., 2017). WMO-endorsed, SPI is widely used as a robust drought indicator in semi-arid and pastoral regions (Aytenfisu et al., 2024; Worku, 2024; Alemayehu et al., 2024). It is calculated using the following formula:

$$\mathrm{SPI} = \frac{\rho_i - \mu}{\sigma} \qquad (Eq.12)$$

Where: P_i = Precipitation for the i^{th} year, μ = Mean precipitation for the period, and σ = Standard deviation of precipitation for the period

Standardised Precipitation Evapotranspiration Index (SPEI)

The Standardized Precipitation Evapotranspiration Index (SPEI), developed by Vicente-Serrano et al. (2010), integrates precipitation and potential evapotranspiration (PET) into a single standardized drought indicator by fitting the precipitation-minus-PET water balance to a log-logistic distribution. Robustness depends on the PET estimation method and a long base period (30–50+ years); since negative P-E values make the gamma distribution unsuitable, log-normal or GEV distributions are preferred instead. A common alternative specification is comparing the simplified Thornthwaite method against more complex PET calculations (Vicente-Serrano et al., 2010).

SPEI has been widely applied in pastoral regions to assess drought variability and its livelihood impacts (Shibru et al., 2023; Aytenfisu et.al.,2024; Worku,2024; Alemayehu et.al.,2024). It is calculated using the following formula, as expressed below:

$$SPEI = \Phi^{-1}[F_D(D_k)] \quad \text{(Eq.13)}$$

Where:

• $D_t = \Sigma (P_i - PET_i)$ over k months (climate balance).

D_t: Climate water balance at time t

P_t: Precipitation at time t (rainfall).

PET_t: Potential evapotranspiration at time t.

• F_D (·) is the cumulative distribution function (CDF) of the fitted probability distribution (typically log-logistic) for D_k.

• Φ^1 (·) is the inverse standard normal CDF (standardized to z-scores).

Based on the above, the following hypothesis is formulated:

H3: The annual precipitation is concentrated in specific months, and the occurrence of mild drought is dominant. This hypothesis will be tested by evaluating the distributions of the previously introduced precipitation and drought index series.

3.5.3. Objective three: To analyse the indicators of perceptions and to identify the key determinants that influence household perceptions of climate change

Pearson's χ^2 test of independence assesses the association between two categorical variables by comparing observed and expected values in a contingency table (Pearson, 1900). This study applied the χ^2 test to "yes/no" responses regarding climate change indicators to verify whether pastoralists' perceptions deviated from independence between groups. This technique is a suitable choice for large-scale survey data with categorical outcome variables where the normality assumption does not hold. Similar approaches have been employed in previous studies to analyse pastoralists' and smallholder farmers' perceptions of climate change (Tesfahunegn et al., 2016; Abrham & Mekuyie, 2022; Debela et al., 2015; Idrissou et al., 2021; Maziya & Nkonki-Mandleni, 2024).

The binary logistic regression model (BLRM), formalized by Cox (1958) based on Burkson's (1944) logit, relates predictor variables to a binary outcome variable via the log odds estimated by maximum likelihood. Binary logistic regression requires a binary outcome, independent observations, linearity of continuous predictors with the logit, and no severe multicollinearity. Normality and homoscedasticity are not required. Model fit and linearity can be assessed using the Hosmer–Lemeshow and Box–Tidwell tests. If linearity is violated, continuous predictors can be categorized as an alternative (Harrison & Pius, 2020).

This model is widely used to analyze determinants of household climate change awareness in livestock grazing and agricultural grazing systems, where the response is dichotomous (e.g., aware = 1, unaware = 0). This binary logistic regression model has been extensively utilized in climate awareness studies and has been employed in empirical research such as Tesfahunegn et al., 2016; Idrissou et al., 2021; Ewalo and Veded, 2023; and Maziya & Nkonki-Mandleni, 2024. Accordingly, the functional form of the model is expressed as:

$$Ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots\ldots\ldots + \beta_x X_{xi} = \beta_0 + \beta_x X_{xi} \qquad \text{(Eq.14)}$$

where P_iDenotes the probability that household i perceives climate change, $1 - P_i$*Represents* the probability that the same household i does not perceive climate change. The terms $X_{1i}, X_{2i} \ldots\ldots\ldots X_{xi}$ are the explanatory variables, β_0 is the intercept, β_1, β_2 … and β_x are regression coefficients of the independent variables of x_1, x_2 … and x_k.

In binary logistic regression analysis, the odds ratio is the key measure for interpreting the effect of explanatory variables on the outcome. An odds ratio greater than 1 indicates that the predictor increases the likelihood of the event occurring, reflecting a positive relationship. An odds ratio equal to 1 shows no association between the predictor and the outcome, while an odds ratio less than 1 suggests that the predictor decreases the likelihood of the event, implying a negative relationship.

Model fit is assessed using several statistics: LR χ^2 (Omnibus Test) to test overall significance, −2LL, where lower values indicate better fit, and Pseudo-R^2 measures (Cox–Snell, Nagelkerke, and McFadden) to indicate explanatory power. The Hosmer–Lemeshow test evaluates calibration, with a non-significant result indicating good model fit.

Based on the above, the following two hypotheses are formulated:
H4: A higher proportion of pastoral households perceive direct (meteorological) climate impacts than indirect (livelihood-related) climate change indicators.

H5: Economic and environmental/physical capital endowments have stronger magnitude effects on household perception than socio-demographic and institutional factors.

3.5.4. Objective four: To measure pastoralists' vulnerability to climate change at the household level and identify its determinants in the study area.

Household vulnerability is typically measured using econometric models such as equal weights, expert-based weights, or vulnerability as expected poverty (VEP) (Deressa et al., 2008; Etwire et al., 2013; Zeleke et al., 2021; Gemeda et al., 2023). Instead, this study applies Principal Component Analysis (PCA), introduced by Pearson and extended by Hotelling, to extract orthogonal components that sequentially maximize the explained variance (Pearson, 1901; Hotelling, 1933). PCA provides an objective, data-driven weighting approach, mitigates multicollinearity among indicators, and generates a composite index capturing multidimensional vulnerability. This form of analysis is widely used in pastoralism and livelihood studies, supporting consistency and comparability (Fenta et al., 2019; Uddin et al., 2019; Asfaw et al., 2021b; Gatew & Guyo, 2024).

Principal component analysis requires sufficient variable intercorrelation, checked via KMO sampling adequacy and Bartlett's test of sphericity. Robustness checks include screening for multicollinearity/outliers via squared multiple correlations, with KMO below 0.5 flagging the

removal of variables. The alternative is exploratory versus confirmatory factor analysis with varimax/oblique rotation as sensitivity checks (Hair et al., 2018).

PCA is a variance-based technique that reduces correlated indicators into fewer uncorrelated components while retaining most of the original information (Jolliffe & Cadima, 2016). It is useful for constructing composite vulnerability indices and assigning objective weights to interrelated indicators (Abdi & Williams, 2010). To ensure comparability, all variables were standardized to zero mean and unit variance before analysis (Lever et al., 2017). Following Lavell et al. (2012), vulnerability is assessed through three core dimensions: adaptive capacity, exposure, and sensitivity, reflecting their combined effect on overall vulnerability and can be expressed as:

$$Vulnerability(v_i) = (Exposure\ +\ Sensitivity\ ) - (Adaptive\ capacity) \qquad (Eq.15)$$

Equation (16) indicates that a household becomes less vulnerable to climate change and extremes when its adaptive capacity outweighs the combined effects of exposure and sensitivity; conversely, when exposure and sensitivity exceed adaptive capacity, the household is more vulnerable. The model is calculated using the following equation:

$$v_i = \left(A_1X_{1j} + A_1X_{2j} + \cdots + A_{1n}X_{nj}\right) - \left(A_{n+1}Y_{1j} + A_{n+2}Y_{2j} + \cdots + A_{n+n}Y_{nj}\right) \qquad \text{(Eq.16)}$$

Where $v_i$denotes vulnerability as an index. X_n represents the elements of adaptive capacity; and Y_n denotes the elements of exposure and sensitivity; and $A_n$refers to the principal component scores obtained from factor analysis. The values of X and Y are standardized through normalization, using their respective means and standard deviations.

Mathematically, the standardized form for adaptive capacity (X) and for exposure/sensitivity (Y) can be expressed as:

$$Z_i^x = \frac{\mathrm{X_{1j}} - \overline{\mathrm{X}}}{\sigma_X} \quad , \; Z_i^y = \frac{\mathrm{Y_{1j}} - \overline{\mathrm{Y}}}{\sigma_Y} \qquad \text{(Eq.17)}$$

where the $\overline{\mathrm{X}}$ and $\overline{\mathrm{Y}}$ represent the mean value of $\mathrm{X_{1j}}$ and $\mathrm{Y_{1j}}$ across household σ_X and σ_y denotes the standard deviation of $\mathrm{X_{1j}}$ and $\mathrm{Y_{1j}}$respectively.

Thus, the normalized values (Z_i^x, Z_i^y) Provide dimensionless indicators that allow comparability across households and are subsequently used in computing the composite vulnerability index. In this context, the first principal component of a set of variables is defined as a linear combination of all variables that captures the maximum proportion of the total variance shared among them. Accordingly, the complete matrix of indicators—comprising adaptive capacity (X_{1j}) and exposure and sensitivity (Y_{1j}) Can be represented as follows:

$$\frac{X_{ij}}{Y_{ij}} = \begin{pmatrix} (X_{11}+X_{12}+\cdots\ldots\ldots X_{2n})-(Y_{11}+Y_{12}+\cdots\ldots\ldots Y_{2n}) \\ \vdots \\ (X_{m1}+X_{m2}+\cdots\ldots\ldots X_{mn})-(Y_{m1}+Y_{m2}+\cdots\ldots\ldots Y_{mn}) \end{pmatrix} \quad (Eq.18)$$

Here, i indexes' rows (individual households, i=1,,341) and j indexes columns (indicators, j=1,…,25 variables) covering adaptive capacity, exposure, and sensitivity. In Equation 20, $\boldsymbol{A}_{1j}$ denotes the first principal-component score (loading/weight) for indicator j, estimated via PCA in SPSS. Finally, the vulnerability index of each household is obtained using Equation 19 as follows:

$$v_i = \begin{pmatrix} A_{11} \\ A_{12} \\ \vdots \\ A_{n+n} \end{pmatrix} * \begin{pmatrix} (X_{11}+X_{12}+\cdots\ldots\ldots X_{2n})-(Y_{11}+Y_{12}+\cdots\ldots\ldots Y_{2n}) \\ \vdots \\ (X_{m1}+X_{m2}+\cdots\ldots\ldots X_{mn})-(Y_{m1}+Y_{m2}+\cdots\ldots\ldots Y_{mn}) \end{pmatrix} \quad (Eq.19)$$

Before conducting PCA, the suitability of the data was evaluated using two diagnostic tests. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy assesses whether the correlation patterns are sufficiently compact for factor analysis; the value ranges from 0 to 1, with > 0.50 considered as suitable for PCA (Kaiser, 1974). The Bartlett's Test of Sphericity should be the level of significance with 'p' values less than 0.5 ($p < 0.5$) for PCA (Bartlett, 1950). The scree plot is a widely used method for retaining principal components. It applies a graphical interpolation technique by plotting eigenvalues in descending order and identifying the point at which a significant breakpoint occurs (Yong & Pearce, 2013). In addition, Kaiser's criterion was considered, where only components with eigenvalues greater than one ($\lambda>1$) are retained for further analysis. To enhance interpretability, the Varimax rotation method was applied, which maximizes high item loadings and minimizes low ones, thereby producing a clearer and more simplified factor structure (Abdi & Williams, 2010).

The previous studies have used several econometric models to identify the determinants of household vulnerability. Common choices include ordinal logistic/probit models (Opiyo et al., 2014;

Tofu & Dedefa, 2018; Gatew & Guyo, 2024), binary logit models (Zeleke et al., 2021; Tefera et al., 2025), multinomial logit models, and ordinary least squares (OLS). Model selection depends on how the outcome is measured: use an ordinal logit/probit model when vulnerability is ranked (e.g., low–medium–high); a binary logit model when it is dichotomous (vulnerable vs. not vulnerable); a multinomial logit model when categories are nominal without a credible order; and OLS when a continuous vulnerability index is analyzed (e.g., a standardized LVI score).

The ordinal logit (proportional odds) model proposed by McCullagh (1980) employs a cumulative logit with a common slope across the threshold. It assumes proportional odds, meaning that coefficients are constant across outcome thresholds. This assumption can be tested using the Brant test. If violated, partial proportional-odds or generalized ordered logit models can be used to allow coefficients to vary across thresholds (Brant, 1990).

This study applies ordered logit model to estimate how the predictor variable alters the probability of belonging to a lower category relative to the top category, utilizing the fact that vulnerability is ranked (high, medium, low). Following Greene (2002 the reduced form of ordinal logit specification is:

$$Y_i = \beta_1 X_{ij} + U_{ij} \quad \text{(Eq..20)}$$

Where Y is the given state of vulnerability. β_1Are parameters estimated, and $U_{ij}$is the disturbance term. The X_{ij}The explanatory variables determining the vulnerability level of the households. The independent variables included in the model are grouped into the five livelihood capitals: human, financial, social, physical, and natural.

The factors that influence human capital include level of education, participation in training, health status, and years of livelihood experience. Financial capital includes total household income and expenditures, savings, credit, remittances from family or friends, and insurance coverage. Social capital includes membership in pastoral cooperatives, access to timely weather information, and veterinary extension support. Natural capital includes Tropical Livestock Units (TLU), pastureland area (ha), farmland area (ha), accessibility to drinking water for people, and access to water sources for livestock. Physical capital includes access to electricity and distance (km) to an all-weather road, the nearest weekly market, school, health center, pastoral training center, and veterinary health post.

Based on the above, the following hypothesis is formulated:

H6: The combined effects of human and financial capital are expected to have a stronger influence on household vulnerability than natural and physical capital.

H7: Higher human capital endowments (education, training, livelihood experience, health status) reduces the probability of high vulnerability of pastoralist household.

3.5.5 Objective five: To examine local pastoral household coping and adaptation mechanisms towards climate change and identify its determinants in the study area.

In previous studies, different models have been applied to identify factors affecting coping and adaptation strategies toward climate change. Among this model Multinomial logistic model (Feyyisa et al.,2025 and Regasa,2025), Binary logistic regression (Alemayehu and Bewket,2017; Tolera and Senbeta,2020 and Snaibi et.al.,2021), Binomial logit model (Kgosikoma et.al.,2018), Heckman model (Opiyo et.al.,2016; Mohamed Sala et.al.,2020; Belay et al.,2022), Descriptive statistics (Opiyo et.al.,2015, Lelamo et.al.,2022).

This study analyzes the coping and adaptation strategies of pastoral households using descriptive statistics and a multivariate probit (MVP) model. The MVP model, proposed by Ashford and Soudan (1970) based on the work of Zellner and Lee (1965), extends the probit model to handle multiple binary choices with correlated latent errors. This model captures the interdependence between strategies adopted simultaneously or sequentially, enabling the identification of complementarity or substitutability. Joint estimation enhances efficiency and inferential power regarding common determinants, while the estimated error correlation (ρ) quantifies the dependence between strategies. A rich set of covariates explains the relationship between household characteristics and adaptation decisions.

The multivariate probit model assumes jointly normally distributed, correlated errors across equations. Estimation typically requires simulation methods such as the GHK simulator to approximate multidimensional normal probabilities, with model complexity increasing as the number of equations grows. If cross-equation correlations are negligible, clustered univariate probit models or multinomial logit/probit models may be considered as alternatives (Cappellari & Jenkins, 2003). The general expression of the multivariate probit model is:

$$y_{m_i} *= \beta_{mi} * x_{m_i} + \mu_i \quad \text{(Eq.21)}$$

Where (y_m = 1... k) represents the dependent variable of choice of existing adaptation strategies to climate change and variability chosen by the i^{th} local pastoralist (i = 1... n). The dependent variables are polychotomous variables, indicating whether local pastoralists choose adaptation strategies to climate change or not.

The study treated the identified coping and adaptation strategies as dependent variables. The four coping mechanisms and five adaptation strategies were selected based on insights from the pilot study and a review of pastoralist coping and adaptation literature, reflecting the responses most used in the area. Their relevance was confirmed through pre-survey consultations with pastoral extension experts and local pastoralists.

The explanatory variables for coping and adaptation strategies are education level, training participation, health status, livelihood experience, access to savings, access to credit, livestock ownership, membership in cooperatives, access to information, access to veterinary services, range land, farmland, access to potable water, proximity to markets, access to electricity, and distance to health centers. In the study area, households primarily relied on four coping strategies: destock (selling livestock), short-term casual labour, participation in the Productive Safety Net Program (PSNP), and reducing daily food intake. The adaptation responses of the households clustered into five approaches: seasonal livestock migration, adoption of drought-tolerant livestock, herd diversification, non-farm diversification, and soil and water conservation.

Every pastoralist used one or more coping /adaptation techniques in response to climate change. X_{im}, a 1 × k independent variable, influences the coping/adaptation methods to climate change, while the unknown parameters to be estimated are represented by β_m, a k × 1 vector. The error terms, denoted as m = 1... m, the variables' follow a multivariate normal distribution with a zero mean, and the variance-covariance matrix V represents the correlations between the variables.

As seen from the following equations, the system consists of m equations, representing the adoption of the m coping/adaptation strategies:

For Coping strategies:

$$y_{1_i} *= \beta_1 x_{1_i} + \mu_{1_i} \quad \text{(Eq.22)}$$

$$y_{2_i} *= \beta 2 x_{2_i} + \mu_{2_i} \quad \text{(Eq.23)}$$

$$y_{3_i} *= \beta_3 x_{3_i} + \mu_{3_i} \quad \text{(Eq.24)}$$

$$y_{4_i} *= \beta_4 x_{4_i} + \mu_{4_i} \quad \text{(Eq.25)}$$

For adaptation strategies:

$$y_{5_i} *= \beta_5 x_{5_i} + \mu_{5_i} \quad \text{(Eq.26)}$$

$$y_{6_i} *= \beta_6 x_{6_i} + \mu_{6_i} \quad \text{(Eq.27)}$$

$$y_{7_i} *= \beta_7 x_{7_i} + \mu_{7_i} \quad \text{(Eq.28)}$$

$$y_{8_i} *= \beta_8 x_{8_i} + \mu_{8_i} \quad \text{(Eq.29)}$$

$$y_{9_i} *= \beta_9 x_{10_i} + \mu_{9_i} \quad \text{(Eq.30)}$$

where i = pastoralist id; For coping mechanism, y_{1_i} = 1 if the pastoralist applied destocking/selling livestock (0 otherwise); y_{2_i} = 1 if the pastoralist used short-term casual labor (0 otherwise); y_{3_i} = 1 if the pastoralist participates in the Productive Safety Net Program (0 otherwise); y_{4_i} = 1 if the pastoralist reduces daily food intake (0 otherwise). In the case of adaptation techniques, y_{5_i} = 1 if the pastoralist used seasonal livestock migration (0 otherwise); y_{6_i} = 1 if the pastoralist applied adoption of drought-tolerant livestock (0 otherwise); y_{7_i} = 1 if the pastoralist applied herd diversification (0 otherwise); y_{9_i} = 1 if the pastoralist non-farm diversification (0 otherwise); y_{10_i} = 1 if the pastoralist used soil and water conservation (0 otherwise). X′i = vector of factors of Coping/adaptation choices of the sample response to climate change extremes; βj = vector of unknown parameters (j = 1, 2, 3,..., 9); and ε = error term.

Decisions about coping/adoption or non-adoption/coping (yki) reveal latent dependent factors in this way:

$$Y= \begin{cases} 1 \\ 0 \end{cases} \text{if } y_k*>0,\ k=1, 2, 3, 4 \text{ otherwise} \quad \text{(Eq.31)}$$

In Equation (32), the value yk* represents an underlying or latent variable used to determine the value of Y based on its sign (whether it is positive or non-positive). This means that Y would take the value 1 if yk* is greater than for any k (1, 2, 3, or 4). If $yk* \leq 0$, then Y is 0.

Calculating the marginal effects of the explanatory (dependent) variable on the propensity to choose adoption strategies on each of the livelihood capital or asset measures as follows

$$\frac{\partial p_i}{\partial x_i} = \phi(X'B)\beta_i, i = 1,2,3,4.....n \quad \text{(Eq.32)}$$

Where ρi i. the probability (likelihood) of event i representing the increased choice of each coping, $\emptyset(.)$ is determined by the standard univariate normal cumulative density function. X and βi are vectors of regressors and model parameters, respectively (Hassan, 1996).

Based on the above, the following hypothesis,

H7: Human, social, financial, natural, and physical capital have significantly different effects on pastoral households' coping and adaptation strategies, is formulated.

4. RESULTS AND DISCUSSION

This section presents and discusses the main research findings, summarizing results in relation to the identified gaps, objectives, and hypotheses. The results are organized into tables and figures, and the study interprets the evidence within the context of the literature and local research area. The outline of the key findings and discussions is presented below.

4.1 Socio–demographic characteristics of respondents

This section presents the demographic characteristics of the 351 household respondents. It considers key variables such as age, gender, educational attainment, and occupational experience. The following paragraphs provide a detailed description of these characteristics.

Table 8: Demographic characteristics of respondents

Variables	Category	Frequency	Percentage
Sex of respondents	Male	264	75.2
	Female	87	24.8
	Total	351	100
Marital status	Married	327	93.2
	Unmarried	11	3.1
	Widowed	4	1.1
	Divorced	9	2.6
	Total	351	100
Age of respondent	Youth/ Adolescence (15-24)	9	2.57
	Adult (25-64)	330	94.01
	Elderly (≥ 65)	12	3.42
	Total	351	100
Family size	0	8	2.28
	1-5	97	27.64
	6-10	223	63.53
	>10	23	6.55
	Total	351	100
Educational level	No formal education/ Illiterate	153	43.60

Variables	Category	Frequency	Percentage
	Primary education (Grade 1-8)	97	27.63
	Secondary education (Grade 9-12)	81	23.07
	Tertiary Education	20	5.70
	Total	351	100

Source: Author's own computation using SPSS version 29

In total, 351 heads of households took part in the study. Table 7 shows that most of the respondents were male household leaders; 264 respondents (75.2%) were male, and only 87 respondents (24.8%) were female. The pastoral and agro-pastoral systems in the study area reflect the male dominance in decision-making and control of resources within the household, as evidenced by the fact that 75.2% of the respondents were male household leaders.

As regards marital status, most respondents, 327 people (93.2), were married. Only 11 (3.1) were single, 4 (1.9) widows, and 9 (2.6) divorced. This high share of married respondents is in line with the social structure of rural and pastoralist societies. In these communities, marriage and family formation usually take place at a young age, and this forms the basis for livelihood organization and division of labour.

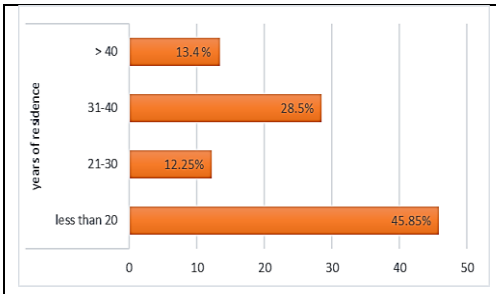
The age distribution of respondents shows that most of the heads of households are in the economically active age group. 0Approximately 330 respondents (94.01 percent) were adults (25-64 years of age), 9 (2.57) were adolescents and young adults (15-24 years of age), and 12 (3.42) were older than 65 years of age. This suggests that most households are run by people of working age, which has a significant impact on their ability to undertake labor-intensive livelihood and adaptation activities in the face of climate variability.

The size of households in the study area is relatively large. Households without additional members (single person households) had only 8 households (2.28) while households with 1 to 5 members had around 97 households (27.64). Most of them, 223 households (63.53%), had 6 to 10 members, while another 23 households (6.55) had 10 or more members. These figures show that most households have a large scale, which may provide more labour for livestock grazing and related activities, but at the same time increases the strain on household resources, food security and access to basic services.

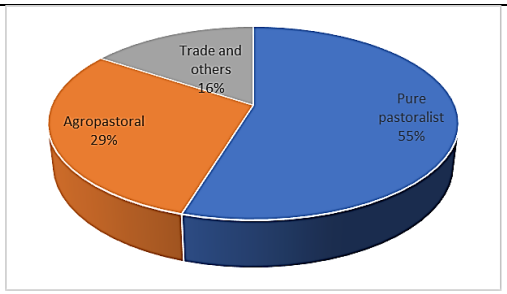
The educational attainment data show that formal education levels of the heads of households are generally low. Some 153 respondents (43.60 percent) did not receive any formal education (illiterate), and 97 respondents (27.63 percent) completed primary education (1-8 years). 91 respondents (23.07 percent) completed secondary education (9-12 years), while only 20 respondents (5.70 percent) completed tertiary education. This pattern indicates that almost three quarters of respondents remain in primary education, which may limit access to climate information, non-agricultural employment opportunities and formal credit services and may influence choices about adaptation strategies.

