EFFECTS OF CLIMATE VARIABILITY ON CROP PRODUCTION AND FARMERS' ADAPTATION STRATEGIES: THE CASE OF GIMBICHU WOREDA, EAST SHEWA ZONE, OROMIA REGIONAL STATE, ETHIOPIA

MA THESIS

ITABEZAW MEKASHA DARGE

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Itabezaw Mekasha Darge

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HARAMAYA UNIVERSITY

POSTGRADUATE PROGRAM DIRECTORATE

We here by certify that we have read and evaluated this thesis, entitled*:" Effects of Climate Variability on Crop Production and Farmers' Adaptation Strategies: The case of Gimbichu Woreda, East Shewa Zone, Oromia Regional State, Ethiopia".* Prepared under our guidance by *Itabezaw Mekasha Darge.* We recommend that it be submitted as fulfilling the thesis requirement.

Tegegne Sishaw (PhD)	______________________	______________________
Major Advisor	Signature	Date
Awol Akmel (PhD)	______________________	______________________
Co-Advisor	Signature	Date

As members of the Examining Board of the Final MA Thesis open defense, we certify that we have read and evaluated the thesis prepared by *Itabezaw Mekasha* and examined the candidate. We recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Arts in Climate change and Disaster Risk management.

__________________________	____________________	_______________
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Internal Examiner	Signature	Date
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DEDICATION

I dedicated to my father Mekasha Darge and my mother Etagegnehu Zewge for their lovely paternity in nursing me through my endowers and their finger prints in all successes.

STATEMENT OF THE AUTHER

By my signature below, I declare and affirm that this Thesis is my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis, and completion of this thesis. Any scholarly matter that is included in the thesis has been given recognition through citation. The Thesis is submitted in partial fulfillment of the requirements for an M.A in Climate Change and Disaster Risk Management at Haramaya University. The thesis is deposited in the Haramaya University Library and is made available to borrowers under the rules of the library. I solemnly declare that this thesis has not been submitted to any other institution anywhere for the award of any academic degree.

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Name: Itabezaw Mekasha Signature: _______________

Date: February 2023

School: School of Geography and Environmental Studies

Program: Climate Change and Disaster Risk Management(CCDRM)

BIOGRAPHICAL SKETCH OF THE AUTHOR

The author was born in January 1995 G.C to her father, Mekasha Darge, and her mother, Itagegnehu Zewge, in Jegol Nechdingay kebele, Gimbichu Woreda, East Shawa Zone, Oromia National Regional State. She attended her primary education at Gubegna elementary School, her secondary education and preparatory education at Chefe Donsa secondary school. She joined Haramaya University College of Social Science and Humanities in 2016 G.C and graduated with a BA degree in Geography and Environmental Studies in July, 2018. After her graduation, she was employed at Haramaya University in the School of Geography and Environmental Studies. Then, she joined the Postgraduate Program Directorate at Haramaya University in October 2019 to study for a Master's of Art in Climate Change and Disaster Risk Management.

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ACRONYMS AND ABBREVIATIONS

CC	Climate Change
CVC	Climate Variability and Change
CV	Coefficient Variation
FAO	Food and Agricultural Organization
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GWAOR	Gimbichu Woreda Agriculture Office Report
HHH	House Hold Head
IPCC	Intergovernmental Panel on Climate Change
MKT	Mann Kendall trend test
NAPA	National Adaptation Program Action
NMA	National Meteorology Agency
SD	Standard deviation
UNAID	United States Agency for International Development
UNFCCC	United Nations Frame Work Conventions on Climate Change
UNISDR	United Nations International Strategy for Disaster Reduction

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ABSTRACT

The objective of this study is to examine the variability and trends of rainfall and temperature, to assess the effects of climate variability on wheat crop production and to examine the existing adaptation strategies of the farmers to the climate variability in Gimbichu woreda, Ethiopia. A descriptive research design and a concurrent mixed research approach were employed. The sample population selected through a simple random sampling technique was 322HHHs settled in varied ecological areas. Both primary and secondary data sources were used. To collect data, survey questionnaires, focus groups, key informant interviews, and field observations were used. Meteorology data was gathered from Chefe Donsa meteorological stations from 1994 to 2021. XLSTAT, Pearson correlation and linear regression, Microsoft Excel version 2010, Statistical Product for Service Solution (SPSS) version 25, and other descriptive statistics were used to analyze this data. In Gimbichu district, annual rainfall ranged from 591.1 to 1080.9 mm with mean rainfall amount of 847.0mm, a SD of 146.7mm and a CV of 17.3%. Furthermore, the results of Pearson Correlation Coefficients indicated that, annual and kiremt minimum temperature against staple crop production had negative correlation for wheat (r = -0.492) and (r = -0.480) and maize (r = -0.467) respectively. While positive correlation of annual and kiremt rainfall(r=0.266) and (r = 0.303) against wheat production. The majority of households were more likely to adopt adaptation strategies to combat climate variability. Local communities' major adaptation strategies included the construction of terraces and check dams, the planting of trees, the improvement of adaptive wheat varieties, the use of mixed farming, and others.