As regards duration of stay, most respondents lived in the study area for a significant period. Approximately 161 (45.85%) reported to have lived in the 10- to 20-year period, 43 (12.25) in the 21- to 30-to-40-year period, 100 (28.50) in the 40-to-40-year period and 47 (13.40) in the above-40-year period. This long period of residence means that many householders have accumulated considerable local knowledge of grassland ecosystems, climate patterns and traditional coping and adaptation practices, which is of great importance in understanding their climate change perceptions and responses.

Figure 6: Duration of respondent's residence in the area, and main livelihood strategies



Duration of residence (years)



Main livelihood strategies (%)

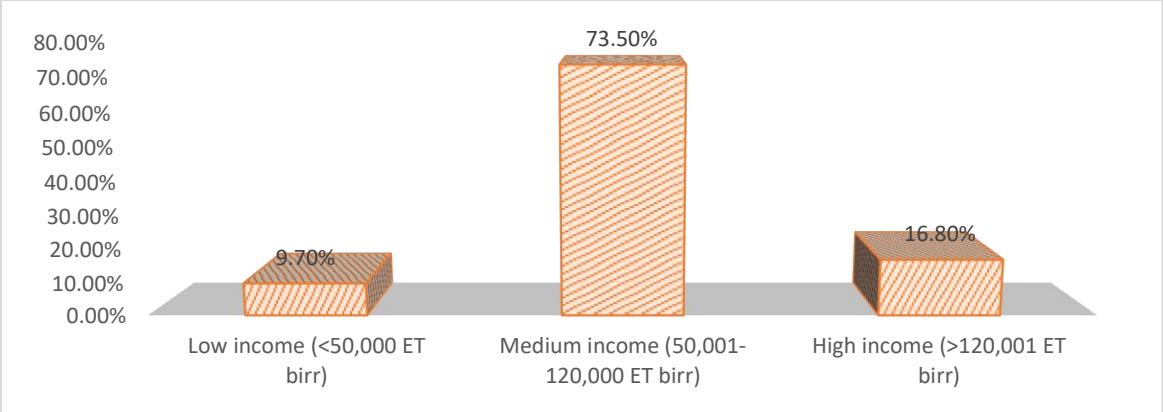
Source: Author's own computation using Excel

The respondents' primary livelihoods reflect the pastoral and agro-pastoral characteristics of the study area. More than half of the 192 individuals (54.70) were pastoralists who relied mainly on livestock rearing and transhumance. Agropastoral, of whom some 104 (29.63) are combined with livestock production, while 55 (15.67) are engaged in trade and other non-agricultural activities. This shows that although livestock still plays a key role in the local economy, a significant number

of households are diversifying into crop production and other income-generating activities. Such diversification can serve as an important strategy for adaptation and risk diversification.

As regards economic status, the annual distribution of income showed that most households were in the middle-income bracket. Approximately 34 respondents (9.70) were classified as low income (less than 50,000 EIBER), 258 households (73.50) as medium income (50,001 EIBER to 120,000 EIBER), and 59 households (16.80) were classified as high income (more than 120,000 EIBER). This indicates that the share of households belonging to the lowest income brackets is relatively low in the pastoral and agro-pastoral environment of the study area. However, a significant number of households remain vulnerable and the share of those who can be considered relatively well-off is limited.

Figure 7: Annual income distribution of respondents



Source: Author's own computation using Excel

Overall, these socio-demographic findings reveal a community characterized by male-headed, married households, high family size, low formal education, long-term settlement, strong reliance on pastoralism and agropastoral livelihoods, and a predominantly middle-class status. These characteristics provide a key background for the interpretation of the vulnerability of households, their perceptions and choices of coping and adaptation strategies in response to climate variability and change in the area studied.

4.2 Climate variability and trend

This section quantifies climate variability and changes by (i) assessing the monthly, seasonal and annual precipitation variability and trends using parametric coefficients and non-parametric tests; (ii) analyzing the minimum, maximum and average temperature for a given time series; and (iii)

estimating the correlation between rainfall and temperature. The results are presented in such a way as to describe the observed patterns and trends in climate variability and changes in the area studied.

4.2.1 Monthly rainfall variability and trends

The monthly rainfall in Rayitu district is very variable. As shown in Table 9, variability peaks in January (CV = 285.8), followed by February (222.9), June (171.2) and December (165.3), which suggest very poor rainfall reliability in Ethiopia (Duba, 2022; Sahilu et al., 2024; Aytenfisu, 2024). March (123.2%), July (107.5), August (112.6) and September (110.2) also show significant volatility, while April (38.2) and May (54.5) are the least volatile and therefore relatively reliable. Evidence therefore suggests that most of the year is characterised by irregular rainfall, with only a few months showing some consistency, especially in the short rains of April and May; this is consistent with the studies on pastoralist areas in the Borana and East Bale areas (Worku, 2024; Gebbisa & Bacsi, 2025).

Most months show no statistically significant trend ($p > 0.05$), except for January, February, April, May, June, July, August, and October, which show only a negligible downward trend, as shown by Tofu and Mengistu (2023), Tadesse et al. (2024), and Shigute et al., (2023). However, two exceptions are noteworthy: the September study shows a significant degressive trend ($\tau = -0.234$, $p = 0.024$, SSA = -0.179), which is consistent with the study in the Southern and Lowland regions of Ethiopia (Dejene et al., 2023; Sahilu et al., 2024).

November, on the other hand, shows a significant upward trend ($\tau = 0.263$, $p = 0.011$, SN slope = 1.044), which is consistent with evidence of localised increases in the late autumn, which may provide opportunities for water use and agricultural planning (Alemayehu et al., 2024; Tadesse et al., 2024). The December trend is close to significance ($p = 0.060$), indicating a possible weakening of the trend, again like the mixed but month-specific signals in the most recent Ethiopia trend studies (Duba, 2022; Kourouma et al., 2022). Overall, despite the large variability, the consistent monthly trends are limited to a few periods, with the September fall problematic and the November improvement potentially beneficial (Worku, 2024; Gebbisa & Bacsi, 2025).

Table 9: Mann Kendall trend test for rainfall (1980-2022)

Variable	Minimum	Maximum	Mean	Std. deviation	CV	Kendall's tau	p-value	Sen's slope
January	0.000	51.900	2.822	8.066	285.80	-0.080	0.472	0.000
February	0.000	40.300	4.772	10.638	222.93	-0.150	0.176	0.000
March	0.000	230.000	38.669	47.650	123.23	0.007	0.953	0.023
April	24.700	255.600	1 21.376	46.376	38.21	-0.095	0.363	-0.504
May	6.600	140.100	58.056	31.620	54.46	-0.147	0.156	-0.516
June	0.000	21.200	2.764	4.733	171.22	-0.107	0.312	-0.008
July	0.000	31.800	6.578	7.073	107.52	-0.040	0.703	-0.014
August	0.000	16.200	3.302	3.718	112.60	-0.052	0.625	-0.010
September	0.300	53.800	8.862	9.764	110.17	-0.234	0.024	-0.179
October	14.400	283.100	85.864	52.706	61.38	0.127	0.221	0.705
November	1.900	280.500	54.978	47.275	85.99	0.263	0.011	1.044
December	0.000	74.400	10.280	16.997	165.34	-0.200	0.060	-0.063
Winter	0.000	90.900	17.874	22.683	126.91	-0.195	0.060	-0.157
Spring	79.100	401.900	218.100	72.222	33.11	-0.188	0.070	-1.453
Summer	0.700	33.800	12.644	9.219	72.91	-0.011	0.922	-0.016
Autumn	19.500	459.400	149.704	87.722	58.60	0.194	0.062	1.934
Annual	168.900	813.100	398.323	120.232	30.18	-0.046	0.660	-0.463

Source: Author's own computation using Excel STATA version 2024

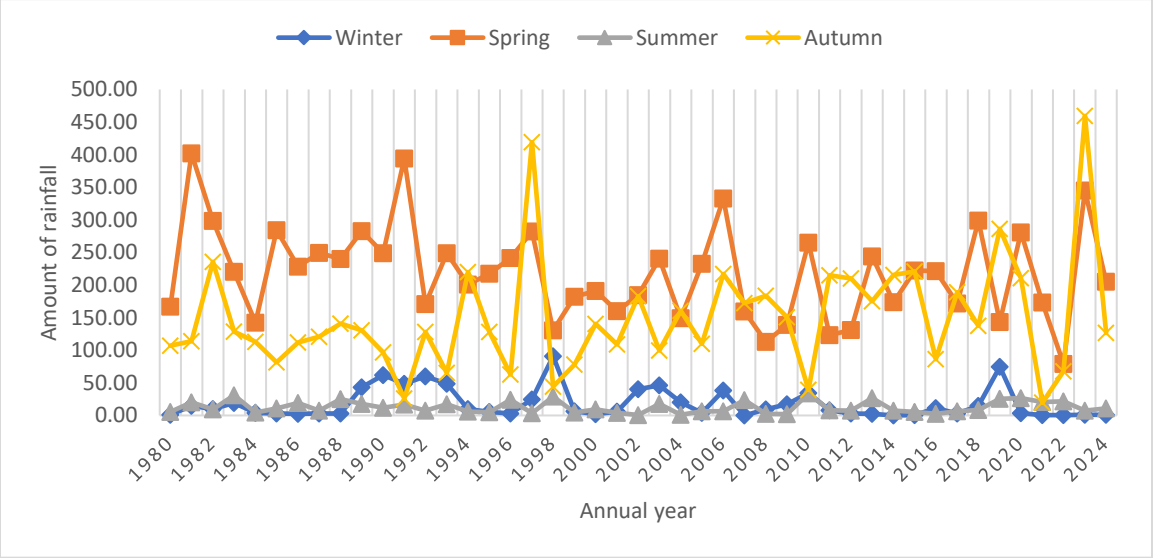
4.2.2 Seasonal rainfall variability and trends

In Rayitu district, the spring rainfall, the main rainy season, is the most stable (CV = 33.1), which suggests a relatively uniform season. However, it shows a close to significant decrease trend (τ = -0.188, p = 0.070; SN slope = -1.453), which raises concerns about livestock productivity. This result is in line with the Asfaw et al. (2018) and Tadesse et al. (2024), which also report on the decreasing spring rainfall and highlight the increasing risk to the main growing season in their respective areas of study.

In contrast, winter is characterized by the highest variability (CV = 126.9) and shows a declining trend which is almost statistically significant (p = 0.060), indicating potential problems in this dry season. This finding is consistent with recent evidence from Borana and the eastern Guji pastoralist area: winter is both the leanest and most unstable season, and while official tests often lack power in December-February (DJF), they nonetheless indicate early drying, which is exactly the signal reflected by Rayitu (Sahilu et al., 2024; Abrham & Mekuyi, 2022).

The summer season shows a moderate variability (CV = 72.9) without a statistically significant trend, in line with the findings of Borana and East Guinean where the season is characterized by drought and variability, but with a large trend (Worku, 2024; Sahilu et al., 2024). In contrast, autumn shows a moderate variability (CV = 58.6) with a rather significant upward trend (p = 0.062) indicating a slight increase in rainfall during this transition period, which is consistent with studies on the intensification of short rains (September-November) in Borana and the eastern Bale region (Worku et al., 2022; Gebbisa & Bacsi, 2025). Seasonality therefore highlights the vulnerability of key growing seasons to climate change, which, if sustained, could undermine food security. This study supports the findings of Worku, 2024; Sahilu et al., 2024; Gebbisa & Bacsi, 2025; and Abrham & Mekuyie, 2022. Figure 9 shows a graph of the seasonal rainfall variability and trends in Rayitu County over the period 1980-2024.

Figure 8: Seasonal rainfall variabilities and trends (1980-2024)



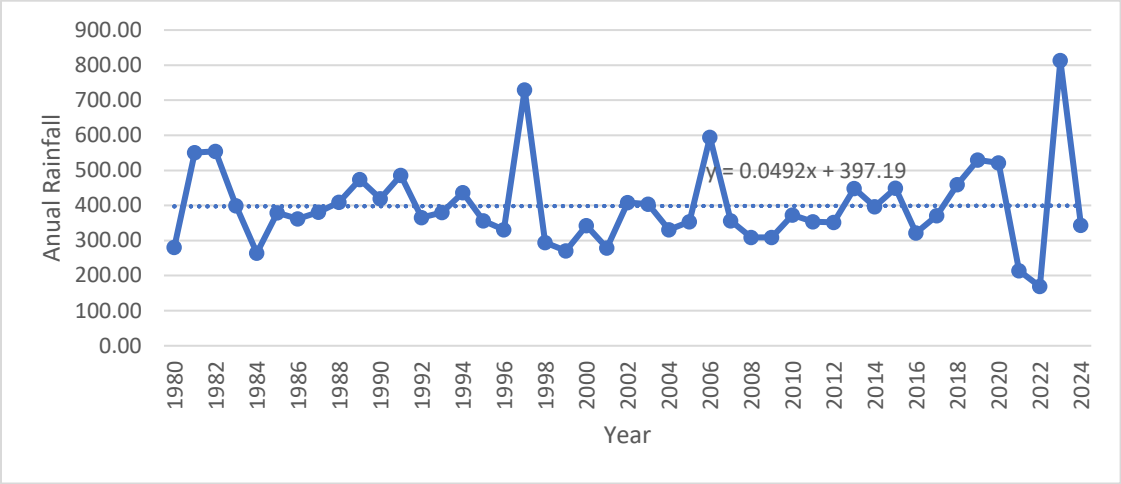
Source: Author's own computation using Excel

4.2.3 Annual rainfall variability and trends

Annual precipitation in the Rayitu is generally stable (CV = 30.18) and does not show a statistically significant trend (t = -0.046; s = -0.463; p = 0.660). However, changes in the timing and distribution of rainfall within a given year reduce the benefits for agriculture and pastoralism. These findings are in line with the evidence from the Sawena East Bale region, where annual precipitation increases are generally small, but with increasing droughts and inter-annual variability (Gebbisa & Bacsi, 2025),

and the West Guji and Borane areas, where precipitation increases are generally small despite increasing droughts and intra-annual variability (Dejene et al., 2023).

Figure 9: Annual rainfall trend of Rayitu district (1980-2024)



Source: Author's own computation using Excel

4.2.4 Minimum average temperature

The steepest increase in the monthly mean temperature is observed in October (S=0.056 Celsius yr^{-}) followed by August (0.038), June (0.037) and May (0.033), all with a p value of >0.33 and p<0.001, respectively, which are consistent with the recent analysis from Ethiopia (Alemayehu et al., 2024). Conversely, March ($\tau = 0.125$, $p = 0.229$) and December ($\tau = 0.129$, $p = 0.214$) do not show a robust trend and January is only marginally affected ($p = 0.049$). The annual variability is highest in October (CV = 5.67), followed by December (4.97) and January (4.67), indicating more unstable nighttime conditions during the seasonal changeover (Alemayehu et al., 2024).

Table 10: Mann Kendall trend test for temperature (1980-2024)

Variable	Minimum average Temperature			Maximum average Temperature			Mean Average Temperature		
	CV	Kendall's tau	Sen's slope	CV	Kendall's tau	Sen's slope	CV	Kendall's tau	Sen's slope
January	4.67	0.204**	0.021	2.32	0.236**	0.017**	2.31	0.335*	0.021
February	4.5	0.287*	0.026	2.44	0.358*	0.029*	2.68	0.372*	0.028
March	4.54	0.125	0.015	4.04	0.145	0.02	4.17	0.164	0.021
April	4.21	0.309*	0.028	4.16	0.269*	0.036	4.31	0.311*	0.034
May	3.65	0.436*	0.033	3.89	0.352*	0.045	3.98	0.39*	0.04

Variable	Minimum average Temperature			Maximum average Temperature			Mean Average Temperature		
	CV	Kendall's tau	Sen's slope	CV	Kendall's tau	Sen's slope	CV	Kendall's tau	Sen's slope
June	3.69	0.463*	0.037	3.89	0.311*	0.041	3.76	0.416*	0.041
July	3.23	0.337*	0.024	3.45	0.317*	0.037	3.29	0.343*	0.032
August	3.21	0.539*	0.038	3.15	0.436*	0.047	3.03	0.529*	0.043
September	3.48	0.527*	0.041	2.57	0.512*	0.043	2.98	0.584*	0.045
October	5.67	0.418*	0.056	3.65	0.2**	0.021	4.3	0.317*	0.038
November	4.31	0.347*	0.028	4.42	-0.024	-0.003	4.12	0.063	0.007
December	4.97	0.129	0.016	3.88	0.194	0.022	3.79	0.206**	0.021
Winter	2.89	0.366*	0.024	1.85	0.378*	0.023	1.85	0.479*	0.025
Spring	3.21	0.366*	0.028	3	0.366*	0.035	3.19	0.366*	0.035
Summer	3.01	0.499*	0.033	2.87	0.446*	0.04	2.92	0.497*	0.038
Autumn	3.69	0.57*	0.042	2.66	0.24**	0.022	2.99	0.402*	0.032
Annual	2.51	0.614*	0.031	1.84	0.545*	0.032	2.13	0.634*	0.034

Source: Author's own computation using XLStata Version 2025. * and ** represents 1 % and 5 % significant level respectively

Seasonal warming is apparent in all quarters, with autumn (SON) ($\tau = 0.366$; 0.378; 0.042) followed by spring (JHA) ($\tau = 0.499$; 0.024); This hierarchy is consistent with the findings of increased night-time warming in SON and JHA across pastoral and agro-pastoral areas (Aytenfisu et al., 2024; Dejene et al., 2023; Alemayehu et al., 2024). The annual signal is both strong and highly significant ($\tau = 0.614$; SN slope = 0.031 Celsius year^{-9}). This is consistent with a steady increase in temperature and pastoralist communities reporting warmer nights and mornings (Gebbisa & Bacsi, 2025; Sintayehu et al., 2025). In practice, increasing the minimum temperature reduces the night-time cooling of the cattle, increases the risk of chronic heat stress, increases water requirements and limits grazing and mobility opportunities (Sintayehu et al., 2025; Aytenfisu et al., 2024).

4.2.5 Maximum average temperature

The monthly maximum temperature (Tmax) in Rayitu shows clear and statistically significant warming, with the highest rates between April and September: 0.036 degrees Celsius, May 0.045, June 0.041, July 0.037, August 0.047, and September 0.043 degrees Celsius. Many of the months have $p<0.001$, which is in line with recent evidence from Ethiopia (Tofu and Mengistu, 2023; Alemayehu et al., 2024; Shigute et al., 2023). March and December show no significant trends; October is borderline ($\tau = 0.200$, $p = 0.054$); and November shows a negligible cooling (0.003

degrees Celsius yr^{-}, p = 0.822), a sample pattern also observed at regional level (Alemayehu et al., 2024; Duba, 2022). The variability of the monthly maximum temperature peaks in transition months (e.g., November), reflecting the higher climatic variability associated with seasonal changes (Alemayehu et al., 2024).

Seasonally, the warming is strongest in the summer (0.040 Celsius year-on-year), followed by spring (0.035 Celsius) and winter (0.023), with a less pronounced but still positive trend in the autumn (0.022 Celsius). These rates are approximately 0.23-0.40 degrees Celsius over a decade, which is consistent with studies in lowland regions (Aytenfisu et al., 2024; Shigute et al., 2023; Tadesse et al., 2024). At annual scale, Tmax also shows a strong warming signal (~0.032 degrees Celsius year-to-year), which is in line with more extensive national and regional assessments, which highlight the peak increase between June and September (Tofu & Mengistu, 2023; Alemayehu et al., 2024).

4.2.6 Mean average temperature

The strongest monthly temperature change (TEM) is observed in September (0.045 Celsius yr^{-},), August (0.043), June (0.041), May (0.040), October (0.038) and April (0.034), with a $p<0.003$. March and November show no significant trend, while January and December show a slight increase (+0.21 degrees Celsius over 10 years). This seasonal asymmetry, with increased warming in the transition and peak months, is consistent with recent studies (Tadesse et al., 2024; Alemayehu et al., 2024; Shigute et al., 2023).

Seasonal warming is significant across all four seasons, with the highest warming (0.038) in summer (Alemayehu et al., 2024) followed by the lowest warming in spring (0.035) and autumn (0.032), and the winter (0.025) reinforcing the concentration of warming in the warmest part of the year (Alemayehu et al., 2024). Annual TMA also shows strong warming (TMA = 0.634; 0.034 °C $year^{-}$) which is consistent with pastoralist reports of increasing heat and recurrent water stress (Gebbisa & Bacsi, 2025; Aytenfisu et al., 2024).

4.2.7 Rainfall and temperature correlation

In Rayitu, the correlation between seasonal and annual precipitation and temperature does not show a significant relationship between winter and summer rainfall and Tmax, Tmin or Tmean, which reflects the poor control of temperature during these low rainfall seasons, as evidenced by the previous finding of Alemayehu et al., 2024; Shigute et al., 2023. On the other hand, spring rainfall

is strongly and negatively correlated to all temperature measures, suggesting that warming particularly, Tmax and Tmean is associated with a decrease in rainfall during this crucial period, resulting in increasing water stress, less pasture re-growth and increased livestock mortality (Alemayehu et al., 2024; Tofu & Mengistu, 2023; Kourouma et al., 2022). Autumn shows a weak, insignificant positive correlation, indicating a mixed warming effect on short rains (Alemayehu et al., 2024; Shigute et al., 2023).

Table 11: Correlation between rainfall and temperature (1980-2024)

Season	Temperature						Rainfall	
	Maximum Temp	P-Value	Minimum Temp	P-Value	Annual Temp	P-Value	Mean	SD
Winter rainfall	-0.256	0.090	-0.086	0.576	-0.210	0.167	17.87	22.68
Spring rainfall	-.495**	0.001	-.326*	0.029	-.443**	0.002	218.10	72.22
Summer rainfall	0.024	0.875	0.061	0.689	0.067	0.662	12.64	9.22
Autumn rainfall	0.036	0.815	0.146	0.339	0.088	0.563	149.70	87.72
Annual rainfall	-.318*	0.033	-0.101	0.510	-0.236	0.119	398.32	120.23

Source: Author's own computation using XLStata Version 2025. ** and * represents significant level at 1% and 5% level respectively.

Annual precipitation is strongly correlated to maximum temperature (Tmax), which increases the role of temperature extremes in long-term aridification (Tofu & Mengistu, 2023; Kourouma et al., 2022; Alemayehu et al., 2024). These combined signals of spring sensitivity combined with the annual dryness accompanied by higher maximum temperatures underline the need for a flexible adaptation to increasing climatic stress and heat and drought in the Rayitu pastoralist system (Aytenfisu et al., 2024; Sintayehu et al., 2025).

From a practical perspective, the above results suggest that pastoral communities are facing changes in the timing of precipitation rather than in total precipitation. This conclusion is because, while there has been a significant decrease in September precipitation and an increase in November precipitation (Table 9), indicating that the early rainy season is becoming shorter and the onset of the late rainy season is being delayed, the total annual precipitation has remained statistically unchanged. This change has a direct impact on pasture regeneration, the scheduling of livestock movements, and the replenishment of water sources, all of which have traditionally been planned according to past rainfall patterns.

Similarly, given the widespread and statistically highly significant temperature increases across nearly all months and seasons (Table 10), particularly the rise in minimum (nighttime) temperatures, which can limit livestock's ability to regulate body temperature and increase the risk of disease and parasitic infections, the findings of this study suggest that rising temperatures are a more consistent and potent climate stressor than changes in precipitation patterns. Furthermore, the significant negative correlation between spring precipitation and temperature (Table 11) suggests that global warming and reduced precipitation are not independent risk factors but rather mutually reinforcing ones; consequently, spring, a critical period for pasture recovery following the dry season, faces the highest combined climate risk for livestock production.

Drawing on the empirical evidence presented above, Hypotheses 1 and 2, which are formulated in relation to Objective 1, are assessed and evaluated as follows:

Hypothesis 1 –The monthly precipitation varies by seasons without an annual precipitation trend

H1 is accepted: precipitation varies widely between months and seasons, but the annual total shows no significant trend. As indicated in table 9, most months (January, February, March, June, July, August, September, and December) have a coefficient of variation (CV) above 100, indicating that rainfall is highly unreliable, while only April (CV = 38.2) and May (CV = 54.5) are relatively stable. Seasonally, winter shows a high variability (CV = 126.9), summer and autumn show a low variability (CV = 33.3), and spring is relatively stable (CV = 33.3). The Mann-Kendall test does not show any significant long-term trend in annual precipitation (τ = -0.046, slope = -0.463, p = 0.660), although there are significant or almost significant trends in some months and seasons (e.g., decreasing September, increasing November).

Hypothesis H2 - Annual and seasonal temperatures show a positive trend and temperatures are negatively correlated to precipitation.

H2 is partially accepted. The Mann-Kendall results (Table 10) show a clear and statistically significant warming trend in the monthly, seasonal, and annual mean temperature. Most minimum, maximum and average mean temperature show positive and significant trends, with a mean slope of approximately 0.03-0.034 degrees Celsius per year, confirming a strong warming signal in the Rayitu districts. However, the relationship between temperature and rainfall is mixed (Table 11): the correlation between winter and summer is weak and negligible, while spring (Belg) rainfall has a strong and significant negative correlation with all temperature indices, which means that warmer

conditions reduce rainfall in the main wet season. Autumn shows a slight, non-significant positive correlation, and annual precipitation is only significantly negatively correlated to maximum mean temperature. Therefore, the warming trend is well supported, but the expected negative relationship between precipitation and temperature is mainly true for spring and annual precipitation in relation to maximum average temperature.