Keywords: Adaptation Strategies, Climate Change, Climate Variability, Gimbichu Woreda

1. INTRODUCTION

1.1. Background of the Study

The world's climate has been changing for several thousand years. Climate change is inevitably resulting in the change in climate variability including the change in frequency, intensity, duration and timing of weather and climate events (IPCC, 2014). The recent changes in the global climate are a result of both natural and human-caused processes. Disasters including flooding, droughts, and storms have become more common and severe as a result of these climate changes in recent years. The social, economic, and environmental systems have been significantly impacted by these changes (Abinet, 2019).

The Intergovernmental Panel on Climate Change (IPCC) states that the average annual temperature will increase by 2–6 °C in Africa under high emission scenarios (RCP8.5) by the end of the 21st century (IPCC, 2014). Climate variability and change affect many economic sectors including agriculture. The most impacts of climate variability and change on agriculture include increased food insecurity and reduced productivity. In order to minimize these effects and others, famers have to adapt their faming systems to the changing climate. Climate variability and change adaptation involves making long-term adjustments in the socio-ecological systems in response to actual or perceived climatic conditions in order to prevent or to mitigate the associated risks (Alam et al., 2017)

Ethiopia is one of the most vulnerable countries to climate variability. The agriculture sector which contributes more than 45% of GDP, 80% to labor force and 85% to foreign exchange earnings is highly susceptible to climate change. More than 95% of crop production which is rainfall dependent has been produced by small holders and subsistent farmers who have less capacity to adaptation of climate change (MoFED, 2006). Climate variability and change impacts differ from one place or community to another, the adaptation strategies also vary depending on the agro-ecological system under attack, socio-economics of the farmers, existing capacities of the farmers at risk, and their own perceptions of climate change (Elum *et al.,* 2017). In countries like Ethiopia where agriculture is dependent on rainfall, the influence of climate variability on crop production is generally large. Previous studies have shown that variability in Ethiopia's agricultural GDP is clearly correlated with rainfall variability (Bewket, 2009). Whereas rainfall variability has always been a major challenge to Ethiopia, *Kiremt* rainfall is less variable in most parts of the country compared to the short rainy season (March–May, known as *Belg*) which is highly variable (Bewket and Conway, 2007 and Mengistu *et al.,* 2013).

Ethiopia is one of the top wheat-producing nations in terms of total production and area under cultivation. Wheat is the second-most important food in the nation after maize (19%) and is superior to *teff* (10%), Sorghum (11%) and *enset* (12%) since it accounts for 14% of the calories consumed in the nation (FAO, 2014). Wheat can be grown in Ethiopia by both large-scale industrial farms and small-scale subsistence farmers (Tadesse *et al.,* 2018).

Wheat is an important cool weather crop grown predominantly in the Ethiopian highlands at optimum altitude ranging from 1000 to 2300 meters above sea level. Wheat occupies large area (0.8 million hectares) of land and produces large amount of grain every year (Dereje and Eshetu, 2022). Wheat production in Ethiopia is constrained by several abiotic and biotic stresses at different levels of intensity across rain-fed and irrigated environments. This is further heightened by increasing occurrence of climate change which is characterized by rising temperature (heat), less and erratic rainfall (drought) or sometimes excessive rainfall (flooding) and emergence of virulent pests and diseases. The main problem associated with rainfall is not the total amount, but the uneven distribution which affects the crop production calendar, productivity and the grain quality when it rains at maturity stage of the crop (pre-harvest sprouting) (Mosissa F., 2021). Wheat is cultivated in Ethiopia's northern, central, and eastern highlands, which make up the majority of the nation. According to regional contributions, the production of wheat is primarily sourced from Oromia (57%) Amhara (28%) SNNP (8.7%) and Tigray (6.2%) (CSA, 2013). The World Bank (2012), states that Ethiopia is one of the different countries extremely vulnerable to drought and flooding, heavy rain, frost and disaster. In Ethiopia, climate variability and change is mainly manifested through the variability and decreasing trend in rainfall and increasing trend in temperature (Belay and Getaneh, 2016). Ethiopia is vulnerable to climatic variability due to its low adaptive capacity accountable to low level of socioeconomic development, high population growth, inadequate infrastructure, lack of institutional capacity and high dependence on climate sensitive natural resource-based activities (NMA, 2007).

1.2. Statement of the Problem

Climate change is a worldwide concern; it is smallholder farmers who are more likely to be influenced due to their low adaptive capacity (Menike and Arachchi, 2016). More specifically, Bewket (2012) illustrated that sub-Saharan Africa is expected to fare worst, given that temperatures are generally already high, and most of the region's inhabitants depend on rain-fed agriculture for their livelihoods. The Ethiopian economy is highly dependent on agriculture, with 38.5% of Gross Domestic Product (GDP) and 80.2% of the populations' earnings coming from this sector (Central Statistical Agency CSA, 2013).

There are studies on the effects of climate variability on crop production in Ethiopia. Bewket (2009) studied the relationship between rainfall variability and crop production in the Amhara region, and reported existence of significant correlations between crop production and rainfall and concluded that farmers are vulnerable to food insecurity partly due to rainfall variability in the region. Desta (2019) studied the Impacts of Climate Variability on Wheat Productivity and Adaptation Strategies among Smallholder Farmers: In Gibe Woreda of Hadiya Zone, Southern Ethiopia'. His result shows that kiremt minimum temperature has a weak and positive correlation with wheat yield. But kiremt maximum temperature has strong and very weak negative correlation with wheat yield. The kiremt total rainfall and maximum temperature has strong positive and negative correlations with the wheat yield respectively. Bekele (2017) investigated correlations between crop yields and rainfall covering some parts of the country (Sinana District, South Eastern Ethiopia). His results show that significant correlation exists between rainfall and yields of crops during the two seasons and noted the significant impact of rainfall variability on crop yields in almost all provinces.

Various studies show the country is highly vulnerable to climate variability and change that compromises the prospect for development. The National Adaptation Program of Action for Ethiopia confirms the vulnerability of Ethiopia to climate variability and change due to multiple causes (National Meteorological Agency, 2007). As a result of extreme rainfall events and variability caused floods and droughts which affected agricultural production. It is anticipated that reduced precipitation and extremely high temperatures and evapotranspiration during droughts will negatively impact staple food production (Muluneh *et al*., 2016). Ethiopia is highly vulnerable to climate change because 85% of its population engages in rain fed agriculture, low-income, and varied topography (Alemu and Mengistu, 2019).

Gimbichu Woreda is particularly vulnerable to climate change and variability because to its increased reliance on climatically vulnerable economic sectors including cattle and subsistence crop farming. The research area has a low level of farmer adaptation for a variety of reasons. These include a lack of information, technology, capital, and awareness, as well as difficulty accessing infrastructure and information (like media). In this study, access the effects of climate variability on crop production and farmers' adaptation strategies to minimize its impacts on crop production especially on wheat crop production in Gimbichu Woreda East Shewa zone. The crops production systems of the study area totally depend on rain fed which is highly vulnerable to climate variability impact. Even though many studies have been done at national and international level, there is still need for communicating climate variability issue for local farmers in appropriate way. In order to fill the gap, this study the first of its kind in Gimbichu woreda, East Shewa Zone, Oromia Regional State focuses on climate variability and its effects on wheat crop production and farmers' adaptation strategies.

1.3. Objectives of the Study

1.3.1. General objective

The general objective of the study is to assess the effects of climate variability on crop production and farmers adaptation strategies in Gimbichu district.

1.3.2. Specific objectives

The specific objectives of the study are:

- To examine the variability and trends of rainfall and temperature in the study area from 1994-2021G.C.
- To assess the effects of climate variability on Wheat crop productivity in Gimbichu district.
- To examine the existing adaptation strategies of the farmers to climate variability in Gimbichu district.

1.4. Research Questions

Based on the objective of the study, the following research questions will be addressed:

1. What are the rainfall and temperature variability and trends in the study area from 1994 to 2021G.C?
2. What are the major effects of climate variability on wheat crop productivity in Gimbichu district?
3. What types of adaptation strategies have been used to cope up climate variability in Gimbichu district?

1.5. Significance of the Study

Climate change and variability have become a serious challenge for the implementation of the country's development strategies. Even though climate variability is affecting the whole world, the extent differs from region to region and from locality to locality. This study was carried out for academic purposes, and it is helpful to Gimbichu Woreda farmers. The finding is a useful insight for those who design various plans and policies that address the ways to minimize the impact level through targeting adaptation options. They contribute little about how to adapt to the effects of climate variability on crop production, especially on wheat crop production in Gimbichu Woreda, East Shewa zone and Oromia regional state. Particularly, the local community was the most benefited from this study.

1.6. Scope of the Study

The scope of this study was limited to effects of climate variability on wheat crop production and farmers' adaptation strategies in Gimbichu Woreda. Geographically, this study is confined to Gimibichu district, East Shewa zone, Oromia regional state, Ethiopia based on four sample kebeles. Those *kebeles* are Areda Gora, Qarsa Rega, Jegol Nechdingay, and Somsa Kombolcha. These four sample kebeles were selected from the Dega, Weina dega, and Kola agro-ecological zones of Gimbichu district. In the analysis and interpretation of climate variability, meteorological data from the Chefe Donsa station (1994-2021) were used.

1.7. Limitations of the study

The study faced the following basic limitations: unavailability of sufficient data in the office due to poor recordkeeping and documentation and turnover of employees from time to time were major observed limitations of the study. These were all the main limitations during the study.

1.8. Definition of Key Terms

Adaptation strategies: The IPCC (2007) defines adaptation as adjustments in natural or human systems in response to actual or expected climatic stimuli or effects, which moderates harm or exploits beneficial opportunities. It also refers to actions that people, countries, and societies take to adjust to climate change that has occurred.

Climate change: Climate change is a change of climate which is attributed directly or indirectly to human activity. It alters the composition of the global and/or regional atmosphere and natural climate variability observed over comparable time periods (IPCC, 2015).

Climate variability: refers to the climatic parameters of region varying from its long-term mean. Every year in specific time period, the climate of location is different. Some years have average rainfall, some have average or above average rainfall (IPCC, 2007).