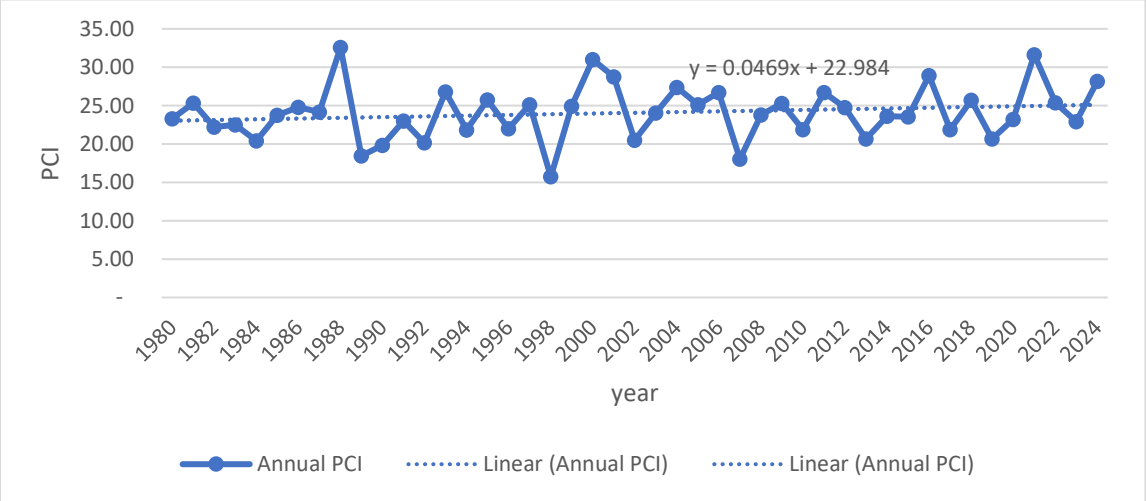
4.3 Drought severity and frequency

The study assesses the severity and frequency of droughts using three complementary indices. The Precipitation concentration index (PCI) characterizes the concentration of rainfall within an annual range and highlights seasonal variations. The Standardized Precipitation Index (SPI) quantifies the meteorological drought on a multi-period scale, while the Standardized Precipitation Evapotranspiration Index (SPEI) integrates the atmospheric demand driven by temperature. Together, these metrics provide a coherent and multisectoral picture of the dynamics of drought in the study area.

4.3.1 Precipitation Concentration Index (PCI)

The annual PCI of Rayitu (1980-2024) shows a significant seasonal variation: values range from 15.73 (1998) to 32.58 (1988), with an average of ~24.17 (SD ~3.69). This index categorizes rainfall as intermediate to extreme and indicates the supply of several months for most annual totals (see figure 10). This is supported by studies by Berihun et al., 2023, and Aytenfisu et al., 2024.

Figure 10: The trend of Precipitation Concentration Index (1980-2024)



Source: Author's own computation using DRIC software

Linear regression (y = 0.0469x + 22.984) shows an increasing trend in concentrations, with renewed peaks in the last years of 2021 (31.62) and 2024 (28.18), which is in line with evidence of increasing precipitation variability and extremes in the different regions (Ayugi et al., 2021; Duba, 2022; Worku, 2024). The decadal trend shows relative stability in the 1980s (except 1988), volatility in the 1990s (1998), frequent high PCI in the 2000s, moderate volatility in the 2010s and high levels in the 2020s. These findings are consistent with studies in Borana, West Guji and Afar, which show that precipitation increases the risk of timing within the year (Dejene et al., 2023; Aytenfisu et al., 2024).

Climatically, higher PCI means shorter, more intense rainy periods, more runoff and erosion and longer dry periods, which weaken the reliability of rain-fed systems and increase the vulnerability to droughts (Shigute et al., 2023; Berihun et al., 2023). For pastoral households in Rayitu, this irregularity complicates the timing of their mobility, access to grazing and water and increases vulnerability (Gatew & Guyo, 2024; Tilahun & Legese, 2020; Worku, 2024).

Table 12: Frequency of precipitation concentration index (1980-2024)

SN	Classification of drought index	Drought Severity Class	Occurrence(year)	Frequency
1	<10	Uniform	0	0
2	11-15	Moderates	0	0
3	16-20	Irregular	7	15.55
4	>20	Strongly irregular	38	84.45
Total			45	100.00

Source: Author's own computation using DrinC software, based on classification of Olive (1980)

As shown in Table 12, the PCI distribution of rainfall in the Rayitu district is overwhelmingly concentrated in a few months: more than four fifths (84.45) fall into the highly irregular category (>20), with the remainder irregular (15.55). No year shows a uniform or even slightly uniform distribution of monthly precipitation. This pattern indicates short, intense rainy seasons, followed by long, interannual dry spells, which are characteristic of arid-smeared pastoralist climates, where the risk of production is determined by timing and not by quantity. This finding, supported by recent evidence from Ethiopia's pastoral rangelands, shows strong seasonal rainfall with recurrent dry gaps, increasing the risk of drought, observed in Borana, West Guji, Central Awash (Afar), East Guji (Dejene et al., 2023; Duba et al., 2021; Sahilu et al., 2024).

From a practical perspective, the results of table 12 suggest that precipitation in the study area is overwhelmingly irregular in terms of its distribution throughout the year. This is because 84.45% of the total years (38 out of 45) fall into the "very irregular" category, while not a single year falls into the "uniform" or "moderate" categories. This means that rainfall does not follow a predictable and evenly distributed pattern within a season but is concentrated in the form of short, intense downpours, thereby increasing both the risk of localized flooding and runoff losses as well as the risk of long-term droughts between rainfall events. Both factors hinder the stable growth of pastures and the recharge of water sources.

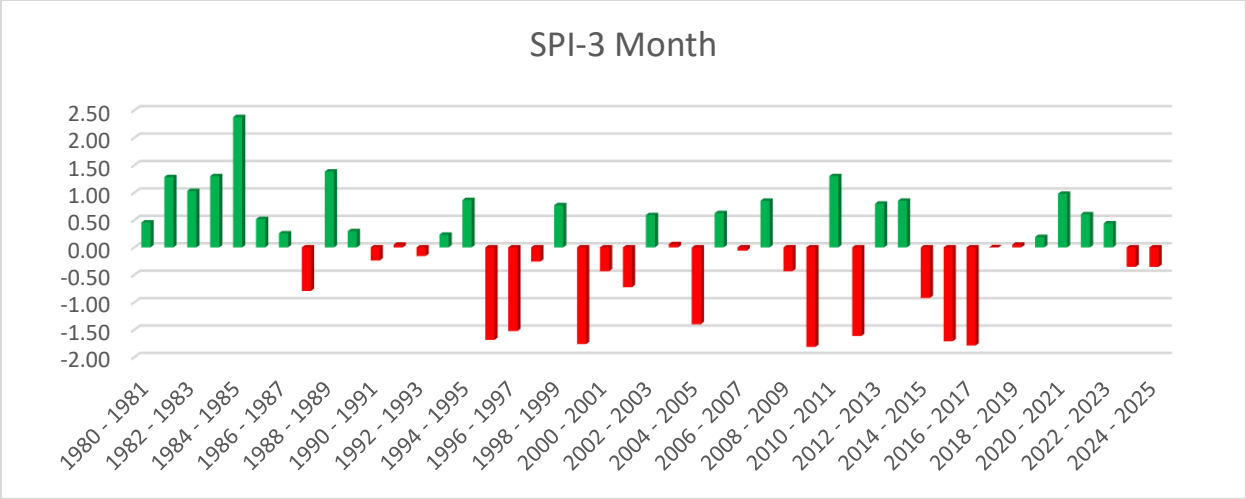
4.3.2 Standard Precipitation Index

The Standardized rainfall index (SPI) is a multisectoral drought metric that captures rainfall anomalies during short (e.g., 3 months), seasonal (6 months) and annual (12 months) droughts (McKeon et al., 1993). In pastoral areas, the SPI-3 is particularly sensitive to recent rainfall and therefore monitors the immediate availability of pasture and water, but it may be highly volatile and may be distorted by longer droughts (Walsh, 2024; Dejene et al., 2023).

The three-month SPI shows a classic boom-bust signal in the short-term: frequent sharp wet spells are followed by clustered negative runs around 1994-1997. As the SPI-3 is only for one season, these negative aggregates indicate acute short-term water and pasture stress during deficient rains, while the short positive bars indicate short-term wet relief which may not reverse the long-term trend of drought. Supporting evidence for this finding is the regional assessments of the drought frequency in Afar, Borana, West and East Guji and the Rift Valley (Aytenfisu et al., 2024; Dejene et al., 2023; Tesfamariam et al., 2019).

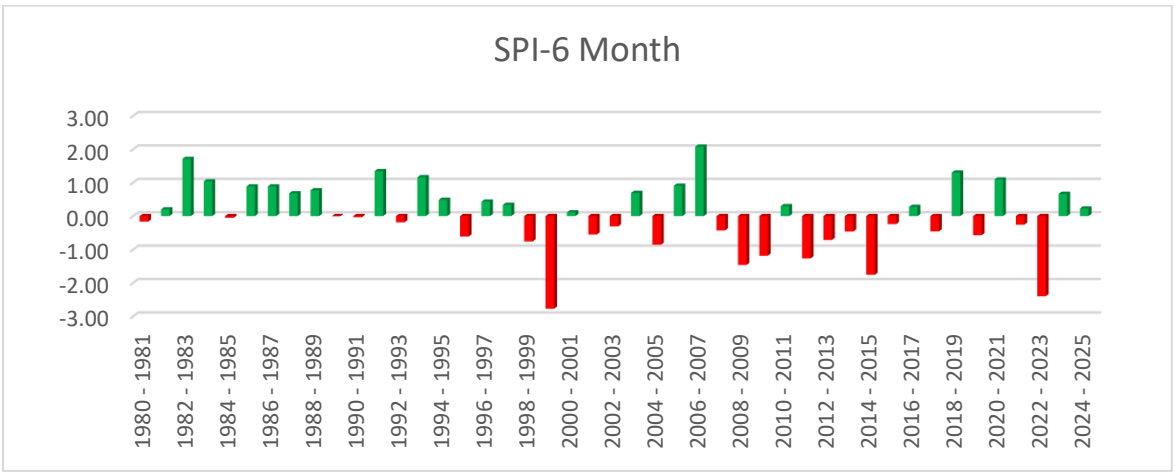
The six-monthly SPI follows the water balance of the different seasons and shows alternating wet and dry regimes with several major droughts. In study area, significant positive developments in SPI-6 occurred in the early to mid-1980s and again in 2007-2011 (peak values >+2). Negative SP-6 is observed in 1999-2001 (≈-2.7), 2003-2006, 2013-2017 (including a trough of -1.8) and 2023-2024 (≈-2.7), with only partial recovery in 2025. As the SPI-6 includes two consecutive seasons in a bimodal environment, these negative spells indicate persistent fodder and water deficits after one rainy season, while short-lived wet spells rarely compensate for cumulative moisture deficits. Studies in Borana, West-East Guji and Afar support this finding, with similar multi-seasonal droughts (Worku, 2024; Aytenfisu et al., 2024; Duba, 2022).

Figure 11: Three-month Standard precipitation index (SPI-3)



Source: Author's own computation using DrinC software

Figure 12: Six-month standardised precipitation index (SPI-6)

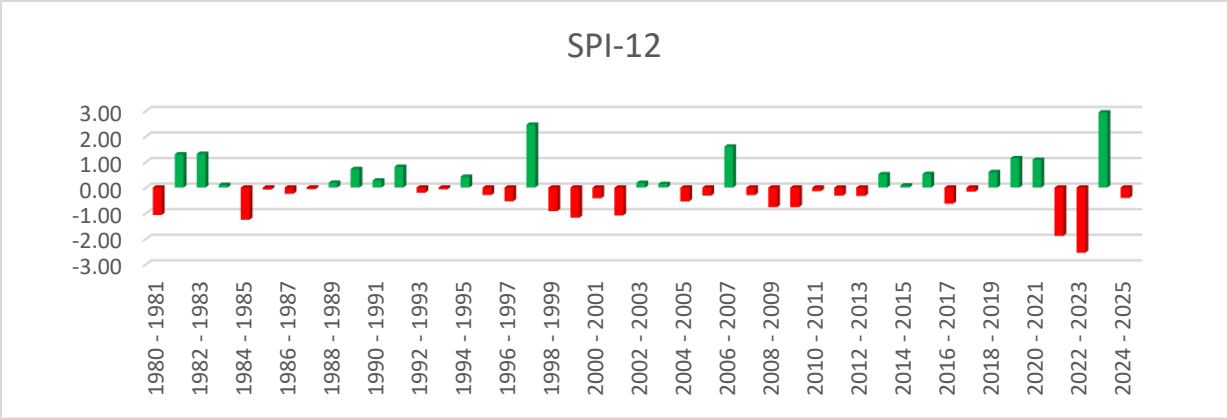


Source: Author's own computation using DrinC software

The SPI-12 for the study area (1980-2024) shows several long-wet periods (early mid-1980s; 1997-1998 > +2; 2006-2008; short-lived recovery from 2018-2021), with a severe trough in 2022-23 (~2) and only partial recovery thereafter. As the SPI-12 is cumulative over the entire hydrological year, these negative trends indicate cumulative water scarcity affecting fodder inputs, shallow aquifers and household exposure beyond the single rainy season. This pattern is consistent with evidence from Ethiopia for repeated 12-month droughts since the late 1990s (Tesfamariam et al., 2019; Kourouma et al., 2022; Berihun et al., 2023) and with case

studies from Borana and Somalia linking low SPI levels to acute pastoralism impacts (Shibru et al., 2023; Lelamo et al., 2022; Duba, 2022).

Figure 13: 12-month Standardised Precipitation Index (SPI-12)



Source: Author's own computation using DrinC software

The frequency profile for the Rayitu district shows the expected spatial effect and is consistent with previous pastoral findings. Table 13 indicated that the decline in drought years from SPI-3: 57.78 to SPI-6: 48.22 and SPI-12: 42.44 is indicative of persistent background moisture deficits, even when the single season appears to be normal. On the other hand, serious events are concentrated on the seasonal scale (SPI-3: 15.56 vs. SPI-6, 12: 2.22), and extreme drought is rare but is mainly observed in the SPI-6 (4.44), reflecting the double-seasonality of the event. This pattern of acute short-term stress, compounded by prolonged, mild aridity, is also shown by the multi-seasonal and annual deficits in Ethiopia's pastoralist lowlands, where the lack of short-term rainfall triggers rapid fodder and water crises (Worku, 2024; Dejene et al., 2023; Duba, 2022).

Therefore, the integration of the three SPI timeframes, such as SPI-3 for short-term decisions, SPI-6 for seasonal planning, and SPI-12 for long-term strategies, provides a comprehensive and more precise framework for monitoring drought in pastoralist areas. This integrated understanding allows for better-informed decisions on mobility, access to water, management of livestock, and policy interventions, ultimately increasing resilience to climate variability.

Table 13: Frequency of SPI of 3-month,6-month and 6-month periods

	Scale	Type	SPI-12		SPI-6		SPI-3	
			Frequency	%	Frequency	%	Frequency	%
1	>0	No drought	19	42.22	22	48.89	26	57.78
2	-0.01 to -0.99	Mild drought	20	44.44	17	37.78	11	24.44
3	-1.00 to -1.49	Moderate drought	4	8.89	3	6.67	1	2.22
4	-1.5 to -1.99	Severe drought	1	2.22	1	2.22	7	15.56
5	< -2.0	Extreme drought	1	2.22	2	4.44	0	-

Source: Author's own computation from DrinC software, based on classification of McKee et al. (1993).

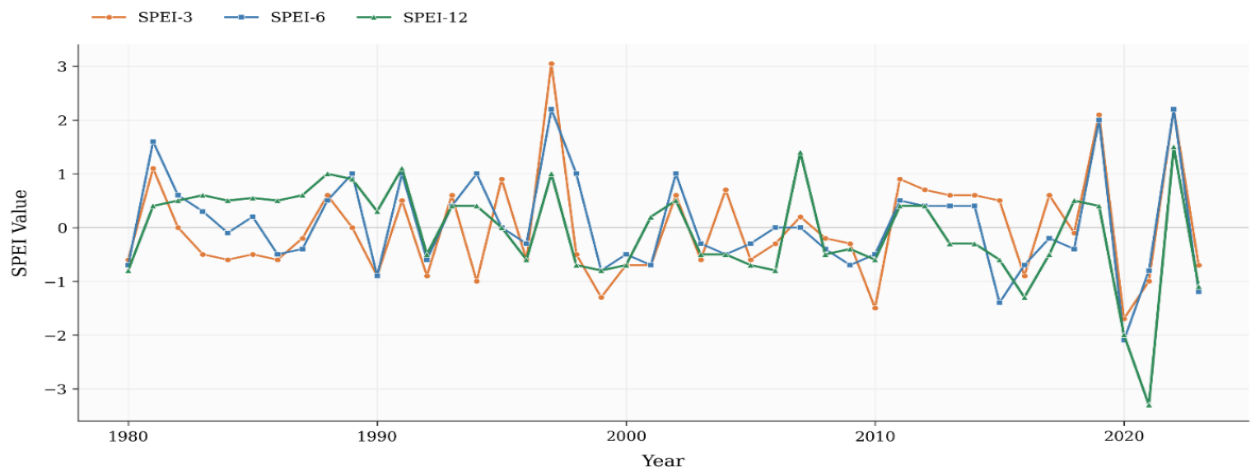
In practical terms, the results of table 13 show that drought is not a rare event but a common and recurring part of the climate in the study area. This is because mild drought conditions occurred in the years across all three-time scales (44.44% for SPI-12, 37.78% for SPI-6, and 24.44% for SPI-3). Moderate to severe droughts occur more frequently on a 3-month scale (17.8%) than on a 6 and 12-month scale, suggesting that short-term, distinctly seasonal droughts, which most severely disrupt pasture regeneration and calf calving cycles, pose a more urgent operational risk than prolonged, multi-year droughts.

4.3.3 Standardized Precipitation Evapotranspiration Index (SPEI)

The Standardized Precipitation-Evapotranspiration Index (SPEI) used three supplementary scales, such as SPEI-3 (3 months, seasonal), SPEI-6 (6 months, biannual), and SPEI-12 (12 months, annual). Negative values indicate drought, and positive values indicate precipitation.

The SPEI-3 of Rayitu district (inter-seasonal water stress) shows a sharp oscillation in the short term, with extreme precipitation in 1997 (+3.15) and 2023 (+2.59) and very wet seasons in 1982 and 2019, followed by a moderate deficit in 2024 (+0.88) and above. These swings typify the Rayitu climate, where one dry season rapidly reduces fodder and water availability and triggers mobility and emergency withdrawals; the strong signal for 2021-22 is consistent with studies on drought in the Borana and Somali rangelands (Dejene et al., 2023; Abrham & Mekuyi, 2022). Operationally, SPEI-3 provides the best early warning of impending pasture and water stress, as it integrates precipitation and evaporation demand (Worku, 2024).

Figure 14: Trend of SPEI-3, SPEI-6 and SPEI-12 (1980-2024)



Source: Author's own computation from DrinC software

SPEI-6 (two-seasonal wet conditions) for the Rayitu district over the period 1980-2024 shows a clear wet-dry phase within six months. The wettest season was in 1997 (+2.98), 2006 (+1.19) and 2019 (+1.98), but there were also strong peaks in the last two seasons: 1998-2001 (-0.97), 2010-2011 (-1.41) and 2016-2017 (-1.31), and 2021-2022 (-2.03, -2.23). This pattern contributes to the collapse of multi-seasonal fodder crops and water scarcity. This study is consistent with the work of Duba (2022), Shibru et al. (2023), and Opiyo et al. (2016).

SPEI-12 (multiple-annual hydrological drought) isolates the cycle of boom and bust that is most important for the recovery of the herd. Multi-annual precipitation peaks in 1982-1989 (up to +1.26), 2006-2007 (+1.41) and 2019-2020 (+1.53), allowing for the re-establishment of rangeland and grazing. This is followed by a record drought in 2021-22 (+3.27, -2.34), a short recovery in 2023 (+2.04), and a return to drought in 2024 (+1.19). The scale and timing of the losses contribute to widespread livestock losses, market distress and dependence on aid. Studies by Gatew & Guyo (2024), Dejene et al. (2023), and Sintayehu (2025) in line with these findings.

Table 14: Frequency of SPEI of 3-month,6-month and 12 -month period

	Scale	Type	SPEI-12		SPEI-6		SPEI-3	
			Frequency	%	Frequency	%	Frequency	%
1	>0	No drought	26	57.78	19	42.22	18	40.00
2	-0.01 to -0.99	Mild drought	16	35.56	21	46.67	22	48.89
3	-1.00 to -1.49	Moderate drought	1	2.22	4	8.89	4	8.89

4	-1.5 to -1.99	Severe drought	0	0.00	0	0.00	1	2.22
5	< -2.0	Extreme drought	2	4.44	1	2.22	0	0.00

Source: Author's own computation from DrinC software, based on classification of McKee et al. (1993).

In the Rayitu SPEI-3 (seasonal) analysis, mild drought is predominant (22 years; 48.9) and moderate (8.9) and rare severe drought is uncommon (2.2) while non-drought periods occur 40.0 per cent of the time (Table 14). This pattern indicates frequent one-season rainfall deficits that rapidly stress fodder and shallow water areas - a typical trigger for herd migration and distress sales in pastoral rangelands. This study aligns with Worku,2024; Aytenfisu et al., 2024, Hussein et al., 2025; Ayugi et al., 2020; Byakatonda et al., 2021; and Makula et al., 2025 which reflect the regional pattern of recurrent, mostly mild but operationally disruptive seasonal droughts, which rapidly translate into stress on pastoral livelihoods.

In the Rayitu district, the incidence of SPEI-6 (two-seasonal) is also close to half of the years with mild drought (46.7) and 8.9 percent with extreme drought (2.2) during the two rainy seasons; the non-drought is 42.2 percent (Table 14). This bi-annual dryness is consistent with the observed delays in pasture regeneration, the borehole overloading and the increased distance travelled when the two-season crossing determines the condition of the herd and milk production. These studies are consistent with Makula et al. (2025) and Byakatondo (1935) (2021), which maps the frequency of three to six months of drought in pastoral and rangeland areas in the northern belt of Tanzania and in Uganda, including Karamoja. SPEI-6 data show recurrent seasonal carry-overs which reduce the availability of fodder and water.

According to the SPEI-12 (annual and multiannual), drought conditions are classified as non-drought in most years (57.8) and severe in a significant proportion (35.6); extreme drought is rare (4.4); and there are very few mild years (2.2). Although annual conditions are often close to normal, occasional extreme multi-year droughts are critical, depressing groundwater supplies, delaying herd recovery, and amplifying market shocks long after rains return. This study is consistent with the pastoralist evidence from East Africa, Kenya, Uganda, Tanzania, Somalia and Southern Ethiopia (Ayugi et al., 2020; Byakatonda et al., 2021; Makula et al., 2025; Hussein et al., 2025; Worku, 2024).

From an operational perspective, the results of SPEI in table 14 suggest that, while the severity of drought has been somewhat mitigated when rainfall and evapotranspiration are considered

comprehensively, a significant drought burden still exists. Drought occurred in 42.22–60% of the years across various scales, and mild droughts still occur frequently (35.6–48.9%). The fact that drought signals persist even after accounting for evapotranspiration confirms that water stress in this livestock system is driven by both insufficient precipitation and increased water demand due to rising temperatures, which is consistent with the previously identified warming trend (Table 10).

Across the focus group discussions, participants agreed that droughts are more frequent and longer lasting than in the past. The elderly reminded them that only once in many years has there been a serious drought, and now only once every two or three years has there been a serious shortage of food and water. Both male and female in the discussion pointed out the high mortality rate of livestock, the decline in dairy cattle, goat and camel production and recurrent crop failures in agro-pastoral areas as éléthe most visible consequences of the recent drought. Youth participants have pointed to increased migration to nearby towns in search of wage-paying jobs during droughts. Key informants in the kebele administration and the line offices confirmed these observations, saying that repeated droughts have eroded the household wealth base and increased the number of people living in.

The above analysis provides a sound basis for the assessment of hypothesis 3 in relation to Objective 2 as follows:

Hypothesis 3 - Annual precipitation is concentrated in specific months, and the occurrence of mild drought is dominant.

Hypothesis 3 is accepted and supported. As shown in Table 12, approximately 84.45% of the recorded years showed highly irregular precipitation (PCI > 20), while 15.55% showed a uniform precipitation distribution (PCI ≤ 20). Similarly, as tables 13 and 14 indicated, the drought patterns range from mild to extreme across the 3-month, 6-month, and 12-month SPI and SPEI scales; the mild drought is dominant at all scales. Therefore, the Rayitu district experiences highly variable precipitation, with recurring episodes of primarily mild drought interspersed with moderate, severe, and extreme droughts that pose significant risks to pastoralists' livelihoods and climate risk management.