1.9. Organization of the Study

The thesis is organized into five chapters, followed by references and appendices. The first chapter introduces the background of the study; the statement of the problem; the objective of the study; research questions and significance of the study; limitation and scope; definition of key words; and organization of the thesis. Chapter two is the literature review section that provides the concept of climate variability and adaptation strategies, the trend of rainfall and temperature, and the impact of climate variability. In Chapter Three, the Research Methodology Section**,** descriptions of the study area, source of data, sampling size and technique, data collection instrument, research design, and method of data analysis were in this chapter. Chapter Four presents the results and discussions of the study. In this chapter, key findings of the study are briefly discussed. Chapter Five presents a summary and conclusion based on the findings of the study. Finally, references and appendices are attached at the end of this thesis.

2. LITERATRE REVIEW

2.1. Concepts of Climate Variability and Adaptation Strategies

2.1.1. Concepts of climate variability

Climate variability is a global issue that requires an urgent international response. Governments, industries, communities and organizations across the global are working together to develop and implement measures to reduce greenhouse gas (GHG) emission and avoid dangerous climate variability (Office of Climate Change, 2010). Several international conferences, seminars and workshops were held about climate variability. Some of them were the first World Climate Summit (1997)in Geneva, Conference on Industries and Climate (1980), Vienna convention (1985, in Australia),Montreal Protocol(Canada1987), Constitution of IPCC by UNEP and WMO in 1988, first Earth Summit (1997 Brazil), Kyoto Protocol(1997, Japan) and so on (Singh and Sweta, 2008 cited Getachew,2014).

According to some scientific experts in the field of climatology, climate variability is caused by human activities that have resulted in an increased concentration of greenhouse gases, in our atmosphere, including carbon oxide, water vapors, methane, ozone and nitrous oxide. Today, climate variability is increasingly recognized as a critical challenge to ecological, health, human well-being and future development (IPCC, 2007). According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the global average surface temperature is likely to rise by 1.8 degrees to 4.0 degrees Celsius by 2100. The sea level may rise by 30 to 60 centimeters. Climate variability will increase almost everywhere. Ethiopia is frequently affected by climate-related disasters, most typically drought and flooding, and has been noted as one of the most sensitive nations to climate variability and change (Burnett, 2013). A large portion of the global population relies on agriculture, which is highly sensitive to climate change, for their local economies and food security (Xiong *et al.,* 2021).

Agriculture productivity can be significantly impacted by both changes in variability and changes in the mean climate. In the country's Oromia regional state, where farmers grow 0.43 hectares of wheat on average per farm, the average wheat acreage per farm is also the greatest. When it comes to area coverage and overall production in Ethiopia, wheat comes in third behind maize and *teff* and sorghum (CSA, 2012).

2.1.2. Concepts of adaptation strategies

Adaptation is processes through which societies make themselves better able to cope with an uncertain future. Adapting to climate change entails taking the right measures to reduce the negative effect of climate change by making the appropriate adjustment and changes (UNFCCC 2007). The UNFCCC (United Nations Framework Convention on climate change) highlights two fundamental response strategies: mitigation and adaptation. Adaptation means anticipating the adverse effects of climate change and taking appropriate action to prevent or minimize the damage they can cause, or taking advantage of opportunities that may arise (Fussel and Klein, 2002 cited in Abinet , 2019).

Adaptation strategies include a broad set of activities ranging from activities that focus on reducing drivers of vulnerability to interventions aimed at confronting not yet experienced climate change impacts (FAO, 2008). In the case of crop management strategies the farmers used mixed farming, crop rotation, crop diversification, timing of planting and pest and weed control respectively as indigenous strategies to overcome the climate change problem. In addition to this, adapting climate related impacts on livestock production the local peoples practiced production of livestock through modern highbred system and sale of livestock reducing the number of animals to alleviating shortage of foods because of climate change (Habtamu and Samuel, 2017). In Borana pastoralists, southern Ethiopia two major categories of adaptation choices, adjustment in pastoral practices and shifts to non-pastoral livelihoods are recently embraced (Wassie and Fekadu, 2014).

A study conducted by Tesfaye and Seifu (2016) identified six major adaptation strategies in the eastern Hararghe Zone (eastern part of Ethiopia) such as adjusting crop planting dates and using drought-tolerant crop types, among others. Another study found that the most common adaptation measures in the central highlands of Ethiopia included adjusting crop planting dates, soil and water conservation, crop diversification, tree planting and soil fertility management (Alemayehu and Bewket, 2017). Gebru *et al*. (2020) found that adaptation strategies in eastern Tigray include soil and water conservation, water harvesting, compost preparation to increase soil fertility, tree planting and changing the quantity of land under cultivation.

Most of the adaptation measures, namely, changing crop variety, changing from livestock to crop, crop and animal diversification, digging water well, build a water-harvesting scheme, changing of planting date, implement soil conservation, planting trees, irrigation and moving to different farming site are yield related and only few, lease your land and reduced numbers of livestock are non-yield related (Tesfaye, 2017).

Adapting to climate change will entail adjustments and changes at every level from community to national and international (Belay, 2016). Indigenous people all over the world have used different strategies to respond and adapt to climate change, these include: diversified resource base (to minimize the risk due to harvest failure, they grow many different crops and varieties, and they also hunt, fish, and gather wild food plants); change in crop varieties and species; change in the timing of activities (crop harvests, wild plant gathering, hunting and fishing); change of techniques; change of location; changes in resources and/or life style(resorting to wild foods in the case of emergency situations such as droughts and floods); exchange (obtaining food and other necessities from external sources through exchange, reciprocity, barter, or markets in times of crises); and resource management (Belay and Getaneh, 2016).

2.2. Climate Variability and Trends

2.2.1. Temperature variability and trends

The global average temperature risk is high to very high with global mean temperature increase of 1.5 °C to 5.4 °C at the end of the century from the preindustrial level with a widespread impact on global and regional food security and normal human activities including growing food (IPCC, 2014). The mean annual temperature is projected to increase by 1.1 - 3.1^{o}C in the 2060s and by 1.5-5.1^{o}C in the 2090s. All projections indicate substantial increase in the frequency of days and nights that are considered ‘hot’ in current climate. All projections indicate decreases the frequency of days and nights that are considered ‘cold’ in the current climate (World Bank, 2008).

According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the global average surface temperature is likely to rise by 1.8 degrees to 4.0 degrees Celsius by 2100. The sea level may rise by 30 to 60 centimeters. Climate variability will increase almost everywhere. According to (NMA, 2007) report, the annual minimum temperature over the past 54 years has been increasing by about 0.37°C every ten years. The temperature increase has been most rapid from July to September (0.32°C per decade). The trend analysis of annual temperature (minimum and maximum) shows statistically significant increase of the district. According to the UNDP Climate Change Profile for Ethiopia (Oxford, 2008, cited in Dawit and Habtamu, 2011), the mean annual temperature in Ethiopia has increased by 1.3°C between and 2006, at an average rate of 0.28°C per decade. The temperature increase has been most rapid from July to September (0.32°C per decade). For the IPCC mid-range emission scenario, the mean annual temperature will increase in the range of 0.9 -1.1 °C by 2030, in the range of 1.7 - 2.1 °C by 2050 and in the range of 2.7-3.4 °C by 2080 over Ethiopia compared to the 1961-1990 normal(USAID ,2012).

Climate models suggest that Ethiopia will see further warming in all seasons of between 0.7°C and 2.3°C by the 2020's and of between 1.4°C and 2.9°C by the 2050s. In Ethiopia, the average annual minimum temperature has increased by about 0.25^{o}C every ten years while the average annual maximum temperature has increased by about 0.1^{o} C (NMA, 2007). The warming of our planet due to the emission of greenhouse gases is now unquestionable, and over the last century, the CO2 atmospheric concentration has increased significantly and average global temperature was increased by 0.74 °C as compared with the preindustrial era (UNFCCC, 2007).

2.2.2. Rainfall variability and trends

Decreased rainfall is very much critical for the farmers and might result in amongst others large decreases in crop yields. Increasing temperatures might be serious in some areas of Ethiopia, because it can result in increased evaporation from the field soil and make it drier even there is much rain. The main wet season for most of Ethiopia is from mid- June to mid- September. The Eastern corner of Ethiopia receives very little rainfall at any time of year (ECAR, 2017).

Ethiopia's projections from different models in the ensemble are broadly consistent, indicating increases in annual rainfall in Ethiopia. These increases are largely a result of increasing rainfall in the 'short' rainfall season of October, November and December (OND) in southern Ethiopia. The OND rainfall is projected to change by 10 to +70% as an average over the whole of Ethiopia. The Proportional increases in OND rainfall in the driest, eastern most parts of Ethiopia are large. The Projections of change in the rainy seasons April, May, June and July, August and September which affect the larger portions of Ethiopia are more mixed, but tend towards slight increases in the south west and decreases in the north east. The models in the ensemble are broadly consistent in indicating increases in the proportion of total rainfall that falls in 'heavy' events. The largest increases are seen in JAS and OND rainfall (ECAR, 2017).

Besides, when the highlands lose a big amount of belg rainfall (35 mm/d), lowlands did not. Different study conducted in Ethiopia showed increasing and decreasing trend in annual, belg and kiremt rainfall, for instance study conducted in Tigiry region (Hadgu *et al.,* 2013). Trend analysis of annual rainfall in Ethiopia shows that rainfall remained more or less constant. When averaged over the whole country while a declining trend over the Northern half of the country and Southwestern Ethiopia (Belay *et al.,* 2017).

2.3. Effects of Climate Variability on Agriculture

Agriculture is one of the sectors most sensitive to, and greatly influenced by, climate change and climate variability. The Intergovernmental Panel on Climate Change (IPCC) and the Food and Agriculture Organization (FAO) has identified the agriculture industry as one of the most vulnerable industries affected by climate change, particularly in developing countries (Alexandris *et al*. 2021). In this regard, all African countries are vulnerable to climate change and variability and Ethiopia in particular is among the most vulnerable countries to climate variability with little adaptive capacity because of its topography and location. Climatic and ecological changes have resulted in several negative consequences on livelihood, health, economy, and environment of the people in the country. Recurrent drought, famine, and flood are the main problems that affect millions of people in the country almost every year (NMSA, 2007). The history of climate extremes, especially drought, is not a new phenomenon in Ethiopia. The most drought prone and affected areas of the country are in the northern, eastern and southern parts. Total failure or shortage of rainfall is often cited as the major cause for the recurring droughts and harvest failures. Such a problem or situation is further exacerbated by the social, economic and ecological situations (Dawit and Habtamu, 2011 cited in Astawsegn, 2014).