4.4 Households' perception of climate change

4.4.1 Indicators of household perception of climate change

In this study, household perceptions of climate change were assessed using direct climate variability and indirect indicators of environmental and livelihood impacts, with significant correlations being confirmed by chi-square tests. As shown in Table 15, most pastoralist households (78.9%) recognized clear signs of climate change, while 21.1% were unaware of its occurrence. This level of awareness was also evident across the specific indicator categories. On average, 79% of pastoralist households identified indirect indicators of climate change, whereas a slightly lower proportion (75%) recognized direct indicators. Conversely, 21% and 25% of households were unaware of indirect and direct indicators of climate change, respectively.

Table 15: Pastoralist perception of indicators of climate change

SN	Climate change indicators	Respondent/household perception		X^2 test
		Yes (%)	No (%)	
I	Direct Indicators	75%	25%	
1	Change in temperature seasonal pattern	257 (73.2%)	94(26.8%)	0.013
2	An extended period of high temperature	217 (61.8%)	134 (38.2 %)	0.006
3	Decreased frequency of rainfall	316(90.3%)	34(9.7%)	0.014
4	Irregular distribution of rainfall	217(61.8%)	134(38.2%)	0.007
5	Increase in wind frequency over time	275(78.3%)	76(21.7 %)	0.002
6	Drought	297 (84.6 %)	54 (15.4 %)	<0.001
II	Indirect indicators	79%	21%	
7	Drying up of grazing land	321 (91.5 %)	30 (8.5 %)	<0.001
8	Reduction in the water source	244(69.5 %)	107 (30.5 %)	0.003
9	Death of livestock	302 (86%)	49 (14%)	<0.001
10	Decline of crop production	248 (70.7%)	103 (29.3%)	<0.001
11	Poor livestock productivity	292 (83.2 %)	59 (16.8%)	<0.001
12	Loss of pastureland	256 (72.9%)	95 (27.1%)	0.002
	Overall (Direct +Indirect)	78.9%	21.1%	

Source: Author's own computation using SPSS Version 29

4.4.1.1 Direct indicators of climate change

This study discusses the direct/meteorological indicators of climate change as follows. Pastoral households are more likely to experience changes in seasonal temperature patterns (73.2), which suggests that traditional seasonal cycles of heat are no longer predictable. This change has an impact on the growth cycles of pastures and the timing of livestock migration. Similar patterns were observed when herders linked these changes to reduced health of the animals and changed grazing strategies (Debela et al., 2015; Tesfahunegn et al., 2016; Mekuyi and Mulu, 2021).

About 61.8 percent of respondents experience prolonged periods of high temperature. Extended heat waves are associated with increased heat stress of livestock, faster evaporation from water bodies, and reduced quality of food. Longer heat waves in pastures and arid areas reduce pasture regeneration and increase water demand for humans and animals (Tesfahunegn et al., 2016; Abrham & Mekuyi, 2022; Maziya & Nkonki-Mandleni, 2024; Teklay et al., 2025).

The decrease in precipitation (90.3) is one of the most significant perceived indicators. Pastoralists have noted fewer rainy days in each season, which reduces the supply of grazing land and water sources. Decreasing precipitation rates have a direct impact on both livestock productivity and food security (Tesfahunegn et al., 2016; Mekuyi and Mulu, 2021; Duba, 2022; Teklay et al., 2025).

Similarly, many people perceive the irregular distribution of rainfall (61.8%) as both problematic and irregular. Respondents described rainfall that occurred in unpredictable bursts, leading to either flash floods or prolonged dry spells. Irregular rainfall is disrupting pasture regrowth and forcing pastoralists to make unplanned migrations, a pattern that is also confirmed by perception studies that highlight the irregular timing and intensity of rainfall (Tesfahunegn et al., 2016; Mekuyi and Mulu, 2021; Duba, 2022; Akafu, 2025).

The increase in wind over time (78.3%) is also recognized as a direct change in climate. Stronger winds accelerate soil erosion and spread dust that obscures food and damages makeshift shelters for animals. Opiyo et al. (2016) reported that increasing wind speeds in the Turkana region of Kenya are exacerbating the degradation of rangeland.

Finally, drought (84.6%) remains the most important direct climate risk as described by the sampled pastoral households. Droughts have become more frequent and intense and have moved from being once every decade to every few years. Recurrent drought has been identified as a major cause of

livestock mortality and displacement (Tesfahunegn et al., 2016; Teshome et al., 2021; Abrham & Mekuyi, 2022; Gemeda et al., 2023; Maziya & Nkonki-Mandleni, 2024).

4.4.1.2 Indirect Indicators

The following discussion focuses on the indirect/livelihood-related indicators of climate change perceived by pastoral households. The most observed indirect household indicator is the drying of pasture (91.5) due to low rainfall, long droughts, and the spread of invasive species. The resulting loss of palatable grasses reduced the carrying capacity of the livestock and increased the grazing pressure on the remaining pasture, in line with the wider degradation of the rangeland under climatic stress (Abrham & Mekuyie, 2022; Mekuyie, 2021).

Another important perception is the reduction in water resources (69.5), with households seeing seasonal rivers drying out and wells pumping less water. Trends in water scarcity are forcing pastoralists to travel long distances for water (Tesfahunegn et al., 2016; Mekuyi and Mulu, 2021; Abrham and Mekuyi, 2022). The consequences include increased time and labor costs (often borne by women and children), increased stress on livestock, and increased competition for remaining water bodies, which further increases vulnerability.

The death of livestock (86 percent) is both a direct consequence of climate stress and a visible loss of livelihood. Respondents link mass animal mortality to prolonged drought, depleted pasture, and water scarcity. Drought-induced livestock losses are severely reducing the resilience of pastoral households (Megersa et al., 2014; Mekuyie & Mulu, 2021; Abrham & Mekuyie, 2022).

Pastoral households most often experienced a decrease in crop production (70.7%), which they attributed to erratic rainfall and shorter growing seasons, which compress critical phenological stages and reduce yields. In line with this perception, studies in Ethiopia show that climate-related production shortages reduce the availability of food for households and increase the dependence on livestock for food and income (Berhanu and Beyene, 2015; Tesfahunegn et al., 2016; Gemeda et al., 2023).

Households generally perceive poor livestock productivity (83.2%), which is reflected in lower milk yields, slower weight gain, and reduced fertility, mainly due to insufficient fodder and heat and water stress during drought (Debela et al., 2015; Mekuyi & Mulu, 2021; Abrham and Mekuyi, 2022).

Climate variability limits the availability of feed and water for animal systems (Tesfahunegn et al., 2016; Idrissou et al., 2021).

Finally, pastoral households experience pasture losses (72.9) due to the combined effects of drought, overgrazing, and soil degradation, which reduce the area available for grazing and increase stocking pressure. The shrinking of rangelands increases the cost of mobility, increases the risk of conflict, and pushes herds to the periphery of the habitat (Opiyo et al., 2016), while pasture areas are shrinking and the range is being reduced (Debela et al., 2015; Tesfahunegn et al., 2016; Abrham & Mekuyi, 2022).

From a practical perspective, as the findings shown in Table 15 suggest that the actual experiences of pastoralists closely reflect the previously identified statistical climate trends, they report high levels of agreement regarding direct indicators (75% on average, particularly a 90.3% decrease in rainfall frequency and drought at 84.6%) as well as indirect biophysical impacts (79% on average), particularly the drying out of pastures (91.5%) and livestock mortality (86%). Since pastoralists are already detecting the same signals confirmed by meteorological data, this high level of awareness within these communities serves as a valuable yet underutilized foundation for developing community-based early warning and adaptation plans.

In addition to the above, evidence from focus group discussions and key informant interviews shows that most households clearly perceive climate change over time, although they do not always use the term "climate change." They reported that the main rainy season is now starting later and ending earlier, and that rainfall is becoming more erratic and concentrated in short, heavy rains followed by prolonged dry periods. These changes are linked by the members of the community to recurrent feed and water shortages, deteriorating health of the livestock, reduced milk production, and an increase in the incidence of animal diseases.

Households rely on several local indicators to identify climate change, including the decreasing availability of grass for grazing, the drying-out of ponds and shallow wells, the reduced milk yield of cattle, goats, and camels, and the increased frequency of crop failures in the surrounding agricultural areas. Elders reported that the traditional signs used for seasonal predictions were no longer reliable, and women pointed out the increased time needed to get water and wood. Perception is broadly similar across social groups, but the emphases vary: older people compare current

conditions with excellent ones in the past, young people focus on the impact of the economy and migration, and women stress the growing burden of domestic work.

4.4.2 Determinant of pastoralist household perception on climate change

The perception of climate change among pastoral households is a dynamic interplay of socio-demographic, economic, institutional, and environmental factors. This study used a binary logistic regression model to evaluate how each factor shapes the perception of climate change within households, as indicated in Table 16.

Table 16: Determinants of household perception by binary logistic regression

SN	Variables	B	S.E.	Wald	Sig.	Exp(B)
I	Socio-demographic factors					
1	Sex of the household	-0.451	0.409	1.216	0.270	0.637
2	Family size	0.570	0.247	5.308	0.021	1.768
3	level of Education	-0.598	0.141	17.949	0.000	0.550
4	Age of the households	0.167	0.074	5.146	0.023	1.182
	Mean	0.446		7.405	0.75	
II	Economic factors					
5	Access to savings	0.613	0.320	3.675	0.055	1.845
6	Range land size (ha)	0.456	0.202	5.090	0.024	1.578
7	Crop production	0.786	0.342	5.271	0.022	2.195
8	livestock holding	1.555	0.435	12.760	0.000	4.735
9	Livelihood diversification	-0.767	0.401	3.665	0.056	0.464
	Mean	0.835		6.092	1.00	
III	Institutional factors					
10	Access to a health facility	0.932	0.334	7.776	0.005	2.540
11	Membership of cooperative	-0.494	0.354	1.950	0.163	0.610
12	Weather/climate information	-0.574	0.438	1.717	0.190	0.563
13	Veterinary extension access	-0.766	0.348	4.852	0.028	0.465
	Mean	0.691		4.073	0.50	
IV	Environmental & physical factors					
14	Grazing land condition	2.170	0.647	11.256	0.001	8.756
15	Distance to weekly market (km)	-0.347	0.201	2.981	0.084	0.707
	Mean	1.259		7.119	0.50	
	Constant	-8.549	1.994	18.378	0.000	0.000

Source: Author's own computation using SPSS Version 29

As the mean coefficients indicated in table 16, an environmental factor (average β = 1.2585) had the greatest positive impact on households' perceptions of climate change, followed by economic factors (average β = 0.8354), institutional factors (average β = 0.6915), and socio-demographic factors (mean β = 0.4465). This suggests that, on average, variables related to direct environmental changes have the greatest influence on shaping pastoralists' perceptions, whereas socioeconomic characteristics make a relatively smaller contribution. The model output of the determinants of pastoral households' perception is discussed as follows:

Socio-demographic determinants reveal mixed effects on the perception of climate change among households in pastoralist areas in the Rayitu. Family size has a significant positive effect (B = 0.570, p = 0.021), with each additional household member increasing by around 77 percent the likelihood of experiencing climate change. Larger families usually have more labour available for climate-sensitive livelihoods such as cattle-herding and water-collecting, which increases their exposure to climate change. Similar evidence from pastoralist communities in eastern Kenya (Nyamai et al., 2024) and Southern Ethiopia (Saguye, 2017) shows that households with multiple members tend to experience changes in the environment more rapidly because of different outdoor activities.

The level of education is negatively correlated to climate change perception (B = -0.598, $p<0.001$), meaning that more educated households are significantly less likely to be aware of climate change. Higher education is often linked to the diversification of livelihoods into non-pastoral employment, which reduces direct exposure to environmental change. On the other hand, those with less formal education remain closely attached to land and livestock, which reinforces their environmental awareness. This study concurs with the study by Alotaibi et al., 2023. However, this finding is inconsistent with the results of Debela et al. (2015) and Tesfahunegn et al. (2016).

The age of the head of household is positively and significantly correlated (B = 0.167, p = 0.023), suggesting that older people are more likely to be aware of climate change. The older pastoralists have valuable native knowledge, particularly for interpreting the rainfall of the early season. Drawing on decades of experience, they see a gradual change in climate, particularly in rainfall and temperature, from the historical patterns that young herder often misses. This is in line with the findings of Debela et al., 2015; Tesfahunegne et al., 2016; Saguye, 2017; Asrat and Simane, 2018; Awoke and Agitewa, 2022; Maziya and Nkonki-Mandleni, 2024; Nyamai et al., 2024.

The coefficient for household head's sex is negative (B = −0.451, p = 0.270), indicating that female-headed households may have lower climate change perceptions, potentially due to limited access to information and extension services, lower literacy, time constraints, and exclusion from male-dominated knowledge networks (Asfaw et al., 2021a; Gashure & Wana, 2023), despite women's greater exposure to environmental stressors through water and fuel collection (Habte Mariam et al., 2016; Opiyo et al., 2015).

Economic variables emerge as important drivers of perceptions. Access to savings is positively correlated with climate change awareness (B = 0.613, p = 0.055), although the correlation is only marginally significant. Households with financial reserves are almost twice as likely to be aware of climate change, probably because economic security makes it easier to invest in information and preparedness measures. This is in line with the judgment in Pienaah and Luginaah (2024).

The size of the range area has a significant positive impact on the perception of climate change (B = 0.456, p = 0.024), suggesting that households with larger grazing areas are more sensitive to the visible signs of the degradation of the pasture and the variability of rainfall. Larger rangeland increases the dependence of rainfall on the production of fodder, which makes fluctuations in vegetation cover, pasture quality and water resources more pronounced. These findings are consistent with the findings of the peer reviewed reports Debela et al., 2015; Tesfahunegn et al., 2016; Nyamai et al., 2024.

Involvement in crop production also increases the likelihood of being perceived significantly (B = 0.786, p = 0.022). Because of the high climatic sensitivity of crop yields to timing of rainfall and temperature extremes, irregularities are detected rapidly by agro-pastoral households. Households have repeatedly observed this pattern in agro-pastoral areas where mixed farming intensifies environmental monitoring. This study is in line with the findings of Tesfahunegn et al., 2016.

Livestock farming is the most powerful economic driver (B = 1.555, p < 0.001), with larger herd owners more than four times more likely to be aware of climate change. This is in line with Opiyo et al., 2015 and Idrissou et al., 2021, which stated that pastoralists are highly dependent on livestock, which are closely monitored for pasture conditions, water sources and animal health, and which react quickly to climatic changes.

In contrast, diversification of income is negatively correlated with perceived income (B = -0.767, p = 0.056). Diversified households may rely less on climate-sensitive activities and may therefore pay

less attention to the impacts of environmental change on the environment. Dependence on a single, climate-sensitive livelihood promotes a heightened awareness of the environment. Nyamai et al.,2024 supports this finding.

Institutional variables show mixed effects. Access to healthcare facilities is positively and significantly correlated with perceived proximity (B = 0.932, p = 0.005), which suggests that proximity to such facilities may facilitate the transmission of climate-related health information, including temperature-related and precipitation-related diseases. These findings, in line with Tesfahunegn et al. (2016) and Idrissou et al. (2021), shows that households with better access to local services and information channels, including veterinary and extension points, have a stronger awareness of climate risks and associated disease outbreaks.

Membership of pastoralist cooperatives is negatively correlated (B = -0.494, p = 0.163) but not statistically significant. Although this pattern is weak, the negative correlation is consistent with Maziya and Nkonki-Mandleni (2024). Cooperatives may be platforms for knowledge sharing, but they often prioritise market functions rather than climate education (Tessema and Simane, 2019).

Households with access to current weather information show a negative, statistically insignificant relationship to climate change perceptions (B = -0.574, p = 0.190). This scenario is plausible if the forecasts are poorly localised, not well-trusted, or not translated into pastoralist decision-making calendars, so that information does not increase the perceived risk.

Access to veterinary extension services is negatively correlated and statistically significant (B = 0.766, p = 0.028). Veterinary information in pastoral areas emphasises clinical and technical animal health (treatment, vaccination) rather than linking disease patterns to temperature and rainfall variations, which may shift the attribution from climatic drivers to management. This finding is supported by Opiyo et al., 2015; Tesfahunegn et al., 2016; Saguye, 2017; Nyamai et al., 2024; Awoke and Agitew, 2022.

Environmental and physical conditions remain the strongest predictors. The condition of grazing land is by far the most important factor (B = 2.170, p = 0.001) and households report that they are almost nine times more likely to be aware of climate change. This is in line with evidence from Ethiopian and regional studies which show that the main drivers of pastoralist climate behaviour are the degradation of the rangeland and the lack of fodder (Debela et al., 2015; Tesfahunegna et al., 2016; Mekuyi and Mulu, 2021; Abrham & Mekuyi, 2022).

Finally, weekly market distance has a negative but marginal effect (B = -0.347, p = 0.084). Greater distance reduces opportunities for social learning and climate information exchange with peers, traders and extension workers, and thus lowers levels of awareness. This is in line with the Saguye (2017).

The model shows that grazing conditions and livestock holdings are the most powerful climate change drivers among pastoral households, with a strong positive impact. Economic participation in climate-sensitive livelihoods, household size and age also increase the perceived value. Conversely, variables such as education, diversification of livelihoods and some institutional factors show unexpected negative associations, suggesting that in the pastoralist household context of the study, direct exposure to the livelihoods is more important than formal channels of knowledge in shaping perceptions. Strengthening perceptions therefore requires integrating experience with tailored climate communication strategies based on trust.

In practice, pastoralists' perceptions of climate change are influenced by sociodemographic, economic, institutional, and environmental factors (Table 16). The study found that perception levels were higher among households with larger sizes, older residents, larger livestock herds, larger pasture areas, and greater access to medical facilities; conversely, higher levels of education and access to veterinary technical support were negatively correlated with perception levels. In particular, the condition of grazing lands emerged as the strongest predictor of climate change awareness (Exp(B) = 8.756, p = 0.001), underscoring the significance of visible grazing land degradation in recognizing climate risks. These findings suggest that awareness-raising initiatives should be tailored to the characteristics of pastoral households, integrated into existing service platforms, and grounded in observable environmental changes.

Diagnostic test

The overall fit of the model shall be tested by the Omnibus test of model coefficients (LR χ^2), log-likelihood minus 2 (2L), pseudo-R^2 (Cox-Snell, Nagelkerke, McFadden) and Hosmer-Lemm test (H-L). Omnibus test of model coefficients (LR χ^2): the model is significantly better than the intercept model (Omnibus LR χ^2 (15) = 139.559, $p<0.001$), suggesting that the predictors are collectively more robust to explaining the climate change perception in households.

H-L Hosmer-Lemme test: H-L = 9.26, p = 0.32. As the p-value is greater than 0.05, the model does not disprove the null hypothesis that the fit is satisfactory. The model is well calibrated - the

predicted probabilities are very close to the observed results across deciles, without any evidence of bias. The Cox-Snell, Nagelkerke, and McFadden tests for 2 log likelihoods (−2LL) and pseudo-R^2 include: the model converged to a 6-step run with log likelihood = 268.32. The pseudo-R^2 indices show significant explanatory power: Cox-Snell = .328 and Nagelkerke = .48 (the latter corrected to 0-1). Taking it together, these data suggest a significant improvement over the intercept-only model and a moderate to strong ability to explain variability in the logarithm of climate change perception.

The logistic model is therefore statistically sound, well calibrated and provides a substantively useful explanation for the variation in household perceptions of climate change - suitable for reporting adjusted probabilities and for drawing policy relevant conclusions.

The above analysis provides a solid foundation for evaluating hypotheses 4 and 5 associated with objective three as follows:

Hypothesis H4 - A higher proportion of pastoral households perceive direct (meteorological) climate impacts than indirect (livelihood-related) climate change indicators.

H4 is rejected. As indicated in table 15, pastoral households perceive climate change more strongly through its livelihood consequences than through direct meteorological cues. Because indirect/livelihood indicators (mean = 79.0%) were perceived at significantly higher rates than direct/meteorological indicators (mean = 75.0%), $\chi^2 = 9.45$, $p < 0.01$). This finding aligns with the availability heuristic (Tversky & Kahneman, 1973) and Protection Motivation Theory (Rogers, 1975) and states that households perceive climate change more strongly through visible and economically consequential livelihood losses, such as livestock deaths, pasture degradation, and crop losses, than through abstract changes in climatic conditions.

Hypothesis H5 - Economic and environmental/physical capital endowments have stronger magnitude effects on household perception than socio-demographic and institutional factors.

This hypothesis is accepted. The supportive evidence shown in table 16 is that economic and environmental/physical capital endowments generate a larger magnitude of change in household climate perception ((4.177+2.517)/5+2=0.956) compared to the change in household climate perception caused by socio-demographic and institutional factors ((1.786+2.766)/4+4=0.569) in shaping perceptions. The acceptance of this hypothesis is theoretically substantiated by the convergence of perspectives from the Asset Vulnerability Framework (Moser, 1998), experience-

based risk processing (Weber, 2006), the availability heuristic (Tversky & Kahneman, 1973), prospect theory (Kahneman & Tversky, 1979), and protection motivation theory (Rogers, 1975). These frameworks suggest that tangible economic and environmental losses are more directly experienced, vivid, and consequential than socio-demographic or institutional conditions. Consequently, such losses generate stronger perceptions of vulnerability and risk responses, explaining their larger effect magnitudes and supporting H5.

4.5 Household vulnerability

4.5.1 Measuring household vulnerability

The main analysis of the components for pastoral households in the Rayitu district combines a broad range of livelihood indicators - organised into human, financial, social, natural and physical capital - into a single basic dimension. The contribution was calculated using principal component analysis (PCA), in which the squared factor loadings of each indicator represent that indicator's proportional contribution to the total variance explained by household vulnerability. The relative contribution of each capital asset was calculated by summing the squared factor loadings of the indicators within each livelihood capital category and converting this into the percentage of total variance explained by the 25 indicators (Table 17).

Table 17: Contribution of livelihood capital assets to household vulnerability

SN	Component Matrix	Component	Square of components	Contribution %
I	Human Capital asset		0.751	12.34
1	Education level of HHs	0.032	0.001	0.02
2	Training participation of HHs	-0.573	0.328	5.4
3	Health status of households	0.301	0.091	1.49
4	Livelihood Experience of HHs	0.575	0.331	5.43
II	Financial Capital Assets		0.937	15.39
5	Total income of HHs	0.379	0.144	2.36
6	Total Expenditure of HHs	0.492	0.242	3.98
7	Access to savings	-0.056	0.003	0.05
8	Access to credit	-0.447	0.2	3.28
9	Remittance receipt	-0.355	0.126	2.07
10	Access to insurance	-0.263	0.069	1.14
11	Livestock ownership _(TLU)	-0.391	0.153	2.51
III	Social Capital Assets		0.455	7.48

SN	Component Matrix	Component	Square of components	Contribution %
12	Membership of cooperative	-0.622	0.387	6.36
13	Weather/climate information	-0.164	0.027	0.44
14	Veterinary extension access	-0.203	0.041	0.68
IV	Natural Capital		0.022	0.36
15	Rangeland size (Ha)	-0.146	0.021	0.35
16	Farmland size (Ha)	0.029	0.001	0.01
V	Physical Capital		3.92	64.43
17	Potable water access	0.664	0.441	7.25
18	Livestock water access	0.802	0.643	10.57
19	Distance to road (km)	-0.04	0.00016	0.02
20	Distance to market (km)	0.61	0.372	6.12
21	Electricity access	-0.526	0.277	4.55
22	Distance to school (km)	0.067	0.004	0.07
23	Distance to health centre (km)	0.888	0.789	12.96
24	Distance to pastoral training(km)	0.81	0.656	10.78
25	Distance to veterinary health post (km)	0.859	0.738	12.13

Source: Author's own computation using Stata Version 17

Physical capital variables show how infrastructure, or lack thereof, drives vulnerability through insulation. The distance from key services has a strong and consistent impact on the vulnerability of pastoralist areas. Physical capital was, by a considerable margin, the dominant contributor to the vulnerability component, accounting for 64.43 percent of the total variance explained, more than four times the combined contribution of the next-largest domain (financial capital, 15.39%). Distance to health centres (12.96%), veterinary posts (12.13%), training centres (10.78%), and access to livestock water (10.57%) carry the strongest loadings in the entire matrix, with electricity access loading strongly in the opposite direction.

This indicates that vulnerability in the study area is primarily a function of spatial/infrastructural remoteness rather than asset ownership. Poor physical access to social services, counselling and markets therefore critically hampers pastoral households' ability to respond to and recover from climate-related stresses. This finding aligns with Tofu et al., 2025; Gatew & Guyo, 2024; Yimam & Holvoet, 2023; Tasnuva et al., 2021; Uddin et al., 2019.

Financial capital contributed 15.39 percent of the total variance, making it the second-most influential domain after physical capital. Household total expenditure (3.98%) and total income

(2.36%) recorded the strongest positive loadings, while the tropical livestock unit (2.51%), access to credit (3.28%), and remittance receipt (2.07%) had negative loadings; in contrast, access to savings (0.05%) and insurance (1.14%) contributed relatively little.