Climatic variability are the types of changes (temperature, rainfall, occurrence of extremes); magnitude and rate of the climate change that causes the impacts on the area of public health, agriculture, food security, forest hydrology and water resources, coastal area, biodiversity, human settlement, energy, industry, and financial services (FAO, 2017). Change in temperature and rainfall have imposed considerable influence on agricultural productively and ecosystem provisioning services provided by forests and agroforestry systems on which many people depend (Lipper *et al*., 2014). The Ethiopian agriculture sector is composed of the crop, livestock, forestry, and fishing sub-sectors of which the crop subsector takes the lion's share of the agriculture sectors, comprising 65.3%, followed by livestock production 25.3% (NBE, 2017). Ethiopia's agricultural sectors, with cereals as the major food crop, are especially vulnerable to the adversities of weather and climate change/variability and are characterized by poor productivity (Oumer, 2016 cited in Tadesse, 2019).

Agrarian communities are the most sensitive social groups to climate variability due to the fact that climate change affects the two most important direct agricultural production inputs such as rainfall and temperature (Philip *et al.,* 2014). Agricultural productivity remained stagnant and low in smallholder production systems over the last few decades (FAO, 2015). These impacts are deepening the problems of vulnerable smallholder farmers to poverty in the developing countries though they produce 70 % of the world's food needs (Campbell and Thornton, 2014; FAO, 2013). Agrarian communities are the most sensitive social groups to climate variability due to the fact that climate change affects the two most important direct agricultural production inputs such as rainfall and temperature (Philip *et al*., 2014).

Case studies Paulos (2018) and Belay (2016) indicate that Ethiopian agriculture is highly vulnerable (with large spatial and temporal variation) to the impacts of climate change because of high exposure and sensitivity of the sector to climate variability and change. It is also because low adaptive capacity of smallholder farmers. Ethiopia is especially vulnerable to climate variability and change because large segments of the population are poor and depend on agricultural income, which is highly sensitive to rainfall variability. Most have low access to education, information, technology, and basic social and support services, and, as a result, have low adaptive capacity to deal with the consequences of climate variability and change (Oxfam 2010, The World Bank Group 2010, Regassa *et al*, 2010 cited in Bishaw *et al*., 2013). Ethiopian agriculture is susceptible to frequent draughts, usually related to the deficiency in total annual and seasonal rainfall amounts, affecting farmers' livelihoods (Mera, 2018).

Rainfall variability impacts the soil's water availability to crops, causing reduced crop production. In particular, annual and seasonal rainfall information is important to overcome the social and economic problems for farmers who entirely depend on rainfall. Farmers usually rely on prior knowledge of weather conditions when planning farm activities. Excessive precipitation increases soil moisture and thereby enhances waterlogging, surface runoff, and erosion (Tian *et al*. 2021). Vertisols are one of the major soil types covering a large portion of the Ethiopian highlands (Elias *et al.,* 2022) and suffering from excess or shortage of rainfall, which makes land preparation difficult for sowing and for the implementation of agronomic practices (Manik *et al.,* 2019). These soils are moderately fertile, but rainfall variability, their physical characteristics, and unsustainable land management practices limit the ability to exploit the full potential and produce sufficient food (Elias, 2019).

2.4. Effect of climate variability on crop production

Many studies have shown the importance of rainfall variability in explaining crop production fluctuations at different spatial scales. At the global level, estimates are that climate variability accounts for roughly a third of observed crop yield variability (Ray *et al.,* 2015). At the continental level, climate variability is widely recognized to be a major driver of crop production fluctuations particularly in Africa, where agriculture is predominantly small scale and rain fed (IPCC, 2014). In Nigeria, rainfall variability was found to have a significant influence on crop production (Yamusa *et al*., 2015).

Changes in temperature, rainfall and severe weather events are expected to reduce crop yield in many regions of the developing world, particularly sub-Saharan Africa and parts of Asia. Crop yields show a strong correlation with temperature change and with the duration of heat or cold waves and differ based on plant maturity stages during extreme weather events. Crop productivity increase slightly at mid to high latitudes for local mean temperature increases of up to 1-3°C depending on the crop, and then decrease beyond that in some regions. At lower latitudes, especially seasonally dry and tropical regions, crop productivity decrease for even small local temperature increases (1-2°C), which would increase risk of hunger and warmer weather was expected to bring longer growing seasons in northern areas, and plants everywhere were expected to benefit from carbon fertilization (Tamiru and Fekadu, 2019).

As a result of extreme rainfall events and variability caused floods and droughts which affected agricultural production. It is anticipated that reduced precipitation and extremely high temperatures and evapotranspiration during droughts will negatively impact staple food production (Muluneh *et al.,* 2016).

Experiment and model prediction have shown that climate change though increased atmospheric CO_2 concentration, and the resulting rise in temperatures and changes in rainfall pattern extent and variability affect crop production negatively in multifaceted way. Increased CO2 concentration increases yield by increasing rate of photosynthesis, leaf area index and accumulation of non-structural carbohydrates, biomass and decreasing stomata conductance and transpiration loss of water (Chauhan *et al*., 2008 cited in Tadesse, 2019). Rising atmospheric CO_2 and climate change may also impact indirectly on crops through effects on pests and disease. Warmer climates will generally accelerate the growth and development of plants, but overly cool or hot weather will also affect productivity (Craufurd and Wheeler, 2009). Global agriculture is facing the probable impact of global warming (Harold, 2015).

As discussed by Central Statistics Agency (2018) the crop production subsector is showing improvement in terms of productivity and the extent and use of modern farm inputs and modern farming system practices though the production comes from smallholder farmers. In Ethiopia, grain crop production is the most widely spread crop production activity both in terms of the extent of cropped land area and volume of production (CSA, 2016). Cereal crops that are classified within the grain crops category are also produced in greater volume compared to the other crops by commercial farms because they are the principal staple crops and export commodities (CSA,2016). Among the major factors which affect rain fed crop production and productivity was the variability of two common elements of climate (unpredictable rainfall and increased temperature) as the most important ones. The impacts of climate variability and change on crop production are more negative, but they can vary substantially between crops (IPCC, 2015).

Crop is the major staple food, foreign exchange earner and source of income for the majority of the people in Ethiopia. Cereals, the principal staple food has a share of more than 80% of area and 86% of crop production. More than 12 million private peasant holders have engaged in the production of crop agriculture (World Bank, 2008). Although temperature was identified as major climatic variable which affects crop agriculture in Ethiopia, there is no consistent data in Ethiopia on this variable. Rainfall variability has significant and negative impact on outputs of crop agriculture in Ethiopia. What matters most in crop production is not per se the amount of rainfall but how that level diverges from the mean rainfall which is supposed to be the optimal level. When the rainfall diverge from the mean value (both upward and downward), the level of production has significantly diminished to all crop types unanimously. Other factors such as fertilizer, area, demand for crop production and labor force have significant impact in addition to rainfall variability in all crops. When rainfall diverges from its mean; fertilizer use has also a negative impact on crop production. This is may be because in case of dry or excess rainfall conditions, fertilizer adoption may burn seeds and increase the probability of crop failure. Area covered by crop production has also been found to be the detrimental factor to crop production in Ethiopia having positive and significant impact on all crop production. Overall, rainfall variability has significant and negative impact on all crop types across the board although the cofactors have varied impacts on each crop types based on the nature of the crops whether it is annual or perennial, drought resistant or drought prone and cash or food. To sustain the agricultural growth, government should play key role by creating awareness on how to adapt to climate change (Amare, 2015).

2.5. Effect of climate variability on wheat crop production

The global average wheat yield variability (SD) was 0.4 tons/ha/year (~17% of average yields over the study period). Approximately 34–45% of the wheat yield variability in the United States, Canada, United Kingdom, Turkey, Australia and Argentina was explained by climate variability. In the top soybean production areas of the world such as in the Midwestern U.S. and Latin American countries, the coefficient of variation was low. Climate variability is a significant factor and responsible for 32–39% of global crop yield variability, it is certainly not the only controlling factor (Ray *et al.,* 2015).

In Ethiopia, wheat has been selected as one of the target crops in the strategic goal of attaining national food self-sufficiency (Amare *et al.,* 2015)**.** Even though it has a huge potential, only 20% of the total wheat production is sold, while 80% of its total production is used for human consumption, seed, in-kind payments for labor, and animal feed (Abafita *et al.,* 2016)**.** In Ethiopia, wheat is one of the largest produced cereal crops in terms of the area coverage (1.6

million hectares), the volume produced (3.9 million tons), and the number of farmers engaged in wheat production (4.7 million farmers) with an average productivity of 2.4 tons per hectare (CSA, 2014). Additionally, wheat is an important food crop in the world, with an estimated 36 million tons of annual global production (Tidiane *et al.*, 2019).

Crop production on Vertisols at Ghinchi is predominantly rain-fed. The major crops grown are wheat and *teff,* which have different responses to waterlogging conditions. Wheat is sensitive to waterlogging conditions, while *teff* can better tolerate waterlogging. The Vertisols farmers of the study area usually grow crops on residual moisture just after the withdrawal of the main rainy season in September to avoid waterlogging. The recent trend in climate change and rainfall variability affects crop production in developing nations like Ethiopia, where rain-fed agriculture dominates the farming system (Alemayehu *et al.,* 2020a). Grain quality is influenced by genetics, management and environment. Maintaining grain quality of wheat under climate change is critical for human nutrition, end-use functional properties, as well as commodity value (Nuttall *et al.,* 2017).

2.6. Conceptual Framework

The study determined the effects of climate variability on crop production and farmers' adaptation strategies in Gimbichu woreda. Figure 2 illustrates the interactions between dependent variables (effect of climate variability; on wheat crop production), farmers' adaptation strategies and socio-economic status and independent variable (climate variability; rain and temperature)**.** Climate variability is the way climate fluctuates monthly, seasonally and yearly as above or below a long-term average value. Climate change includes major changes in temperature, rainfall, wind pattern and other climate variables that occur over decades or longer (IPCC, 2015).