The financial capital dimension reflects an income-versus-buffering-strategy dimension of vulnerability. Income and expenditure show the strongest positive loadings, distinguishing households with greater cash-flow capacity from those more dependent on alternative financial buffers, such as credit, remittances, and livestock holdings, which load in the opposite direction. This pattern suggests that households with limited direct income rely more heavily on informal coping mechanisms to manage financial risks. The fragile loading of savings access (-0.056) indicates that formal savings practices play a limited role in differentiating households, potentially reflecting restricted access to formal financial services. This pattern aligns with recent evidence from Asfaw et al. (2021b), Gatew & Guyo (2024), Tasnuva et al. (2021), Tofu et al. (2025), Yimam & Holvoet (2023), and Uddin et al. (2019).

Human capital accounted for 12.34 percent of the total variance explained by the first component, positioning it as a moderate contributor to household vulnerability. Within this domain, livelihood experience (loading = 0.575, contribution = 5.43%) and training participation (loading = -0.573, contribution = 5.40%) emerged as the dominant indicators, while education level (0.032, 0.02%) and health status (0.301, 1.49%) contributed comparatively little.

The human capital dimension indicates that livelihood experience and access to training are the main differentiating factors in household vulnerability. Their opposite loadings suggest a distinction between households relying on accumulated experiential knowledge and those benefiting from formal skills training. In contrast, formal education (0.032) has a negligible loading, while health status (0.301) has only a modest association with vulnerability. Overall, the findings suggest that practical livelihood experience and skills development are more important dimensions of human capital than formal education or health status in the study population (Gatew & Guyo, 2024; Tofu et al., 2023; Yimam & Holvoet, 2023).

Social capital explained 7.48 percent of the total variance, the second-lowest contribution among the five domains. Cooperative membership carried by far the strongest loading in this domain (6.36%), accounting for approximately 85 percent of the domain's total explanatory contribution, while access

to up-to-date weather information (0.44%) and access to veterinary extension services (0.68%) contributed only marginally.

The social capital dimension is driven by cooperative membership, which indicates that collective organisational participation is the key social-capital factor that differentiates household vulnerability. Cooperative membership may provide access to pooled resources, collective bargaining, and mutual risk-sharing mechanisms. In contrast, access to weather information and veterinary extension services shows negligible loadings, suggesting a limited association with household vulnerability in the study population. This aligns with Gatew & Guyo, 2024, and Opiyo et al., 2014.

Natural capital recorded the lowest contribution of all five domains at only 0.36 percent, comprising solely the land-based indicators of pastureland (0.35%) and farmland (0.01%) holdings. The near-negligible loadings of pastureland and farmland indicate that landholding size has limited explanatory power in differentiating household vulnerability within the sample. This may reflect limited variation in landholdings or the greater importance of land quality, tenure security, fragmentation, and access to communal resources.

The finding emphasizes the necessity of more comprehensive natural capital indicators beyond landholding size when assessing vulnerability in pastoral and agro-pastoral contexts. While greater access to pasture improves feed availability and flexibility in herd management, its contribution to reducing vulnerability is modest, probably because much of the pasture is communal rather than individual land and therefore not fully taken up by households (Gatew & Guyo, 2024; Molla et al.,2024; Tofu et.al.,2025).

From a practical perspective, the finding in Table 17 shows that physical capital is by far the most important factor in household vulnerability (64.43% contribution). This is especially true for distance to health centres, pastoral training centres, and veterinary posts, as well as access to potable and livestock water. This means that vulnerability in this pastoral area is mostly a problem with infrastructure and service access, not a problem with resource endowment. Financial capital (15.39%) and human capital (12.34%) contribute moderately, while social capital (7.48%) and especially natural capital (0.36%) contribute minimally, suggesting that land availability alone does little to explain vulnerability compared to access to services and markets.

Diagnostic test

For this study, Principal Component Analysis (PCA) was used to build quantitative household vulnerability indices based on 28 indicators. Table 18 shows that the suitability of the data set for principal component analysis (PCA) was assessed by the Kaiser-Meier-Olkin (KMO) and Bartlett Sphericity tests. The KOM of 0.706 is within the medium range (Kaiser, 1974), which indicates that the adequacy of the sample is acceptable. The result shows that the variables have a sufficient degree of common variance and that the correlation patterns are sufficiently compact to warrant factor analysis. The Bartlett Sphericity test further confirmed the adequacy of the PCA, yielding a chi-square of 1794.917 with 406 degrees of freedom and a very significant level of probability ($p<0.001$). This result disproves the null hypothesis that the correlation matrix is an identity matrix and thus confirms that meaningful correlations between variables are present. Overall, these findings show that the data are suitable for PCA and ensure that the extracted components give valid and interpretable results as shown in Table 18.

Table 18: Kaiser Mayer-Olkin and Bartletts test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.706
Bartlett's Test of Sphericity	Approx. Chi-Square	1794.917
	Df	406
	Sig.	0.000

Source: Author's own computation using Stata Version 17

4.5.2 Determinants of household vulnerability

Vulnerability to livelihood shocks is shaped not by a single factor but by the interaction of multiple forms of capital available to households. Drawing on the Sustainable Livelihoods Framework (Scoones, 1998; DFID, 1999), this section examines the marginal effects of human, financial, social, natural, and physical capital on the probability of households experiencing low, moderate, or high levels of vulnerability.

Table 19: Marginal effects of determinants of household vulnerability

Variable	Low Vulnerability		Moderate Vulnerability		High Vulnerability	
	dy/dx	P>|z|	dy/dx	P>|z|	dy/dx	P>|z|
Human capital						
Education (years)	0.0098	0.019	-0.0018	0.033	-0.0081	0.020
Training received	0.1070	0.001	-0.0191	0.012	-0.0879	0.001
livelihood experience	-0.0107	0.000	0.0019	0.000	0.0088	0.000
Health status	-0.3117	0.000	0.0556	0.000	0.2561	0.000
Financial Capital						
Access to savings	0.0501	0.108	-0.0089	0.118	-0.0412	0.109
Access to credit	0.0980	0.005	-0.0175	0.017	-0.0806	0.005
Remittance receipt	0.1294	0.000	-0.0231	0.002	-0.1063	0.000
Insurance access	0.1199	0.011	-0.0214	0.019	-0.0985	0.012
Livestock ownership _(TLU)	-0.0107	0.059	0.0019	0.067	0.0088	0.062
Social Capital						
Membership of cooperative	0.0714	0.034	-0.0127	0.062	-0.0587	0.032
Weather/climate information	0.0842	0.028	-0.0150	0.051	-0.0692	0.027
Veterinary extension access	0.0599	0.071	-0.0107	0.072	-0.0492	0.075
Natural Capital						
Rangeland size (ha)	-0.0243	0.123	0.0043	0.154	0.0200	0.120
Farm size (ha)	0.0041	0.754	-0.0007	0.758	-0.0033	0.754
Physical Capital						
Potable water access	-0.0129	0.263	0.0023	0.246	0.0106	0.269
Livestock water access	0.0191	0.082	-0.0034	0.079	-0.0157	0.087
Distance to road (km)	-0.0357	0.000	0.0064	0.001	0.0293	0.000
Distance to market (km)	-0.0048	0.532	0.0009	0.533	0.0040	0.532
Electricity access	-0.0316	0.630	0.0056	0.641	0.0260	0.628
Distance health facility (km)	-0.0044	0.213	0.0008	0.229	0.0036	0.213
Distance to PTC (km)	-0.0337	0.000	0.0060	0.000	0.0277	0.000

Source: Author's own computation using Stata Version 17

Human capital asset

Human capital assets determine how households experience and react to climate change. Education, training, health status, and livelihood experience are important dimensions of human capital in these studies. An extra year of school raises the chance of being low vulnerable by about 1.0 percentage point and lowers the chance of being highly vulnerable by 0.8 percentage points. Both effects are statistically significant at the 5% level. Training has the largest vulnerability-reducing effect in the model: trained households are approximately 8.8 percentage points less likely to experience high vulnerability and 10.7 percentage points more likely to fall into the low-vulnerability category ($p < 0.01$). These findings indicate that both formal education and practical skills enhance households' capacity to anticipate, adapt to, and cope with livelihood shocks. They are consistent with previous studies highlighting education, training, and skills development as important mechanisms for reducing vulnerability among rural and pastoral households (Fenta et al., 2019; Zeleke et al., 2021; Snaibi et al., 2021; Lankamo et al., 2025).

Health status is the strongest human-capital determinant in the model. A one-unit deterioration in health status increases the probability of high vulnerability by approximately 25.6 percentage points ($p < 0.001$). This large effect highlights the importance of household health for livelihood resilience, particularly where livelihoods depend substantially on household labor. The finding aligns with evidence that health shocks significantly increase household vulnerability by reducing income-generating capacity (Wingfield et al., 2020; Zhao et al., 2025).

Livelihood experience is also positively and significantly associated with vulnerability. Rather than necessarily providing greater protection, longer livelihood experience may reflect continued dependence on traditional livelihood activities that remain highly exposed to climatic and economic shocks. These findings support the idea that greater farming experience is associated with lower adoption of new adaptive strategies, as households tend to prefer familiar practices over innovative ones (Taruvinga et al., 2016). This finding suggests that experience alone is insufficient to reduce vulnerability; improved skills, information, and adaptive capacity are also necessary.

Financial capital assets

Financial capital is a key determinant of the vulnerability of households in pastoralist systems. It affects how quickly and efficiently households can react to shocks, stabilize consumption, and protect key productivity assets. Results from the ordinal logistic model show that savings, credit

transfers, transfers of funds, and insurance reduce vulnerability, except for larger livestock farms. Taken together, these factors demonstrate the critical importance of financial capital for the resilience of the teaching sector.

Access to credit, remittances, insurance, savings, and livestock holdings in terms of tropical livestock units represents the financial resources available to households for managing livelihood shocks. Credit access reduces the probability of high vulnerability by approximately 8.1 percentage points ($p = 0.005$), while remittances and insurance reduce it by approximately 10.6 and 9.9 percentage points, respectively. Savings has the expected negative association with high vulnerability but is not statistically significant ($p = 0.109$). Overall, the results indicate that external financial resources, particularly remittances, credit, and insurance, provide important buffers against livelihood shocks. This finding is consistent with Dejene (2020) and Zeleke (2021) and Opiyo et al. (2014), who identified credit and remittances as important contributors to climate resilience.

TLU is positively associated with high vulnerability and is marginally significant ($p = 0.062$). This suggests that larger livestock holdings do not necessarily provide greater protection and may increase exposure to feed and water shortages during shocks. The result highlights the importance of livestock productivity and resilience rather than herd size alone. This study confirms the previous findings of Dejene (2020).

Social capital assets

Social capital affects vulnerability to shocks by shaping the way pastoral households share information, organize themselves, and access support services. The marginal effect of ordered logit model analysis shows that cooperative membership, access to weather information, and extension services for animal and plant health all play a protective role. Together, these social capital assets strengthen coordination, improve decision-making, and support early responses to climate and livelihood risks. Strengthening social networks and institutional links is therefore essential to build resilience in the teaching sector.

Cooperative membership decreases the probability of high vulnerability by approximately 5.9 percentage points ($p = 0.032$), while access to climate information reduces it by 6.9 percentage points ($p = 0.027$). These findings highlight the importance of social networks, collective action, and timely information in strengthening households' adaptive capacity and are consistent with previous pastoral vulnerability studies (Opiyo et al., 2014; Zeleke et al., 2021).

In addition to cooperative support and climate information, access to veterinary and agricultural extension services is another source of protection, which has a negative relationship with high vulnerability but is marginally statistically significant ($p = 0.072$). By reducing disease and mortality in livestock and improving management decisions, veterinary and agricultural extension support increases resilience and further reduces vulnerability. This conclusion is consistent with previous work by Addis et al. (2021), Opiyo et al. (2014), and Zeleke et al. (2021).

Natural capital assets

Natural capital shapes the way pastoral households interact with land and thus affects their exposure to climate shocks and livelihoods. The study considers natural capital in terms of grazing areas and agricultural land. The findings show that neither rangeland size nor farm size attained statistical significance. This suggests that land quantity, in isolation, is a weak predictor of vulnerability, a pattern consistent with arguments that land quality, degradation, and tenure security rather than sheer size determine natural capital's protective value (Behnke & Kerven, 2013).

Physical capital

Physical capital includes the infrastructure and basic services that determine how pastoral households access markets, information and support in the event of shocks. The findings of the study suggest that the distance and isolation of physical capital assets such as roads, markets, electricity, health facilities and pastoralist education centres increase vulnerability.

Physical capital is reflected primarily in access to roads, markets, health facilities, PTCs, and electricity. Distance from both roads and PTCs is positively and significantly associated with high vulnerability. An additional kilometre of distance from a road increases the probability of high vulnerability by approximately 2.9 percentage points, while an additional kilometre from a PTC increases it by about 2.8 percentage points. Both variables also significantly reduce the probability of being in the low-vulnerability category. These findings suggest that geographical isolation limits households' access to markets, public services, information, and emergency support, thereby increasing their exposure to livelihood shocks. This findings in line with Ghosh and Ghosal, 2020. In contrast, distance to markets and health facilities, as well as access to electricity, are not statistically significant, possibly because road and PTC distances already capture much of the variation in physical accessibility.

In practical terms, Table 19 shows that infrastructural remoteness and limited financial buffering, rather than land-based assets, primarily drive vulnerability. Policy should prioritize improving access to services (health, veterinary, training, water), expanding financial tools (credit, remittances, insurance), and strengthening cooperative networks. Training and education are effective household-level levers, while reliance on traditional experience alone may hinder adaptation. Land-based natural capital plays a limited role, confirming that vulnerability stems more from structural access constraints than asset ownership, pointing to the need for integrated interventions across infrastructure, finance, and human capital.

As a summary of the above results the following statements can be made about the hypotheses associated with objective four.

Hypothesis H6 - The combined effects of human and financial capital are expected to have a stronger influence on household vulnerability than natural and physical capital.

H6 is rejected because it is not supported by empirical evidence. The results of Table 17 show that natural and physical capital account for 64.79% (0.36% + 64.43%) of the explained variance, while human and financial capital account for 27.73% (12.34% + 15.39%). Therefore, the contribution of natural and physical capital is 37.06 percentage points higher, and the contribution ratio is approximately 2.3:1 (Table 17). This significant difference is consistent with the asset-vulnerability framework (Moser, 1998; Chambers & Conway, 1992) and the sustainable livelihoods approach (Scoones, 1998; DFID, 1999), which emphasize that physical and natural assets provide the essential conditions that enable human and financial capital to effectively reduce household vulnerability.

Hypothesis H7 - Higher human capital endowments (education, training, livelihood experience, health status) reduces the probability of high vulnerability of pastoral households.

H7 is partially supported/confirmed. Formal education and technical training reduce the likelihood of high vulnerability among nomadic households (Table 19) and are consistent with human capital theory (Becker, 1964; Schultz, 1961). However, experience in livelihood activities and health status are associated with an increase rather than a decrease in vulnerability, suggesting that not all dimensions of human capital consistently function as protective assets in this context (Table 19).

4.6 Coping and adaptation strategies toward climate change

The qualitative findings of the focus group discussion and the key informant interviews show that households rely mainly on short-term coping strategies to cope with climate shocks, particularly droughts. The main strategies reported were destocking (distributing small ruminants and weak animals to purchase food and basic supplies), participation in the Product Safety Net Programme (PSNP), short-term casual work, both within and outside the community, and reducing food and food consumption, while giving priority to children and other vulnerable groups. These measures were considered essential for immediate survival but insufficient to ensure livelihoods in the face of repeated and prolonged climate stress.

Similarly, the study identified a few long-term adaptation strategies adopted by pastoral households to cope with increasing climate variability and recurrent droughts. The main strategies included seasonal rearing of livestock, introduction of drought-resistant breeds, diversification of the livestock sector (keeping of a mix of cattle, goat and camel), diversification into non-agricultural activities (pet trade, small businesses and employment outside the farm) and the implementation of measures to protect the soil and the main grazing areas. Although these strategies have been widely recognised as essential to sustain pastoral livelihoods in changing climate conditions, their effectiveness has been limited by limited resources and institutional challenges.

Before running the regression/marginal effects model for coping and adaptation strategies, the study checked the diagnostic test of multicollinearity, and the result confirmed that there is no serious multicollinearity among the independent variables: the mean VIF (1.26) is well below the threshold of 5, and all pairwise correlations are below 0.80. This satisfies the assumption of independence among explanatory variables, so all variables can be safely retained in the model.

4.5.1 Determinants of Coping Strategies

According to the results of the multivariate probit analysis, the coping choices of pastoral households are systematically shaped by differences in human capital, asset holdings, and access to basic services. This study identified destocking, participation in a productive safety net programme, short-term casual labor, and reduction of daily food intake as coping strategies for climate change. Table 20 presents the key findings and provides a detailed discussion below.

Table 20: Marginal effect (dy/dx) of determinants of household coping strategies

Variable	DS	PSNP	SCL	RDFI
Human Capital				
Education level of HHs	.0527***	.0545***	0.055***	.0317***
Training participation of HHs	.0178	.0013	0.0013	.0335**
Health status of households	-.0898*	-.0459	-0.046	.0288
Livelihood experience of HHs	-.0012	-.0021	-0.002	-.0014
Financial capital				
Access to savings	-.0203	-.0779	-0.078	-.0699**
Access to credit	-.0441	.1199**	0.119**	-.0127
Access to an insurance	.0504	.1014	0.101	-.0422
Tropical Livestock Unit	.2246***	-.1267*	-0.127*	.0151
Social capital				
Members of cooperative	-.1152	-.0111	-0.011	-.0048
Access to information	-.0178	.0254	0.025	-.0128
Access to extension service	.0482	-.0532	-0.053	.0366
Natural capital				
Rangeland (Ha)	.0706**	-.0784***	-0.078***	-.0172
Farmland (Ha)	.0395**	.0339	0.034	-.0182
Physical capital				
Access to potable water	-.0081	-.0057	-0.006	-.0134***
Distance to market (km)	-.0137	-.0226	-0.023	-.0388***
Access to electricity	-.2571***	-.0863	-0.086	-.1442***
Distance to health center (km)	.0091	.0122**	0.012**	.0015

Source: Authors' own computation using Stata version 17. **DS:** De-stocking, **PSNP:** Productive Safety Net Program, **SCL**: Short-term casual labour, **RDFI**: reduction in daily food intake. ***, ** and * represents significance at 1%, 5% and 10% level, respectively.

Human Capital

Human capital shapes how pastoral households respond to shocks, primarily through education, training, health status, and livelihood experience, which together strengthen households' knowledge, decision-making capacity, and adaptive ability (Silvestri et al., 2012). Education and training raise

awareness and improve access to relevant information (Alemayehu & Bewket, 2017; Gebre et al., 2021), while good health and accumulated experience support labour mobilisation and more effective resource management (Gebbisa & Bacsi, 2025; Megersa et al., 2022). Stronger human capital generally translates into a greater capacity to adopt appropriate coping strategies, though the specific effects of education, training, health status, and experience vary across strategy types, as discussed below.

Education improves the capacity of households to interpret information, to make informed choices, and to interact with institutions, thus strengthening their resilience. The results indicate that education has a positive and statistically significant effect on the reduction in stocking, short-term causal labour, and the reduction in daily food intake by approximately 5.3, 5.5, and 3.2 percentage points, respectively. However, the effect on the productive safety net program is not statistically significant. These findings suggest that education strengthens the capacity of households to adopt asset- and labour-based protection strategies but does not significantly influence their participation in formal safety net schemes. Thus, a reduction in food intake in higher education households may be a deliberate and planned adjustment, rather than a purely reactive response (Alemayehu & Bewket et al., 2017; Gebre et al., 2021; Megersa et al., 2022; Silvestri et al., 2012).

Training has a significant positive effect only on the reduction of daily food intake (dy/dx = .0335, p = 0.040), without having a significant effect on the other three strategies. This pattern suggests that trained households may prioritize the protection of productive assets over consumption when shocks hit the asset-smoothing response, which is consistent with training to build technical and managerial capacity around livestock and land rather than directly accessing food (Silvestri et al., 2012).

Health status and livelihood experience lack statistical significance for all four treatment strategies (all p>0.05; livelihood experience is only marginally statistically significant for the Productive Safety Net Program with p=0.057). This suggests that, once education, training, and wealth variables are taken into account, the personal health status of the household head and the years of work experience in this sample do not independently influence the choice of coping strategies; access to resources seems to matter more than personal health or tenure.

Financial Capital

Financial capital such as savings, credit, insurance, and livestock gives pastoral households a cushion against shocks, allowing them to smooth consumption, protect productive assets, and avoid distress-

driven coping (Abay et al., 2022). These assets are complementary: savings and credit provide liquidity for short-term gaps, while livestock serves as a tangible store of wealth that can be drawn down when needed (Feyissa et al., 2025).

Access to savings supports smoothing consumption rather than reducing food consumption. Access to savings is significantly reduced by about 7.0 percent for daily food intake (dy/d x = -0.0699, p=0.044) and shows a marginally significant positive association with participation in a production safety net programme (dy/d x = 0.0911, p=0.077). This suggests that saving acts as a buffer against the adjustment mechanism, allowing households to maintain consumption in times of stress.

Access to credit improves the resilience of households by facilitating their participation in both formal and informal labour markets. It has a strong positive impact on participation in the product safety net programme (PSNP) (dx = .1386, p = 0.009) and short-term casual labour (dx = .1199, p = 0.025), increasing the probability of participation by approximately 13.9% and 12.0%, respectively. This highlights the importance of financial inclusion in increasing the range of coping options for households (Abay et al., 2022; Snaib et al., 2021).

Livestock ownership complements savings and credit as a tangible, negotiable asset. Livestock holding (TLU) positively and significantly influences de-stocking, increasing the likelihood by roughly 22.5 percent (dy/dx = .2246, p<0.001), while showing a marginally significant negative effect on short-term casual labour (dy/dx = -.1267, p=0.071). This finding indicates that livestock-wealthy households adjust their herd size as their primary adaptive lever and are less dependent on casual labour (Feyissa et al., 2025; Tilahun & Legese, 2020; Megersa et al., 2022; Sintayehu et al., 2025).

Social Capital

Social capital, including cooperative membership, access to information, and extension services, shapes how pastoral households respond to livestock-related shocks (Ragasa, 2025). These networks influence households' coping strategies by determining the resources and support available during periods of stress (Opiyo et al., 2015), which will be discussed in the following sections:

Membership in cooperatives reduces the probability of stock depletion by approximately 11.5 percent (dy x dx = -.1152, p = 0.016), without significantly affecting the other three strategies. This suggests that cooperatives provide alternative support, such as pooling resources, market

information, or informal risk sharing, which reduces the need for herd liquidation specifically (Ragasa, 2025).

Access to information, as well as veterinary and extension services, is not statistically significant for any of the four treatment strategies (all $p < 0.30$). This finding suggests that existing information and service-delivery channels do not translate into measurable differences in households' responses to shocks. This may reflect inadequate targeting, limited-service quality, or delays in delivering relevant information, preventing households from using it effectively when making real-time coping decisions (Opiyo et al., 2015).

Natural Capital

Natural capital assets determine the room for manoeuvre that pastoral households have in response to shocks, and rangeland and agricultural land play important and complementary roles. As shown below, the size of rangelands has a significant impact on both livestock and labour-intensive management strategies, while farmland plays a more limited role, mainly in supporting household liquidity and coping capacity.

Rangeland size has mixed effects: it positively and significantly influences de-stocking while negatively and significantly affecting short-term casual labour, increasing/decreasing the respective likelihoods by roughly 7.1 and 7.8 percentage points. This finding implies that households with larger grazing areas rely more on livestock-based adaptation and less on labour-based coping (Letsoalo et al., 2023; Tsegaye et al., 2013).

Farmland shows only a marginally significant positive effect on de-stocking ($dy/dx = .0395$, $p = 0.053$) and no significant effect on PSNP participation or the other two strategies. This is a more limited role than land plays for de-stocking-related liquidity, and the claim of a strong PSNP link should not be carried forward without further data support (Alemayehu & Bewket, 2017; Zeleke et al., 2023).

Physical Capital

Physical capital assets shape how easily pastoral households connect to markets, services, and economic opportunities. Nearby roads, markets, health centers, training facilities, and infrastructure such as electricity expand livelihood options and reduce reliance on distress coping, whereas poor and remote infrastructure narrows choices and heightens vulnerability during shocks. Within this

broader landscape, distance to markets, access to electricity, and proximity to health centers emerge as particularly influential dimensions.

Reliable access to drinking water only has a statistically significant effect on the reduction in daily food intake (dys = -.0134, p = 0.009), reducing this risk by approximately 1.3 percentage points; however, the effect of de-stocking is not statistically significant (dys = -.0081, p = 0.311). This finding suggests that access to water is the most directly alleviating pressure on food consumption, presumably through freeing up time that would otherwise be spent gathering water rather than influencing asset disposal decisions (Degefu et al., 2019; Ndiritu, 2021).

Access to electricity has a strong and statistically significant negative effect on destocking (dy/dx = −0.2571, p < 0.001) and reducing daily food intake (dy/dx = −0.1442, p < 0.001), reducing the probability of adopting these coping strategies by approximately 25.7 and 14.4 percent, respectively. This finding indicates that electrified households are significantly less likely to rely on these two coping strategies, potentially because access to electricity facilitates income diversification into non-agricultural activities and reduces losses associated with storage and food spoilage (Gebrehiwot & Hassen, 2022).

Being close to a health center has a statistically significant negative effect on PSNP participation (dy/dx = -.0167, p = 0.009). This means that as distance decreases, the likelihood of accessing PSNP decreases by about 1.7 percentage points. In other words, households that are closer to health centers are less likely to use PSNP. This may reflect that better-connected, less-remote households are comparatively better-off and therefore less dependent on the safety net, or alternatively that PSNP outreach itself is weaker in more remote areas even though remote households may be more vulnerable, a targeting question worth flagging explicitly (Abay et al., 2022).

4.5.2 Determinants of Adaption strategies

This study employed a multivariate probit model to estimate the determinants of five key climate change adaptation strategies adopted by pastoral households, such as seasonal livestock migration, introduction of drought-resistant livestock breeds, livestock diversification, non-agricultural diversification, and soil and water resource conservation. Table 21 presents the key findings and provides a detailed discussion below.

Table 21: Marginal effect (dy/dx) of determinants of household adaptation strategies

Variables	SLM	DTL	HD	NFD	SWC
Human Capital					
Education level of HHs	0.0095*	0.0074	-0.0040	-0.0065	-0.0099
Training participation of HHs	-0.0325	0.0287	0.0045	-0.0255	-0.0157
Health status of households	0.0585	-0.0271	0.0009	-0.0330	-0.0588
Livelihood experience of HHs	0.0053**	0.0023	0.0015	-0.0030	0.0052**
Financial capital					
Access to savings	-0.0706	-0.0288	0.0968**	0.1331***	0.0679
Access to credit	-0.0107	-0.0728	0.0619	0.0187	-0.0354
Access to an insurance	-0.0039	-0.0977	-0.0233	0.1256	0.0351
Tropical Livestock Unit	0.3168***	0.2181***	-0.1435**	-0.0260	-0.0444
Social capital					
Members of cooperative	-0.0747*	0.0204	0.1182***	-0.0406	0.0354
Access to information	0.0375	-0.1185**	0.0409	-0.0133	-0.0018
Access to extension service	-0.0144	-0.0154	0.1155**	0.1058**	-0.0688
Natural capital					
Rangeland (Ha)	0.0764***	0.0733**	-0.0126	-0.0081	0.0052
Farmland (Ha)	0.0276	0.0318	0.0389*	0.0327*	-0.0434**
Physical capital					
Access to potable water	-0.0138*	0.0197**	0.0039	0.0178**	-0.0184*
Distance to market (km)	-0.0001	-0.0004	-0.0001	-0.0019***	0.0016***
Access to electricity	-0.0410	-0.2392***	-0.0687	0.1172**	-0.0648
Distance to health center (km)	0.0085	0.0099	-0.0032	0.0222***	0.0032

Source: Author's own computation using Stata Version 17. **SLM:** Seasonal livestock migration, **DTL:** adoption of drought-tolerant livestock, **HD**: Herd diversification, **NFD**: Nonfarm diversification, **SWC**: Soil and water conservation.

Human capital assets

Human capital assets shape which adaptation strategies pastoral households can adopt and how they combine them. Differences in education, training exposure, health status, and accumulated livelihood experience influence how climate risks are understood, how information is used, and how households allocate effort across herding, non-farm work, and conservation.

Education (EDUHHS) has a positive and marginally significant effect on seasonal livestock migration (SLM), increasing its likelihood by approximately 0.95 percentage points ($p = 0.07$). This suggests that more educated household heads are better able to process climate and market information and plan mobility accordingly (Berhanu & Beyene, 2015; Gebbisa & Bacsi, 2025).

Training participation and health status show no statistically significant effect on any of the five strategies (all $p > 0.10$). This indicates that, in this sample, exposure to training programs alone has not translated into a measurable shift in adaptation behaviour, possibly reflecting limited coverage, relevance, or follow-through of training content relative to households' actual constraints. In addition, household head health might be expected to affect labour-intensive strategies such as migration or conservation; the results do not support a systematic link here, suggesting other capital assets dominate the decision margin.

Livelihood experience has a positive and significant effect on both SLM and SWC, increasing their respective adoption probabilities by about 0.52 and 0.53 percent. This implies that households with longer accumulated experience in pastoral or agropastoral livelihoods are more likely to rely on traditional mobility-based coping (transhumance) and are also more likely to invest in soil and water conservation, consistent with experience-based learning about long-run land degradation risks (Gebbisa & Bacsi, 2025; Regasa, 2025; Belay et al., 2017).

Financial capital assets

Financial capital assets set the practical limits of what adaptation strategies households can pursue and sustain. Access to savings, credit, insurance, and livestock wealth determines whether households can cover mobility costs, invest in improved breeds, adjust herd structure, or diversify into non-farm and conservation activities.

Access to savings has a positive and significant effect on herd diversification and non-farm diversification, raising their adoption probabilities by about 9.68 and 13.31 percent, respectively. This finding supports the view that savings act as a buffer that frees households to diversify livestock composition and income sources rather than relying solely on mobility (Letsoalo et al., 2023; Megersa et al., 2014; Yussuf & Mohamed, 2022).

Access to credit and insurance are not significant for any of the five strategies (all $p > 0.10$). This suggests that, unlike savings, formal credit and insurance access have not yet been strongly linked to adaptation choices in this sample, possibly reflecting limited penetration, restrictive terms, or a mismatch between these products and pastoral livelihood needs.

Livestock holdings (TLU) remain a strong and highly significant driver of adaptation; they increase the probability of seasonal livestock migration and drought-tolerant livestock by about 31.68 and

21.81 percent, respectively, while reducing the probability of herd diversification by about 14.35 percent. This reinforces the earlier finding that households with larger herds favour mobility and drought-tolerant breeds over diversifying herd composition, likely due to specialization and asset concentration (Berhanu & Beyene, 2015; Megersa et al., 2022; Regasa, 2025; Bedo et al., 2024).

Social capital assets

Social capital assets shape how information, support, and collective action feed into adaptation decisions through cooperative membership, access to information, and extension services. Cooperative membership has a positive and significant effect on herd diversification, increasing its adoption probability by about 11.82 percent. This is consistent with cooperatives promoting diversification through knowledge sharing and pooled resources (Bedo et al., 2024

Access to information now has a negative and marginally significant effect on a drought-tolerant livestock adoption, reducing its likelihood by about 11.85 percent. This is a notable reversal from a purely facilitative role and may indicate that households with better general information access substitute other strategies (e.g., mobility or diversification) for drought-tolerant breed adoption, or that information channels are not specifically tailored to breed-related decisions.

Access to (veterinary) extension remains an important driver of diversification, with positive and significant effects on herd diversification and nonfarm diversification, raising their probabilities by about 11.55 and 10.58 percent, respectively. This finding confirms the earlier interpretation that extension services provide technical knowledge that supports both livestock and income diversification (Feyera et al., 2017; Mohamed Sala et al., 2020).

Natural capital assets

Natural capital assets provide the resource base underpinning adaptation choices, captured here by rangeland and farmland access. Rangeland has a positive and significant effect on both seasonal livestock migration and drought-tolerant livestock, increasing their adoption probabilities by about 7.64 and 7.33 percent, respectively. This finding confirms that access to grazing resources strengthens households' capacity for livestock-based adaptation, particularly mobility and drought-tolerant breed adoption (Gebbisa & Bacsi, 2025; Regasa, 2025; Wario et al., 2016).

Farmland has broader significance in this updated model: it positively affects herd diversification and nonfarm diversification while negatively affecting soil and water conservation. This suggests

that larger landholdings expand households' capacity to diversify both livestock and income sources, while simultaneously reducing the perceived urgency of soil and water conservation investment, consistent with lower land-pressure explanations (Gebrehiwot & van der Veen, 2013; Ndiritu, 2021).

Physical capital assets

Physical capital assets such as water access, market and health-facility proximity, and electricity shape the relative cost of different adaptation options. Potable water access now demonstrates a broader significance pattern, and it negatively affects seasonal livestock migration and soil and water conservation and has a positive effect on drought tolerance livestock and nonfarm diversification. This suggests that improved domestic water access reduces the need for mobility and conservation investment while freeing households to adopt drought-tolerant breeds and diversify into non-farm activities (Degefu et al., 2019; Tofu et al., 2023). The effect on HD is not significant.

Distance to market has a negative and highly significant effect on nonfarm diversification and a positive and significant effect on soil and water conservation. This indicates that greater distance from markets discourages non-farm diversification (fewer opportunities to engage off farm) while encouraging soil and water conservation, possibly because remote households depend more heavily on land productivity in the absence of market alternatives (Feyissa et al., 2025; Gashure & Wana, 2023).

Electricity access continues to have a strong negative effect on drought tolerance livestock, reducing its adoption probability by about 23.92 percent, and now also shows a positive and marginally significant effect on nonfarm diversification. This suggests that households with electricity access shift away from livestock-cantered drought adaptation toward non-farm income activities enabled by infrastructure access (Gebrehiwot & Hassen, 2022).

Distance to health centers has a positive and significant effect on nonfarm diversification, increasing their probabilities by about 2.22 percent. The greater distance from health services is associated with more non-farm diversification and may reflect that remoter households face fewer institutional constraints on mobility or use non-farm income partly to offset the higher costs of accessing distant health services (Abate et al., 2020; Alemu et al., 2023).

From a practical perspective, the determinants of coping (Table 20) and adaptation strategies (Table 2) reveal complementary pathways that lead to resilience. Households with large herds are more

likely to rely on reducing their livestock numbers when shocks occur, but they also adopt proactive strategies such as seasonal transhumance and drought-resistant livestock breeds. Access to electricity, cooperatives, credit, and savings reduces reliance on coping strategies that deplete resources and promotes livelihood diversification. Similarly, the size of grazing lands and access to markets, health services, and other infrastructure influence both the intensity of coping and adaptation choices.

Therefore, the hypothesis 8 associated with objective five is evaluated as follows.

Hypothesis H8 - Human, social, financial, natural, and physical capital have significantly different effects on pastoral households' coping and adaptation strategies.

This hypothesis is accepted, although the magnitude and direction of impacts vary across asset-related strategies and indicators. Results from the marginal effect model provide strong support for this. For coping strategies, variables covering all five areas of capital are statistically significant in at least one of the four coping equations (destocking, participation in the PSNP, short-term casual work, and reduction of daily food intake). Similarly, adaptation strategies, indicators of human, social, financial, natural, and physical capital, have a significant impact on at least one of the five adaptation options (seasonal livestock migration, adoption of drought-tolerant livestock, herd diversification, non-crop diversification, and soil and water protection).

Table 22: Summary of hypothesis evaluation

Hypothesis and brief description	Decision
H1: The monthly precipitation varies by seasons without an annual precipitation trend	Accepted
H2: Annual and seasonal temperatures show a positive trend and temperatures are negatively correlated to precipitation.	Partially accepted
H3: Annual precipitation is concentrated in specific months, and the occurrence of mild drought is dominant	Accepted
H4: A higher proportion of pastoral households perceive direct (meteorological) climate impacts than indirect (livelihood-related) climate change indicators.	Rejected

Hypothesis and brief description	Decision
H5: Economic and environmental/physical capital endowments have stronger magnitude effects on household perception than socio-demographic and institutional factors.	Accepted
H6: The combined effects of human and financial capital are expected to have a stronger influence on household vulnerability than natural and physical capital.	Rejected
H7: Higher human capital endowments (education, training, livelihood experience, health status) reduces the probability of high vulnerability of pastoralist household.	Partially Accepted
H8: Human, social, financial, natural, and physical capital have significantly different effects on pastoral households' coping and adaptation strategies.	Accepted

Source: Author's own construction

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The study examined the vulnerability of pastoral households to climate change and variability shocks and adaptation strategies in the Rayitu district of southeastern Ethiopia at the micro level. It also argues that despite the significant economic, social, cultural, and environmental contributions of pastoralism, these contributions are still widely misunderstood and systematically underestimated in policy and governmental decision-making processes. The study adopted a mixed triangulation approach, integrating quantitative and qualitative approaches to address the issue in a comprehensive manner. Primary data were collected through structured household surveys, focus group discussions (FGDs), key informant interviews (KIs), and direct observation. Secondary data consisted of long-term precipitation and temperature records (1984-2024) from the Meteoblue database. The mixed-method approach enabled the validation of findings from diverse perspectives, ensuring the reliability and depth of the study.

The study found that Precipitation in the Rayitu district has very distinctive seasonal characteristics, concentrated in a few months. Although the annual variability is very high, there is no statistically significant long-term trend in the total annual precipitation (H1). Temperatures, on the other hand, show a clear and statistically significant upward trend in both the minimum, maximum, and average values at monthly, seasonal, and annual scales. This warming phenomenon is strongly negative for spring (Belg season) and annual precipitation, although it does not occur in the same way in all seasons (H2). These patterns support a drought regime dominated by frequent mild seasonal and bi-annual droughts, with severe multi-seasonal and multi-year droughts occurring intermittently and coinciding with major livelihood crises (H3).

Climate change is not an abstraction for pastoral households. It is generally accepted and interpreted through a series of direct and indirect indicators that are internally consistent and are well linked (H4). This perception of change is shaped by a complex web of socio-demographic, economic, institutional, and environmental factors, including educational attainment, land ownership, pasture conditions, and accessibility to services (H5). Some unexpected spillover effects (e.g., formal education, diversification, veterinary services) reflect the complexity of information flows, pathways of exposure, and differences in confidence between formal and indigenous knowledge systems.

The vulnerability of pastoral households in the study area is fundamentally determined by physical and infrastructural accessibility rather than simply by resource endowment (H6), and while human and financial capital assets exert a statistically significant and theoretically consistent protective effect, this effect is limited to a secondary level (H6). However, there is one important limitation. Not all aspects of human capital (health status and livelihood experience) serve a protective function (H7). This suggests that, as a prerequisite for investments in human and financial capital to lead to tangible improvements in resilience, vulnerability mitigation strategies must prioritize infrastructure development (roads, training centres, health, and veterinary services) (H6).

Building on this capital-based understanding of vulnerability, the five capital domains also shape how pastoral households respond to climate change through their choice of coping and adaptation strategies (H8). Households in poorer and more remote areas, constrained by limited assets and infrastructure, tend to rely on reactive coping strategies such as destocking and reducing food consumption. In contrast, households with stronger economic resources and institutional support are better positioned to adopt proactive and investment-oriented strategies, including herd diversification, drought-resilient livestock breeds, non-farm livelihood diversification, and soil and water conservation. This highlights how differences in access to livelihood capital shape not only the level of vulnerability but also households' capacity to move from short-term coping to longer-term adaptation.

To sum up the results indicate that the climate risk of Rayitu district is more affected by a combination of high precipitation, rapid warming, and frequent droughts with long-term water, grazing, and infrastructure deficiencies than by variations in annual precipitation. While people are aware of climate change, the uneven but closely interlinked combination of human, financial, social, natural, and physical capital is limiting their ability to translate this awareness into effective, long-term adaptation. Effective climate risk management in pastoral and agro-pastoral areas, therefore, needs to go beyond short-term emergency responses and address these structural constraints, in particular, water access, the health of the rangeland, and the links to markets and services, as well as strengthen human and financial capacity.

5.2 Policy Recommendation and Implication

The findings of this study challenge a policy framework that has long cantered pastoral development on rangeland conditions and livestock holdings. Rainfall stability at the annual scale masks a

significant seasonal decline in spring rains, the system's primary water source. Physical capital deprivation, not natural capital, explains most household vulnerability (64.43% of variance), while financial capital emerges as the strongest lever for shifting households away from distress-based coping. Together, these results suggest that conventional pastoral policy has targeted the wrong levers of resilience.

This part translates these findings into five intervention areas, each tied to a significant finding from result and discussion part and mapped to the concerned government bodies and stakeholder institutions best positioned to implement them, including the Productive Safety Net Programme (PSNP), the Drought Resilience and Sustainable Livelihoods Programme (DRSLP), and relevant financial and extension service providers as follows,

i. Shift monitoring from annual to seasonal scale: Rayitu's annual rainfall shows no significant trend, yet this covers opposing intra-year shifts: September rainfall is declining, November rainfall is rising, and spring, the season contributing most to annual rainfall, shows a marginal decline. Annual-scale monitoring thus obscures the risk that matters most. The policy makers should recalibrate drought triggers to monthly/seasonal indicators, agro-climate advisories should revise autumn onset guidance, and monitoring frameworks should report seasonal alongside annual trends.

ii. Expand basic service infrastructure. Physical capital is the dominant contributor of vulnerability, followed by financial, human, social, and natural capital assets. Distance to health centres, training centres, veterinary posts, and water points is the strongest fault line, while natural capital contributes almost nothing. This points to decades of misplaced policy focus on land and herd size. Priority should shift toward health post coverage, siting veterinary/training centres within reach of mobile herders and developing dual-purpose water points.

iii. Expand financial inclusion. Credit, insurance, and remittance access show large, significant effects on vulnerability. Savings access reduces distress coping (casual labour, food intake reduction) and increases sustainable adaptation (herd/nonfarm diversification). As a lower-cost, faster lever than infrastructure, financial inclusion should be expanded through tailored livestock/drought-index insurance, microfinance and village savings groups, mobile money/remittance channels, and SPEI-informed destocking incentives.

iv. Reorient cooperatives and extension around climate risk. Social capital's overall contribution is modest, but cooperative membership drives most of it, reducing destocking and increasing diversification; extension access similarly boosts diversification. However, veterinary extension access is negatively associated with climate change perception, indicating that extension services currently operate independently of climate messaging. Cooperatives should be reoriented around risk-sharing (fodder banks, joint water infrastructure, collective destocking), with climate-adaptive content integrated into extension delivery.

v. Secure rangeland access and herd mobility. Rangeland access significantly increases seasonal migration and the adoption of drought-tolerant livestock while reducing reliance on casual labour. As warming reduces the reliability of spring rainfall, mobility to track rainfall variability across other seasons becomes more critical, not less. Mobility is thus a measurable adaptive strategy under threat from land fragmentation. Governance bodies should treat corridor protection as core drought-resilience infrastructure, resist the fragmentation of communal grazing land, and formalise mobility rights within pastoral resilience programming.

5.3 Limitation and direction for future research

Although the study provides valuable insights into the vulnerability of pastoral households and their adaptation to climate change and variability, there are still some limitations that offer opportunities for further research, as mentioned below.

The study was conducted using a cross-sectional survey design and self-reported household responses. There are limitations in establishing a causal relationship between the identified determinants and climate change perceptions, and the results may be biased by response bias. Future research should therefore take a longitudinal approach integrating actual climatic and meteorological data with household perceptions to better understand how perceptions change in pastoralist communities and lead to specific adaptation practices.

This study constructs the vulnerability index using PCA-derived weights, which may be sensitive to indicator selection and scaling procedures. Consequently, alternative indicators, weighting approaches, or normalization methods could produce different vulnerability scores and household rankings. To address this methodological limitation, future research should assess the sensitivity and robustness of the vulnerability index by testing alternative indicator sets, weighting schemes, and

normalization methods. Such analysis would help determine the stability of vulnerability estimates and strengthen the reliability, comparability, and generalizability of vulnerability assessments in pastoral contexts.

This study inadequately addresses potential endogeneity between vulnerability, adaptation behaviour, and household characteristics, a problem that the cross-sectional models used cannot sort out. Future research should apply instrumental variable regression, panel data with fixed effects, or simultaneous equation modelling, along with longitudinal data collection, to better establish causal direction and capture how vulnerability and adaptation co-evolve over time.

This study compares its findings with existing international research, emphasising the necessity of more systematic comparisons across diverse contexts. Future research should conduct comparative analyses that encompass different countries and pastoral environments to identify similarities and differences arising from ecological, socioeconomic, and institutional conditions, thereby enhancing the generalisability of the findings and their scientific contribution.

6. NEW SCIENTIFIC RESULTS

This study provides some new empirical and methodological insights on climate variability, drought dynamics, perceptions of vulnerability and adaptation strategies among pastoral households in the Rayitu district and in Ethiopia's lowland pastoralist areas as described below.

1. **Climate variability in Rayitu with no trend in annual precipitation, increasing rainfall concentration and dominance of mild drought, with strong, multi scale warming and season specific rainfall -temperature link**

Monthly rainfall in Rayitu shows high variability, except during April–May, with spring being the most stable and winter the least stable season. This confirms H1, indicating that the main climatic risk is the timing and distribution of rainfall rather than annual totals. The PCI shows that more than four-fifths of years have highly irregular rainfall, while SPI/SPEI results indicate that mild drought is dominant, with less frequent but clustered severe and extreme events. These findings support H3, highlighting a concentrated rainfall regime with recurrent, mostly mild but disruptive droughts. Temperature records also show a significant warming trend across monthly, seasonal, and annual scales, strongest in SON and JJA (about 0.3–0.4°C per decade). Spring and annual rainfall are strongly and negatively correlated with temperature, particularly Tmax, partially confirming H2 by indicating that warming has its clearest adverse effect during the main rainy season.

2. A multi-index, multi – scale drought monitoring framework for pastoral areas

The study establishes a three-tiered framework for drought monitoring in pastoralist decision-making, combining precipitation concentration index (PCI), standard precipitation index (SPI), and standard precipitation evapotranspiration index (SPEI) for 3, 6, and 12 months: short-term (inter-seasonal), seasonal and bi-seasonal, and annual and multiannual. The findings suggest that acute seasonal stress (SPI, SPEI-3), persistent multi-seasonal deficits (SPI, SPEI-6), and occasional extreme drought events (SPEI, SPEI-12) are the cause of the collapse of herds and water systems. This integrated approach is a new methodological contribution to operational drought early warning in pastoralist systems in Ethiopia.

3. **Pastoral household perceive and validate climate change more strongly through livelihood-based (indirect) impacts than through direct meteorological cues.**

Indirect indicators recorded a higher mean recognition rate (79%) than direct climatic indicators (75%), with "drying up of grazing land" (91.5%) emerging as the single most recognised indicator of all twelve, even surpassing "decreased frequency of rainfall" (90.3%), which is the highest-ranked direct indicator. All indicators were statistically significant at different level, confirming that these perceptions are not random but reflect a consistent, shared cognitive pattern across the sampled households. Pastoral daily dependence on pasture, water, and livestock makes these changes more immediately tangible than gradual temperature or rainfall shifts. The result indicates that the knowledge system of pastoral households is outcome-oriented, reading climate change through ecosystem effects rather than meteorological parameters, which is supported by H4.

4. Physical capital as the dominant axis of Pastoral vulnerability

Physical capital and accessibility were identified as the principal factors influencing the vulnerability of pastoral households. The distance to health centers (12.96%), veterinary clinics (12.13%), pastoral training centers (10.78%), and access to livestock water (10.57%) collectively constituted a substantial portion of this vulnerability. These findings challenge existing perspectives that have emphasized natural and financial capital as the primary determinants of pastoral vulnerability. The results suggest that vulnerability is determined not only by the availability of household resources but also by access to essential services, water, and supporting infrastructure, which determine pastoral ability to respond effectively and promptly to climate-related shocks as supported by H5.

5. The livestock wealth paradox: larger livestock holding increases rather than decreases vulnerability

Livestock holdings (TLU) significantly increase, rather than reduce, the vulnerability of pastoral ($dy/dx = +0.0088$, $p = 0.062$, based on the high vulnerability criterion) as the result indicated in table 19. This supports Hypothesis H6 while overturning the conventional assumption that livestock function as assets that buffer resilience. This finding is supported by Table 16, where livestock ownership was also the strongest predictor of perceptions of climate change ($Exp(B) = 4.735$, $p < 0.001$), nomads with larger herds are, in fact, exposed to greater risks and therefore perceive those risks more acutely. This finding redefines livestock not as an asset that buffers against risk but as one that bears risk, calling into question existing livelihood-capital theory and suggesting that insurance or diversification must accompany livestock accumulation to prevent increased vulnerability.

6. **Determinants of vulnerability distinguish structural risk enhancers from protective factors among pastoral households.**

The marginal effect of ordinal logistic regression result indicated in Table 19, which provides a policy-relevant map of pastoral household vulnerability, clearly separating protective factors (formal education, skills training, financial capital instruments, and social/institutional networks) from structural risk enhancers (cumulative livelihood exposure, chronic health burden, and large livestock holdings), offering a more nuanced target for vulnerability-reduction interventions than a simple capital-endowment approach.

7. **Coping and adaptation strategies are structurally governed by distinct determinants of pastoral households.**

The study findings indicate that coping and adaptation strategies follow different capital mobilization pathways. Livestock assets increase both destocking and the adoption of drought-resistant breeds, but they reduce herd diversity, whereas access to electricity reduces extreme coping responses. In contrast, savings do not significantly influence coping but promote adaptation based on diversification. These findings suggest that strengthening adaptive capacity does not necessarily reduce coping strategies, and they underscore the need for differentiated policies that address short-term coping and long-term adaptation separately. This serves as a useful complement to the "Sustainable Livelihoods Framework" for livestock development policies.

7. SUMMARY

Ethiopia's pastoral sector remains undervalued. Fragile and fragmented data, coupled with policy biases, obscure its true contribution, thereby promoting settlement-centred interventions that restrict mobility and weaken community systems. While drought risks are worsening in some pastoral areas due to climate change, this is not the case everywhere. Previous studies have often lacked long-term climate/remote sensing validation, omitted key pastoral factors, and employed methodologies that obscure how households employ multiple strategies, particularly in under-researched areas like Rayitu district. Therefore, this study examined pastoral households' vulnerability to climate change and variability-induced shocks and adaptation strategies in the Rayitu district, Southeast Ethiopia.

This study utilized primary and secondary data to examine climate variability, drought, vulnerability, and adaptation strategies among pastoral households in the Rayitu district. Primary data were obtained through household surveys (351 households), six focus group discussions (FGDs) (72 participants), 36 key informant interviews, and direct observation of livelihood activities and coping mechanisms. The survey was carried out during the spring season (April–May), a period when pastoral households typically returned from their seasonal migration. Secondary data were obtained from the Meteoblue climate database (precipitation and temperature, 1980–2024) for climate trends, variability, and drought index analysis. Methodological triangulation was conducted to enhance the reliability and validity of the findings.

The study employed the Mann–Kendall statistical test, Sen's slope estimator, the coefficient of variation, and correlation coefficient models to analysed climate variability and change. Drought conditions were assessed using indices such as the Precipitation Concentration Index (PCI), Standardized Precipitation Index (SPI), and Standardized Precipitation Evapotranspiration Index (SPEI). The binary logit model was used to identify the determinants of household perception toward climate change. Principal component analysis (PCA) and ordinal logit (proportional odds) models were applied to investigate vulnerability and its determinants. In addition, descriptive statistics and multivariate probit models were utilized to identify coping and adaptation strategies and their determinants.

Descriptive statistics indicate that the households in the study area have a low level of education (44 percent are illiterate, and only 6 percent have a university degree) but have lived there for a long time (usually more than 10 years) and thus have substantial knowledge of the local ecology. Most

households earn their livelihoods from pure pastoralism (55%) or agropastoralism (30%), while a minority of people work in business or other non-agricultural activities (16%). This situation makes many households vulnerable, as they are highly dependent on climate-sensitive resources.

Climate analysis revealed that monthly and seasonal precipitation is highly irregular (with the coefficient of variation frequently exceeding 100%), yet the long-term annual precipitation trend is insignificant, confirming that this variability stems from seasonal characteristics rather than an annual decrease. In contrast, temperatures (minimum, maximum, and average) exhibit a clear and significant warming trend. This warming is associated with reduced spring precipitation and a decrease in annual precipitation relative to maximum temperatures.

Drought indicators (precipitation concentration index, standardized precipitation index, and standardized precipitation-evapotranspiration index) reveal high precipitation concentration and recurrent droughts, predominantly characterized by mild events with occasional severe/extreme occurrences. Households strongly perceive these changes, with perception and vulnerability shaped by multiple factors, notably difficulties in water access and service utilization. Meanwhile, coping (reducing livestock, productive safety net programs, casual labour, reduced daily food intake) and adaptation (seasonal migration, drought-resistant varieties, livestock and non-agricultural diversification, soil and water conservation) are multidimensional and driven by all five forms of livelihood capital.

8. APPENDICES

Appendix 1: References

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Appendix 2: Questionnaire prepared for household survey, focus group discussion and key informants' interview

Appendix 2.1: Questionnaire prepared for household survey

Instruction

Please provide accurate information about yourself by putting / X in the blanks or circling your choice for close-ended questions. Please express your opinion in the designated space for open-ended questions.

General information about household respondent

District Name ---------- Kebele _____

1. Sex male ☐ female ☐
2. Marital status 1= married☐ 2= unmarried ☐ 3= widowed ☐ 4= divorced ☐
3. What is total number of family members in your household**:** Total_____ Male _____ Female_____
4. How long have you lived in this village?
   1= less than five years ☐ 2= 5-10 years ☐ 3= 11-15 years ☐ 4= over 15 years ☐
5. What is the educational level for the household head?
   1= Unable to read and write ☐ 3 = Able to read and write ☐
   2= Religious education ☐ 4 = Formal education (please indicate in years): ------
6. Have you participated in any skill development or training programs? 1= yes 2 = no
7. If your answer of question 9 is yes, how often do you attend workshops or training related to your work or livelihood?
   1. At least once a month 2. At least once a year 3. Never attend
8. Do household members have access to health facilities? 1= yes 2 = no
9. If your answer of question 14 is yes, how would you rate the overall health facility service?
   1. Excellent 2. Good 3. Fair 4. Poor
10. What is your primary source of livelihood? (You may select more than one occupation.)
    A. Livestock herding ☐ C. Crop farming ☐
    B. Trade /Business man ☐ D. Wage labor ☐
    E. If others specify _____

11. How many years of experience do you have in your primary livelihood occupation?

    _____

12. What is/are your main source(s) of household income (in order of importance)?

    1. Crop sale 2. Livestock sale 3. Off-farm income 4. Relatives' support

    5. Community support 6. Others, specify _____

13. What was the estimated total annual income of the household in 2023/2024 (2016 E.C)? ETB _____ ($US_____)

14. What is your household average expenditure per month? Amount in ETB _____($US_____)

15. Do you currently have any savings? 1= Yes 2 = No

16. If your answer for question 24 is yes, how often do you save money?

    1. Weekly 2. Monthly 3. Quarterly

17. What motivates you to save money? (Select all that apply)

    1. Emergencies 4. Business investment
    2. Education 5. Buying assets (e.g., land, house, car)
    3. Retirement 6. Other (please specify): _____

18. Have you ever taken credit from any formal or informal institution? 1= Yes 2 = No

19. If your answer to Question 29 is "Yes," what was the purpose of the loan? (Circle the appropriate option)

    1. Personal borrowing for household consumption
    2. To start a new business
    3. To expand an existing business
    4. To construct a residence
    5. Other (specify: _____)

20. If your answer to Question 29 is "Yes," what was the amount borrowed? (Amount: __ETB/USD)

21. Do you receive financial support or remittances from family members or friends living outside this community? 1. Yes 2. No

22. If yes, how much did you receive remittance? (1) <2,000 ETB (2) 2,000–5,000 ETB (3) 6,000–10,000 ETB (4) >10,000ETB

23. Are you currently enrolled in any insurance program? 1. Yes 2. No

24. If your answer for question 37 yes, how much (ETH birr/USD) have you spent on insurance over the past 12 months? (Amount: _____ / _____ETB/USD)

25. Livestock Production and Marketing in the last 12 months

code	Livestock name	Have household raised or produced any of the following animals in the last 12 months? 1= Yes 0 = No	Number owned currently	How many did you sale	Average selling price
01	Cow				
02	Heifer				
03	Calves				
04	Ox				
05	Bull				
06	Goat				
07	Sheep				
08	Pigs				
09	Donkey				
10	Mule				
11	Horse				
12	Camel				

26. Have any livestock died in recent years due to climate change or other factors?

1.Yes 2. No

27. If your answer for question 42 is "Yes," what was the main cause of livestock death?

01= diseases 02 = drought 03 = floods

04= conflicts 05 = predation 06= slaughter

28. Do you, or any your household members, belong to any pastoral area cooperatives?

1=yes 2= No

29. If question 44 yes, what are the major activities of the cooperatives? _____

30. Do you have access to up-to-date information on weather/climate? 1= yes 2= No

31. If you answered "Yes" to Question 46, please indicate your main sources of climate information and rate your satisfaction with each on a scale of 1 (very unsatisfactory) to 5 (very satisfactory).

Source information	Tick the box		Rate of satisfaction				
	Yes	No	01	02	03	04	05
1= Public media (newspaper, radio, TV)							
2= The Internet (email, website, etc)							
3= Fellow Farmers/pastoralist							

4= Community meeting							
5= Cooperative leaders							
6= non-governmental organization							
7= Kebele leaders							
8= Other (please Specify) _____							

32. If your answer to Question 46 is "Yes," what type of climate or weather information or forecasts do you access?
    1. Short-range (day to week) forecast
    2. Long-range/seasonal forecast
    3. Other (specify): _____

33. If your answer to Question 46 is "Yes," how often do you access each of the forecasts?
    1. Regularly (daily/weekly) 3. Monthly
    2. On-demand basis 4. Other (specify): _____

34. In the past 12 months, have you been visited by the Veterinary extension service worker?
    1= yes 2= No

35. If your answer to Question 50 is "Yes," how many times have you interacted with a veterinary extension service worker in the past 12 months? 1. Once 2. Twice 3. More than twice

36. What are the main feed sources for your livestock?

1. Open rangelands 3. Private enclosure
2. Communal enclosure 4. Hay and feed supplements
5. Other (please specify): _____

37. Do you own private pastureland or an enclosure? 1. Yes 2. No

38. If your answer to Question 53 is "Yes," fill the following table

S.L	Type of natural asset	1= Yes 0=No	Size of land in hectare	How do you own the piece of land that you are currently have access to? 1= Inherited, 2=Allocated to by the government, 3= Bought, 4= Other (Specify
1	Farm land			
2	Range land			

39. Do you have reliable access to water resources in your locality?
    1. Yes 2. No

40. If your answer to Question 61 is "Yes," fill the following table

Code	Type of Infrastructure	1= Accessible 0=in accessible	Distance in your home kilometer
	Water Availability		
1	For human		
2	For livestock		

41. Have you access the following physical capital asset infrastructure listed below?

Code	Type of Infrastructure	1= Accessible 0=in accessible	Distance from your home (kilometer)
1	All weather Road		
2	Weakly Markets		
3	Electricity		
4	Irrigation system		
5	School		
6	Clinics /hospitals		
7	Pastoral training Centre		
8	Veterinary Health Post		

Part II. Climate change Perception and Vulnerability

42. Have you noticed any changes in the climate in this area? 1) Yes 2) No

43. If your answer to Q64 is "Yes," please specify the changes you have observed and their frequencies over time.

Code	Climate variable	Is change observed?	
		Yes	No
1	Increase in average temperature		
2	Changes in temperature Seasonal Patterns		
3	Reduced temperature variability between day and night		
4	Extended periods of high temperatures		
5	Increased/decreased frequency of rainfall.		
6	Irregular distribution of rainfall within the season		
7	Delayed or earlier onset of rainy seasons.		
8	Shortened or prolonged rainy seasons		
9	Drying up of grazing land		
10	Reduction in water levels in rivers, or wells		
11	Death of livestock		
12	Decline of crop production		

44. Do you think climate variability and change has affected the social life of pastoral communities? 1) Yes 2) No

45. If you answered "Yes" to question 66, what challenges have you faced due to climate variability and change? (***Remark***: it is possible to select more than one***)***

Problems	Yes	No	Problems	Yes	No
Crop failure			Increases flood disaster		
Poor livestock productivity			Loss of income		
Loss of pasture land			Increase deforestation		
Loss of agricultural land			High intensity wind		
Severe soil erosion			Drying of vegetation		
Shortage of water			Drying of streams and rivers		

Part III. Choice of Adoption /Coping strategy

46. If you answered "Yes" to question 66, do you currently implement any adaptation strategies to minimize the long-term effects of climate change? 1) Yes 2) No

47. If you answered "Yes" to question 68, is your household engaged in any of the following long-term climate change adaptation strategies or activities?

Code	Type of livelihood activities	1= if participate/involved 0 = not participate
01	Seasonal livestock migration	
02	Raising drought-tolerant livestock	
03	Herd diversification	
04	Nonfarm diversification	
05	Soil and water conservation	
06	Others	

Remark: it is possible to select more than one

48. If you answered "Yes" to question 66, do you currently implement any coping strategies to minimize the short-term effects of climate change? 1) Yes 2) No

49. If you answered "Yes" to question 70, is your household engaged in any of the following Short-term climate change coping strategies or activities?

Code	Type of livelihood activities	1= if participate/involved 0 = otherwise
01	Herd destocking	
02	Productive Safety Net Program	
03	Short term causal labor	

04	Reduction in daily food intake	
05	Others	

Remark: it is possible to select more than one

50. Do you believe that there are constraints or barriers to adaptation and Copping strategies?

    1. Yes 2. No

51. If your answer for question 72 is "Yes," What factors do you believe influence your ability to adapt and cope with climate impacts? (Circle your answer**)**

    1. Lack of climate information 4. Financial constraints
    2. Labour shortages 5. Lack of skills
    3. Limited education 6. Absence of alternative options
    7. Others (please specify): _____

Appendix 2.2: Guiding questions for focus group discussion

1. How do you perceive changes in the climate over the past few years in your area?
2. What specific weather patterns or changes have you noticed? (e.g., rainfall, temperature, droughts, and floods)
3. How have these climates changes affected your daily life and livelihood activities, such as livestock herding or farming?
4. Have you noticed seasonal changes in rainfall? How does this affect grazing areas?
5. How has climate change affected the availability of water for domestic and livestock use? Are there any changes in the availability of water sources?
6. How do you manage water scarcity, especially during drought periods?
7. What strategies do you use to cope with the challenges posed by climate change?
8. Are there any community-level practices /strategies in place to cope with climate-related stresses?
9. How do elders or traditional knowledge help in adapting to climate change?
10. What recommendations would you give to improve the Adaptation and coping strategies for climate variability in your community? Are there any innovative ideas that could help?

Appendix 2.3: Guiding question for key informant's interview

1. How has the local climate changed over the years (e.g., rainfall, temperature, droughts)?
2. What is the most significant climate-related challenges faced by pastoralists (e.g., droughts, floods, water scarcity)?

3. Are there cultural or social practices influencing how households perceive and respond to climate vulnerability?
4. What adaptation and coping strategies do pastoralists use to cope with climate challenges?
5. Are there traditional or indigenous practices that help manage climate risks?
6. What actions are critical to reduce climate vulnerability in the area?

Appendix 2.4: Personal observation matrix

SN	What to observe	Where	Method of Observation
1	Adoption Strategies employed by the household	Anywhere in the community	Direct Observation
2	Level of the household participation on the existing adoption strategies of the area	Six kebeles in the study area	Direct observation
3	Factor affecting adoption strategies in the community	Six kebeles in the study area	Direct observation
4	Community culture toward work to improve livelihoods	Anywhere in the community	Direct observation
5	Perceptions of climate change and variability factors	Six kebeles in the study area	Direct observation
6	Impacts of climate change on key pastoral resource (e.g., livestock, grazing lands, water resources)	Six kebeles in the study area	Direct observation and discussion
7	Signs of climate-related vulnerabilities (e.g., drought effects, pasture degradation)	Anywhere in the community	Direct observation
8	Community practices and responses to climate variability (e.g., migration, water harvesting)	Six kebeles in the study area	Direct observation and discussion
9	Availability and utilization of resources during climate crises (e.g., water points, fodder)	Six kebeles in the study area	Direct observation
10	Evidence of alternative livelihood practices (e.g., small businesses, wage labour)	Six kebeles in the study area	Direct observation

Appendix 3: Assessment of Household Perception statistics

Appendix 3.1: The binary logistic regression model *for determinants of Perception*

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Sex of the household	-.451	.409	1.216	1	.270	.637
	Family size	.570	.247	5.308	1	.021	1.768
	level of Education	-.598	.141	17.949	1	<.001	.550
	Age of the house holds	.167	.074	5.146	1	.023	1.182
	Access to health facility	.932	.334	7.776	1	.005	2.540
	Access to saving	.613	.320	3.675	1	.055	1.845
	Mebers of pastoral area Cooperative	-.494	.354	1.950	1	.163	.610
	Access to up to date weather information	-.574	.438	1.717	1	.190	.563
	Access to Veterinary Extension service	-.766	.348	4.852	1	.028	.465
	Size of Pasture land (Ha)	.456	.202	5.090	1	.024	1.578
	Distance of weekly market from home (ha)	-.347	.201	2.981	1	.084	.707
	grazing land condition	2.170	.647	11.256	1	<.001	8.756
	Crop Production	.786	.342	5.271	1	.022	2.195
	livestock	1.555	.435	12.760	1	<.001	4.735
	Livelihood diversification of household	-.767	.401	3.665	1	.056	.464
	Constant	-8.549	1.994	18.378	1	<.001	.000

a. Variable(s) entered on step 1: Sex of the household, Family size, level of Education, Age of the house holds, Access to health facility, Access to saving, Mebers of pastoral area Cooperative , Access to up to date weather information, Access to Veterinary Extension service, Size of Pasture land (Ha), Distance of weekly market from home (ha), grazing land condition, Crop Production, livestock, Livelihood diversification of household.

Classification Table[a,b]

			Predicted		
			Household climate change perception		
	Observed		No	yes	Percentage Correct
Step 0	Household climate change perception	No	0	94	.0
		yes	0	257	100.0
	Overall Percentage				73.2

a. Constant is included in the model.

b. The cut value is .500

Appendix 3.2: **Diagnostic test for Household Perception model (**Omnibus test of model coefficients (LR χ^2), log-likelihood minus 2 (2L), pseudo-R^2 (Cox-Snell, Nagelkerke, McFadden) and Hosmer-Lemm test (H-L)).

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	1.006	.121	69.624	1	<.001	2.734

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	139.559	15	<.001
	Block	139.559	15	<.001
	Model	139.559	15	<.001

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	268.349[a]	.328	.477

a. Estimation terminated at iteration number 6 because parameter estimates changed by less than .001.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	9.264	8	.320

Contingency Table for Hosmer and Lemeshow Test

		Household climate change perception = No		Household climate change perception = yes		
		Observed	Expected	Observed	Expected	Total
Step 1	1	32	31.453	3	3.547	35
	2	21	21.309	14	13.691	35
	3	17	13.676	18	21.324	35
	4	5	9.241	30	25.759	35
	5	8	6.636	27	28.364	35
	6	4	4.534	31	30.466	35
	7	2	3.084	33	31.916	35
	8	1	2.165	35	33.835	36
	9	2	1.299	33	33.701	35
	10	2	.603	33	34.397	35

Appendix 4: Assessment of vulnerability statistics

Appendix 4.1: **Communalities of livelihood capital asset vulnerability indicators**

Communalities

	Initial	Extraction
level of Education	1.000	.822
Training participation	1.000	.684
Health status of household	1.000	.543
Livelihood Experience of house holds	1.000	.857
Total income of HHs	1.000	.828
Total Expenditure of HHs	1.000	.835
Access to saving	1.000	.581
Access to credit	1.000	.535
Received remmitance from family or friend	1.000	.567
Access to insurance program	1.000	.600
Tropical Livestock unit	1.000	.637
Mebers of pastoral area Cooperative	1.000	.709
Access to up to date weather information	1.000	.639
Access to Veternary Extension service	1.000	.509
Amount of Pasture land (Ha)	1.000	.757
Amount of farm land (Ha)	1.000	.762
Distance of potable water for human being from home	1.000	.861
Distance of livestock water from home	1.000	.869
Distance of all weather road from home (ha)	1.000	.616
Distance of weekly market from home (ha)	1.000	.696
Access to Electricity	1.000	.782
Distance of School from home (ha)	1.000	.684
Distance of all Health centers from home (ha)	1.000	.876
Distance of Pastoral training centers from home (ha)	1.000	.904
Distance of Vetarnary health post from home (ha)	1.000	.918

Extraction Method: Principal Component Analysis.

Appendix 4.2 Factor score for the first principal component analysis

Component Matrix[a]

	Component								
	1	2	3	4	5	6	7	8	9
level of Education	.017	-.153	.039	.211	-.037	.543	-.223	-.376	-.514
Training participation	-.573	.274	.113	-.133	.074	-.314	.281	.024	-.257
Health status of household	.301	-.001	.328	-.305	.304	-.043	-.122	.325	-.193
Livelihood Experience of house holds	.575	.131	-.540	.317	.195	-.009	.270	-.050	-.060
Total income of HHs	.379	.119	.606	.278	-.366	.084	.091	-.233	.148
Total Expenditure of HHs	.492	.209	.475	.402	-.285	.044	.163	-.167	.158
Access to saving	-.056	.432	.228	-.317	.373	.263	.019	-.122	.127
Access to credit	-.446	.488	.130	.047	.240	.032	.101	-.069	.067
Received remmittance from family or friend	-.355	.161	.201	.003	.212	-.046	.530	-.212	-.041
Access to insurance program	-.262	-.209	.434	.190	.440	-.205	.137	-.090	.020
Tropical Livestock unit	-.391	-.036	-.055	-.157	-.176	.158	.338	.039	.533
Mebers of pastoral area Cooperative	-.622	.488	.066	-.168	.013	-.112	.113	.015	-.160
Access to up to date weather information	-.164	.014	.158	-.518	-.055	.486	-.064	-.061	.267
Access to Veternary Extension service	-.203	.218	-.143	.209	-.393	-.403	-.151	.092	.088
Amount of Pasture land (Ha)	-.146	.560	.331	.338	.260	.156	-.045	.319	.047
Amount of farm land (Ha)	.029	.453	.124	.509	.040	.399	-.049	.344	.027
Distance of potable water for human being from home	.664	.516	-.158	-.236	-.093	.089	.132	-.149	-.129
Distance of livestock water from home	.802	.354	-.056	-.263	.021	-.020	.113	-.014	-.115
Distance of all weather road from home (ha)	-.004	.732	-.252	.011	-.095	-.044	-.024	.039	-.057
Distance of weekly market from home (ha)	.610	.373	-.153	-.257	-.214	-.044	.137	-.168	-.014
Access to Electricity	-.527	-.590	-.253	.059	-.152	.123	.216	-.042	.050
Distance of School from home (ha)	.068	.612	-.316	-.160	-.013	-.047	-.346	-.029	.239
Distance of all Health centers from home (ha)	.888	-.114	.209	-.113	.029	-.115	.019	.028	.049
Distance of Pastoral training centers from home (ha)	.810	-.267	.368	-.043	.129	-.144	.000	.043	.013
Distance of Vetarnary health post from home (ha)	.859	-.223	.290	-.101	.080	-.148	.012	.018	.084

Extraction Method: Principal Component Analysis.
a. 9 components extracted.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.706
Bartlett's Test of Sphericity	Approx. Chi-Square	1794.917
	df	406
	Sig.	<.001

Appendix 4.3: Marginal effects of Ordered logistic model for determinants of vulnerability

Marginal effect for low vulnerability

```
Average marginal effects                        Number of obs     =        351
Model VCE    : Robust

Expression   : Pr(vulnerablity_level==1), predict(outcome(1))
dy/dx w.r.t. : edu_years training livexp Healthstatus acc_saving acc_credit remittance insurance tlu coop_member
               weather_info vet_extension rangeland_ha farm_ha potable_access livestock_water_access dist_road_km
               dist_market_km electricity dist_health_km dist_ptc_km
```

	Delta-method dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
edu_years	.0098406	.0042126	2.34	0.019	.001584	.0180971
training	.1070221	.0322382	3.32	0.001	.0438364	.1702077
livexp	-.0106887	.0017392	-6.15	0.000	-.0140975	-.00728
Healthstatus	-.3117298	.0284214	-10.97	0.000	-.3674348	-.2560249
acc_saving	.0500916	.0311247	1.61	0.108	-.0109116	.1110949
acc_credit	.0980349	.0351774	2.79	0.005	.0290885	.1669814
remittance	.1294252	.0328323	3.94	0.000	.065075	.1937754
insurance	.1199253	.0473126	2.53	0.011	.0271943	.2126564
tlu	-.0106733	.0056613	-1.89	0.059	-.0217691	.0004226
coop_member	.071396	.033654	2.12	0.034	.0054354	.1373566
weather_info	.0841657	.0383701	2.19	0.028	.0089617	.1593698
vet_extension	.0598551	.0331347	1.81	0.071	-.0050877	.124798
rangeland_ha	-.0243402	.0157827	-1.54	0.123	-.0552737	.0065934
farm_ha	.0040568	.0129627	0.31	0.754	-.0213496	.0294632
potable_access	-.0129463	.0115566	-1.12	0.263	-.0355968	.0097042
livestock_water_access	.0191248	.0110051	1.74	0.082	-.0024449	.0406945
dist_road_km	-.0356996	.0069916	-5.11	0.000	-.0494028	-.0219964
dist_market_km	-.0048182	.0077062	-0.63	0.532	-.0199222	.0102857
electricity	-.0316347	.0656451	-0.48	0.630	-.1602966	.0970273
dist_health_km	-.0043721	.0035099	-1.25	0.213	-.0112513	.0025071
dist_ptc_km	-.033738	.0053232	-6.34	0.000	-.0441712	-.0233047

Marginal effect for moderate vulnerability

```
Average marginal effects                        Number of obs     =        351
Model VCE    : Robust

Expression   : Pr(vulnerablity_level==2), predict(outcome(2))
dy/dx w.r.t. : edu_years training livexp Healthstatus acc_saving acc_credit remittance insurance tlu coop_member
               weather_info vet_extension rangeland_ha farm_ha potable_access livestock_water_access dist_road_km
               dist_market_km electricity dist_health_km dist_ptc_km
```

	Delta-method dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
edu_years	-.0017552	.000823	-2.13	0.033	-.0033682	-.0001422
training	-.019089	.0076195	-2.51	0.012	-.0340229	-.004155
livexp	.0019065	.0004737	4.02	0.000	.000978	.002835
Healthstatus	.0556016	.010221	5.44	0.000	.0355689	.0756343
acc_saving	-.0089346	.0057223	-1.56	0.118	-.02015	.0022808
acc_credit	-.017486	.0073329	-2.38	0.017	-.0318581	-.0031138
remittance	-.0230849	.0073335	-3.15	0.002	-.0374584	-.0087114
insurance	-.0213904	.0090879	-2.35	0.019	-.0392025	-.0035784
tlu	.0019037	.0010401	1.83	0.067	-.0001349	.0039424
coop_member	-.0127345	.0068286	-1.86	0.062	-.0261184	.0006494
weather_info	-.0150122	.0076771	-1.96	0.051	-.0300591	.0000347
vet_extension	-.010676	.0059401	-1.80	0.072	-.0223184	.0009663
rangeland_ha	.0043414	.0030437	1.43	0.154	-.0016241	.010307
farm_ha	-.0007236	.0023446	-0.31	0.758	-.005319	.0038718
potable_access	.0023092	.0019915	1.16	0.246	-.0015941	.0062124
livestock_water_access	-.0034112	.0019453	-1.75	0.079	-.0072238	.0004014
dist_road_km	.0063675	.0018908	3.37	0.001	.0026616	.0100735
dist_market_km	.0008594	.0013794	0.62	0.533	-.0018441	.0035629
electricity	.0056425	.0120858	0.47	0.641	-.0180453	.0293303
dist_health_km	.0007798	.0006477	1.20	0.229	-.0004896	.0020493
dist_ptc_km	.0060177	.0016803	3.58	0.000	.0027243	.009311

Marginal effect for high vulnerability

```
Average marginal effects                        Number of obs     =        351
Model VCE    : Robust

Expression   : Pr(vulnerablity_level==3), predict(outcome(3))
dy/dx w.r.t. : edu_years training livexp Healthstatus acc_saving acc_credit remittance insurance tlu coop_member
               weather_info vet_extension rangeland_ha farm_ha potable_access livestock_water_access dist_road_km
               dist_market_km electricity dist_health_km dist_ptc_km
```

	Delta-method dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
edu_years	-.0080853	.0034747	-2.33	0.020	-.0148956	-.0012751
training	-.0879331	.0256692	-3.43	0.001	-.1382439	-.0376224
livexp	.0087823	.0014744	5.96	0.000	.0058925	.011672
Healthstatus	.2561283	.0282297	9.07	0.000	.2007991	.3114574
acc_saving	-.041157	.0257097	-1.60	0.109	-.091547	.0092329
acc_credit	-.080549	.0288064	-2.80	0.005	-.1370084	-.0240895
remittance	-.1063403	.0272739	-3.90	0.000	-.1597962	-.0528844
insurance	-.0985349	.0393663	-2.50	0.012	-.1756914	-.0213784
tlu	.0087695	.0046978	1.87	0.062	-.0004381	.0179772
coop_member	-.0586615	.0273497	-2.14	0.032	-.1122659	-.0050571
weather_info	-.0691536	.0313522	-2.21	0.027	-.1306027	-.0077044
vet_extension	-.0491791	.0276079	-1.78	0.075	-.1032896	.0049314
rangeland_ha	.0199987	.0128738	1.55	0.120	-.0052335	.045231
farm_ha	-.0033332	.0106227	-0.31	0.754	-.0241532	.0174868
potable_access	.0106371	.0096189	1.11	0.269	-.0082156	.0294899
livestock_water_access	-.0157136	.0091865	-1.71	0.087	-.0337189	.0022917
dist_road_km	.029332	.0056349	5.21	0.000	.0182878	.0403763
dist_market_km	.0039588	.0063385	0.62	0.532	-.0084643	.016382
electricity	.0259922	.0536108	0.48	0.628	-.0790831	.1310675
dist_health_km	.0035923	.0028828	1.25	0.213	-.0020578	.0092424
dist_ptc_km	.0277203	.0041801	6.63	0.000	.0195275	.0359131

Appendix 5: Marginal effects estimate of Adaptation and Coping strategies statistics

Diagnostic test

Multicollinearity

Variable	VIF	1/VIF
POTABLEWATER	1.92	0.521314
DIST_MARKE~q	1.80	0.555034
ELECTRICITY	1.52	0.656480
DIS_HEALTH~R	1.43	0.698913
SIZEPASTUR~D	1.37	0.727691
FARMLAND	1.27	0.788036
MEMBEROFCO~E	1.18	0.845499
ln_livestock	1.12	0.889820
ACCINFORMA~N	1.11	0.903890
ACCSSAVING	1.11	0.904511
ACCCREDIT	1.10	0.906386
EDUHHS	1.10	0.908626
LIVELIHOOD~E	1.10	0.912975
ACCINSURANCE	1.08	0.928975
ACC_VET_EX~N	1.07	0.932339
HEALTHSTATUS	1.07	0.936356
TRAINING_P~N	1.05	0.947873
Mean VIF	1.26	

Correlation coefficient

	EDUHHS	TRAINI~N	HEALTH~S	LIVELI~E	ACCSSA~G	ACCCRE~T	ACCINS~E	ln_liv~k	MEMBER~E	ACCINF~N	ACC_VE~N
EDUHHS	1.0000										
TRAINING_P~N	0.0691	1.0000									
HEALTHSTATUS	0.1189	-0.0292	1.0000								
LIVELIHOOD~E	-0.1296	-0.1323	-0.0258	1.0000							
ACCSSAVING	0.0267	0.0741	0.0328	0.0014	1.0000						
ACCCREDIT	0.0464	0.0229	-0.0009	-0.0637	-0.1336	1.0000					
ACCINSURANCE	-0.0678	0.0868	-0.0273	0.0353	0.0553	0.0204	1.0000				
ln_livestock	-0.1155	0.0180	-0.0178	0.0803	0.1316	-0.0491	-0.0215	1.0000			
MEMBEROFCO~E	-0.1214	0.0454	-0.1068	-0.0421	0.0445	0.1270	0.0964	0.0597	1.0000		
ACCINFORMA~N	0.0097	0.0881	0.0073	-0.0601	0.1320	0.0976	-0.0027	0.0474	0.1944	1.0000	
ACC_VET_EX~N	-0.1078	0.0469	-0.0339	-0.0018	0.0152	-0.0037	0.0238	0.1980	0.0951	0.0263	1.0000
SIZEPASTUR~D	-0.1252	0.0124	0.1391	-0.0025	0.0966	0.0692	0.0923	0.1685	0.0400	-0.0394	0.0440
FARMLAND	-0.0748	0.0238	-0.0298	0.1616	0.0730	-0.1022	0.0744	0.0978	-0.0313	-0.1028	0.0615
POTABLEWATER	-0.0343	-0.0897	0.0309	0.1288	0.0557	-0.0000	-0.1783	0.0924	-0.1019	-0.0751	0.0070
DIST_MARKE~q	0.0006	-0.0734	0.0405	0.0827	-0.0356	-0.0565	-0.1566	0.1215	-0.1440	-0.0363	-0.0206
ELECTRICITY	-0.0098	0.0900	-0.0965	-0.0717	-0.0756	-0.0059	0.0638	-0.0661	0.0706	0.1240	0.0856
DIS_HEALTH~R	-0.0353	-0.0389	0.0615	0.1022	0.0627	-0.1420	-0.0920	0.0594	-0.2683	-0.0870	0.0004

	SIZEPA~D	FARMLAND	POTABL~R	DIST_M~q	ELECTR~Y	DIS_HE~R
SIZEPASTUR~D	1.0000					
FARMLAND	0.3836	1.0000				
POTABLEWATER	0.1211	0.0487	1.0000			
DIST_MARKE~q	0.0643	-0.0133	0.5944	1.0000		
ELECTRICITY	-0.2713	-0.1413	-0.4355	-0.4739	1.0000	
DIS_HEALTH~R	0.0158	0.0262	0.4750	0.3492	-0.2706	1.0000

Appendix 5.1: Multivariate Probit model for Adaptation strategies

SLM: Seasonal livestock migration

	Delta-method				
	dy/dx	Std. Err.	z	P>|z|	[95% Conf. Interval]
EDUHHS	.0094669	.0051225	1.85	0.065	-.000573	.0195068
TRAINING_PARTICIPATION	-.032494	.0472863	-0.69	0.492	-.1251735	.0601855
HEALTH_STATUS	.0585244	.0421369	1.39	0.165	-.0240624	.1411112
LIVELIHOOD_EXPRIENCE	.0053243	.0022298	2.39	0.017	.000954	.0096946
ACCSSAVING	-.0706012	.0433267	-1.63	0.103	-.15552	.0143176
ACCCREDIT	-.0106525	.0429013	-0.25	0.804	-.0947374	.0734324
ACCINSURANCE	-.0038664	.0627499	-0.06	0.951	-.1268539	.1191211
LIVESTOCK	.3168387	.0505847	6.26	0.000	.2176946	.4159829
MEMBEROFCOPPERATIVE	-.0747264	.0429191	-1.74	0.082	-.1588464	.0093936
ACCINFORMATION	.0374902	.0528893	0.71	0.478	-.0661709	.1411513
ACC_VET_EXTENSION	-.0143668	.0443408	-0.32	0.746	-.1012731	.0725396
SIZEPASTURELAND	.0764451	.0292971	2.61	0.009	.0190238	.1338664
FARMLAND	.0276155	.0203156	1.36	0.174	-.0122024	.0674334
POTABLEWATER	-.0138312	.0073841	-1.87	0.061	-.0283037	.0006414
DIST_MARKET_sq	-.0001251	.0004938	-0.25	0.800	-.001093	.0008428
ELECTRICITY	-.0410401	.0518228	-0.79	0.428	-.142611	.0605308
DIS_HEALTH_CENTER	.0084614	.005174	1.64	0.102	-.0016795	.0186022

DTS: Drought tolerance species

	Delta-method dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
EDUHHS	.0074035	.0054552	1.36	0.175	-.0032884	.0180955
TRAINING_PARTICIPATION	.0286733	.0506474	0.57	0.571	-.0705938	.1279404
HEALTH_STATUS	-.0270732	.0464677	-0.58	0.560	-.1181484	.0640019
LIVELIHOOD_EXPRIENCE	.0022739	.0021748	1.05	0.296	-.0019886	.0065364
ACCSSAVING	-.0288382	.0446809	-0.65	0.519	-.1164112	.0587348
ACCCREDIT	-.072833	.0457817	-1.59	0.112	-.1625636	.0168975
ACCINSURANCE	-.0976559	.0735595	-1.33	0.184	-.2418298	.046518
LIVESTOCK	.2180508	.056414	3.87	0.000	.1074814	.3286202
MEMBEROFCOPPERATIVE	.0203609	.0456128	0.45	0.655	-.0690384	.1097603
ACCINFORMATION	-.1185055	.0571918	-2.07	0.038	-.2305993	-.0064117
ACC_VET_EXTENSION	-.015448	.0460421	-0.34	0.737	-.1056889	.0747929
SIZEPASTURELAND	.0733275	.0300425	2.44	0.015	.0144453	.1322096
FARMLAND	.031821	.0195181	1.63	0.103	-.0064337	.0700757
POTABLEWATER	.0197449	.008656	2.28	0.023	.0027795	.0367104
DIST_MARKET_sq	-.0004417	.0005114	-0.86	0.388	-.0014439	.0005605
ELECTRICITY	-.2392257	.0512023	-4.67	0.000	-.3395804	-.1388709
DIS_HEALTH_CENTER	.0099368	.0061476	1.62	0.106	-.0021123	.0219859

HD: Herd diversification

	Delta-method dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
EDUHHS	-.0039554	.0056053	-0.71	0.480	-.0149415	.0070308
TRAINING_PARTICIPATION	.0044795	.0536488	0.08	0.933	-.1006702	.1096291
HEALTH_STATUS	.0009363	.0485754	0.02	0.985	-.0942697	.0961423
LIVELIHOOD_EXPRIENCE	.0015074	.0022477	0.67	0.502	-.002898	.0059128
ACCSSAVING	.096797	.0471678	2.05	0.040	.0043499	.1892442
ACCCREDIT	.061938	.0494496	1.25	0.210	-.0349814	.1588575
ACCINSURANCE	-.0233178	.0751295	-0.31	0.756	-.1705689	.1239333
LIVESTOCK	-.1435008	.0665631	-2.16	0.031	-.273962	-.0130395
MEMBEROFCOPPERATIVE	.1182356	.0478649	2.47	0.014	.0244222	.2120491
ACCINFORMATION	.0408698	.0564864	0.72	0.469	-.0698416	.1515812
ACC_VET_EXTENSION	.1155041	.048362	2.39	0.017	.0207164	.2102918
SIZEPASTURELAND	-.0125773	.0273557	-0.46	0.646	-.0661934	.0410388
FARMLAND	.0388711	.0213129	1.82	0.068	-.0029014	.0806437
POTABLEWATER	.003856	.0091938	0.42	0.675	-.0141636	.0218756
DIST_MARKET_sq	-.0001285	.0005323	-0.24	0.809	-.0011718	.0009148
ELECTRICITY	-.0687486	.0610815	-1.13	0.260	-.1884662	.050969
DIS_HEALTH_CENTER	-.0032158	.0053056	-0.61	0.544	-.0136147	.0071831

NFD: Nonfarm diversification

	Delta-method dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
EDUHHS	-.0065482	.0052557	-1.25	0.213	-.0168491	.0037527
TRAINING_PARTICIPATION	-.0255265	.0483283	-0.53	0.597	-.1202481	.0691952
HEALTH_STATUS	-.0329686	.0447473	-0.74	0.461	-.1206716	.0547344
LIVELIHOOD_EXPRIENCE	-.0029622	.0020687	-1.43	0.152	-.0070168	.0010925
ACCSSAVING	.133143	.0449254	2.96	0.003	.0450907	.2211952
ACCCREDIT	.018653	.0454737	0.41	0.682	-.0704738	.1077798
ACCINSURANCE	.1256487	.0775973	1.62	0.105	-.0264393	.2777367
LIVESTOCK	-.0259782	.0629236	-0.41	0.680	-.1493062	.0973498
MEMBEROFCOPPERATIVE	-.0405597	.0459119	-0.88	0.377	-.1305454	.049426
ACCINFORMATION	-.0133011	.0540286	-0.25	0.806	-.1191953	.0925931
ACC_VET_EXTENSION	.1057638	.0461273	2.29	0.022	.015356	.1961716
SIZEPASTURELAND	-.0081444	.0257031	-0.32	0.751	-.0585214	.0422327
FARMLAND	.0326633	.0174471	1.87	0.061	-.0015323	.066859
POTABLEWATER	.0178427	.0083494	2.14	0.033	.0014782	.0342073
DIST_MARKET_sq	-.0018785	.0005102	-3.68	0.000	-.0028785	-.0008785
ELECTRICITY	.1172079	.058924	1.99	0.047	.001719	.2326968
DIS_HEALTH_CENTER	.0221984	.0055764	3.98	0.000	.0112688	.033128

SWC: Soil and water conservation

	Delta-method dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
EDUHHS	-.0098725	.0062433	-1.58	0.114	-.0221091	.0023642
TRAINING_PARTICIPATION	-.0156554	.0602782	-0.26	0.795	-.1337986	.1024878
HEALTH_STATUS	-.0587922	.0546888	-1.08	0.282	-.1659804	.0483959
LIVELIHOOD_EXPRIENCE	.0051899	.0025237	2.06	0.040	.0002435	.0101363
ACCSSAVING	.0678769	.0535546	1.27	0.205	-.0370882	.172842
ACCCREDIT	-.0353954	.0547689	-0.65	0.518	-.1427404	.0719496
ACCINSURANCE	.0351134	.0835436	0.42	0.674	-.1286291	.1988559
LIVESTOCK	-.0444328	.0746714	-0.60	0.552	-.1907861	.1019205
MEMBEROFCOPPERATIVE	.0353711	.0547151	0.65	0.518	-.0718685	.1426107
ACCINFORMATION	-.0018215	.0633215	-0.03	0.977	-.1259295	.1222864
ACC_VET_EXTENSION	-.068768	.0550343	-1.25	0.211	-.1766332	.0390972
SIZEPASTURELAND	.0052048	.0303369	0.17	0.864	-.0542544	.064664
FARMLAND	-.0434007	.0223437	-1.94	0.052	-.0871935	.0003922
POTABLEWATER	-.0184133	.0097756	-1.88	0.060	-.0375732	.0007465
DIST_MARKET_sq	.0016122	.0005911	2.73	0.006	.0004536	.0027708
ELECTRICITY	-.0648132	.0710975	-0.91	0.362	-.2041616	.0745353
DIS_HEALTH_CENTER	.0032251	.0057551	0.56	0.575	-.0080547	.014505

Appendix 5.2: *Multivariate Probit model for coping strategies*

DS: De stocking of livestock

	Delta-method dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
EDUHHS	.0527612	.0144576	3.65	0.000	.024425	.0810975
TRAININGPART	.0178706	.0223143	0.80	0.423	-.0258646	.0616057
HEALTHSTA	-.0898493	.0497924	-1.80	0.071	-.1874406	.007742
LIVELIHOODEXPER	-.0012431	.0025006	-0.50	0.619	-.0061441	.003658
ACCSSAVING	-.020384	.0479156	-0.43	0.671	-.1142969	.0735289
ACCCREDIT	-.0441747	.047632	-0.93	0.354	-.1375316	.0491822
ACCINSURANCE	.0504705	.0815126	0.62	0.536	-.1092912	.2102322
LIVESTOCK	.2246345	.0586984	3.83	0.000	.1095878	.3396813
MEMBEROFCOPPERATIVE	-.1152398	.0478637	-2.41	0.016	-.2090509	-.0214286
ACCINFORMATION	-.0178257	.0599985	-0.30	0.766	-.1354207	.0997693
ACC_VET_EXTENSION	.048298	.0491566	0.98	0.326	-.0480471	.1446431
SIZEPASTURELAND	.070677	.0279863	2.53	0.012	.0158248	.1255293
FARMLAND	.039532	.0204359	1.93	0.053	-.0005216	.0795855
POTABLEWATER	-.0081867	.0080824	-1.01	0.311	-.0240279	.0076544
DIST_MARKET	-.0137694	.014571	-0.94	0.345	-.0423282	.0147893
ELECTRICITY	-.2571746	.0622972	-4.13	0.000	-.3792748	-.1350744
DIS_HEALTH_CENTER	.0091197	.0059157	1.54	0.123	-.0024749	.0207142

PSNP: Productive safety net program

	Delta-method dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
EDUHHS	.0142914	.0164799	0.87	0.386	-.0180087	.0465915
TRAININGPART	-.0048816	.0244276	-0.20	0.842	-.0527588	.0429956
HEALTHSTA	-.0147897	.0546972	-0.27	0.787	-.1219942	.0924148
LIVELIHOODEXPER	.0052058	.002733	1.90	0.057	-.0001508	.0105625
ACCSSAVING	.091109	.0515762	1.77	0.077	-.0099786	.1921966
ACCCREDIT	.1386666	.0532035	2.61	0.009	.0343897	.2429435
ACCINSURANCE	.063952	.0821777	0.78	0.436	-.0971134	.2250174
LIVESTOCK	-.020525	.0692185	-0.30	0.767	-.1561907	.1151408
MEMBEROFCOPPERATIVE	.0573947	.0517251	1.11	0.267	-.0439846	.158774
ACCINFORMATION	.0296475	.062744	0.47	0.637	-.0933285	.1526235
ACC_VET_EXTENSION	.0187044	.053862	0.35	0.728	-.0868631	.1242719
SIZEPASTURELAND	.0063787	.029335	0.22	0.828	-.0511168	.0638742
FARMLAND	.008008	.0223302	0.36	0.720	-.0357584	.0517744
POTABLEWATER	-.0029873	.0092433	-0.32	0.747	-.0211038	.0151291
DIST_MARKET	.0186379	.0158933	1.17	0.241	-.0125125	.0497882
ELECTRICITY	-.0179674	.0724227	-0.25	0.804	-.1599133	.1239785
DIS_HEALTH_CENTER	-.0167733	.0064102	-2.62	0.009	-.0293371	-.0042094

SCL: Short-term Casual labour

	Delta-method dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
EDUHHS	.0545238	.0171072	3.19	0.001	.0209942	.0880533
TRAININGPART	.0013301	.0246813	0.05	0.957	-.0470443	.0497045
HEALTHSTA	-.0459484	.0556923	-0.83	0.409	-.1551033	.0632065
LIVELIHOODEXPER	-.0021595	.0026335	-0.82	0.412	-.0073211	.0030022
ACCSSAVING	-.0779801	.0517992	-1.51	0.132	-.1795046	.0235445
ACCCREDIT	.119978	.0534753	2.24	0.025	.0151685	.2247876
ACCINSURANCE	.1014896	.0825579	1.23	0.219	-.0603209	.2633001
LIVESTOCK	-.126747	.0703151	-1.80	0.071	-.264562	.0110681
MEMBEROFCOPPERATIVE	-.0111616	.0550123	-0.20	0.839	-.1189837	.0966606
ACCINFORMATION	.0254016	.0628955	0.40	0.686	-.0978714	.1486746
ACC_VET_EXTENSION	-.0532039	.0545413	-0.98	0.329	-.160103	.0536952
SIZEPASTURELAND	-.0784124	.0303666	-2.58	0.010	-.1379299	-.018895
FARMLAND	.0339806	.023289	1.46	0.145	-.0116651	.0796263
POTABLEWATER	-.0057662	.0092523	-0.62	0.533	-.0239003	.0123679
DIST_MARKET	-.0226709	.0163445	-1.39	0.165	-.0547055	.0093637
ELECTRICITY	-.0863153	.0730303	-1.18	0.237	-.2294521	.0568216
DIS_HEALTH_CENTER	.0122303	.0064106	1.91	0.056	-.0003343	.0247949

RDFI: Reduction in daily food intake

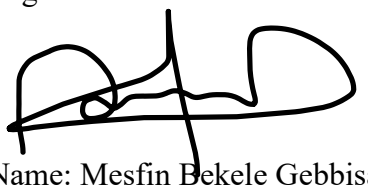
	Delta-method dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
SEX	.0356521	.2718084	0.13	0.896	-.4970826	.5683868
FAMSIZHHs	-.6693164	.2358656	-2.84	0.005	-1.131605	-.2070282
EDUHHS	.4725603	.1041855	4.54	0.000	.2683604	.6767601
AGEHHs	-.0541723	.0563047	-0.96	0.336	-.1645275	.0561828
ACCSSAVING	-.4111131	.2117893	-1.94	0.052	-.8262124	.0039863
ACCCREDIT	-.0503457	.2191086	-0.23	0.818	-.4797907	.3790994
LIVESTOCK	.1480225	.2908825	0.51	0.611	-.4220968	.7181417
MEMBEROFCOPPERATIVE	-.0097828	.2072638	-0.05	0.962	-.4160122	.3964467
ACCINFORMATION	-.0614712	.2365187	-0.26	0.795	-.5250394	.402097
ACC_VET_EXTENSION	.1807228	.2106948	0.86	0.391	-.2322313	.593677
SIZEPASTURELAND	-.1142046	.1133672	-1.01	0.314	-.3364003	.1079911
FARMLAND	-.0681801	.0784632	-0.87	0.385	-.2219652	.0856049
POTABLEWATER	-.2131824	.1035016	-2.06	0.039	-.4160417	-.010323
LIVESTOCKWATER	.0931847	.1029871	0.90	0.366	-.1086663	.2950357
MARKET	.1050263	.1374563	0.76	0.445	-.164383	.3744357
ELECTRICITY	-1.096491	.268849	-4.08	0.000	-1.623425	-.5695564
HEALTHCENTER	.0059492	.0220834	0.27	0.788	-.0373335	.0492319
PTC	.0557398	.0339792	1.64	0.101	-.0108582	.1223377

DECLARATION

I, **Mesfin Bekele Gebbisa**, hereby declare that this dissertation entitled *"Pastoralist Households' Vulnerability to Climate Change and Variability-Induced Shocks: Adaptation Strategies in the Rayitu District, South-east Ethiopia"* is my original work and has not been submitted, either in whole or in part, for any degree, diploma, or other qualification at any university or institution.

I further declare that I used artificial intelligence (AI)-assisted tools such as *Quill Bot*, primarily for paraphrasing limited sections of text and for checking the grammar and clarity of sentences. All sources of information and references used in this dissertation have been properly acknowledged.

Signature



Name: Mesfin Bekele Gebbisa

Date: 14.09.2026

DEDICATION

This dissertation is dedicated to the memory of my beloved father, Bekele Gebbisa Oda, who passed away while I was pursuing my PhD. His love, sacrifice, and guidance continue to motivate me.

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