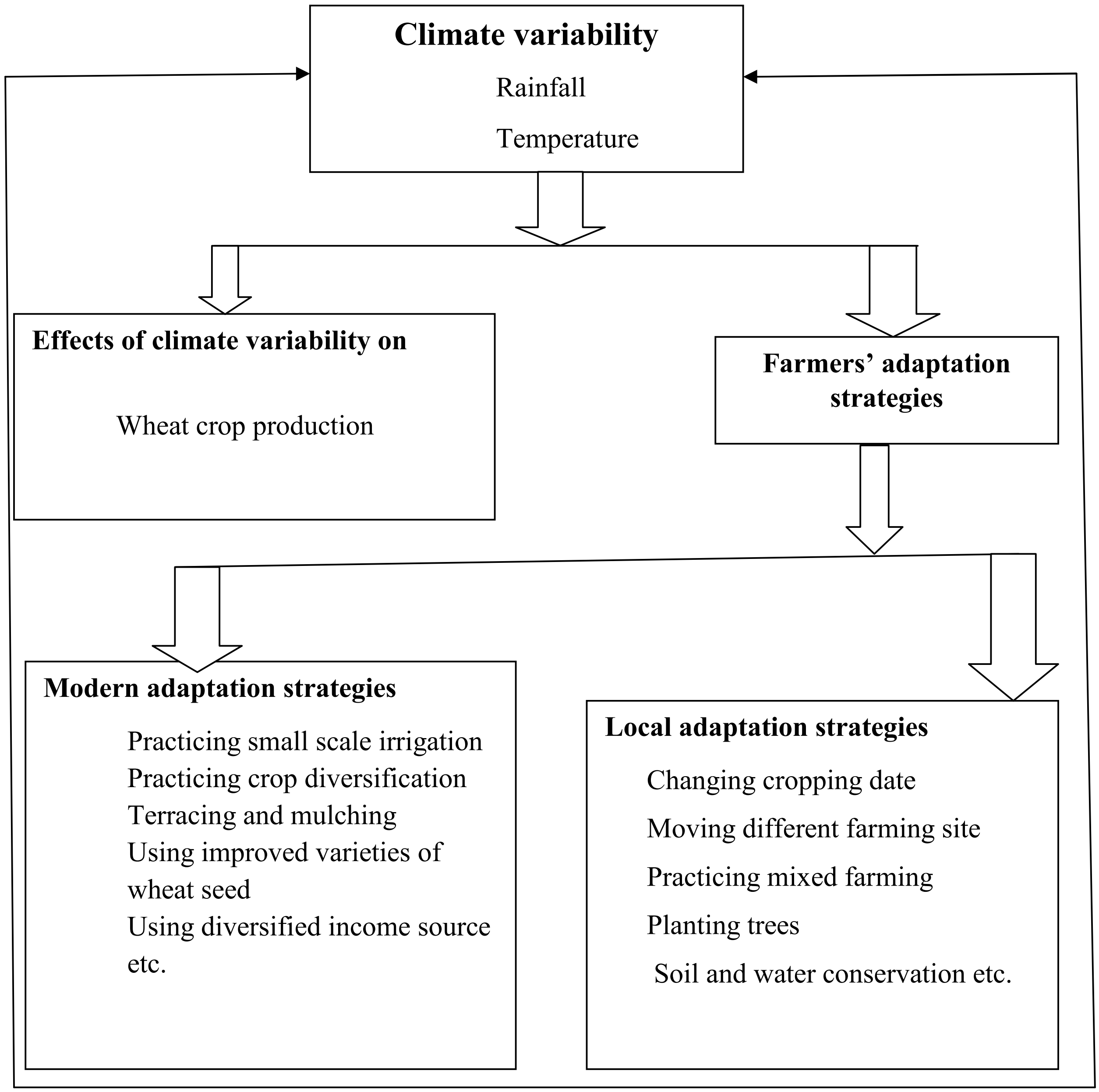

Figure 1: Conceptual frame work

Source: Developed by researcher, 2022

3. RESEARCH METHODOLOGY

3.1. Description of the Study Area

3.1.1. Location and size of the study area

The study was conducted in Gimbichu Woreda, which is one of the Woredas in the East Shewa zone in the Oromia Regional State of Ethiopia. Geographically, the Gimbichu Woreda is located between 8^0 42′0″ - 9^0 13′ 30″ North Latitude and 38^0 55′30″ - 39^0 27′0″ East Longitude (Figure 1). Gimbichu woreda is bordered to the east by Amhara national regional state and Lume woreda, to the west by Barak Aleltu and Akaki woreda, to the south by Lume and Adea woreda, and to the north by Amhara regional state. The District Town, Chefe Donsa, is found about 65 kilometers northeast of Sandefa and about 85 kilometers northeast of Bishoftu town from the capital city of Ethiopia, Addis Abeba, and 90 kilometers from the zone capital town, Adama, through Debre Zeit town. The district has an area of 754.31 km^2 and is the 3rd smallest district in the East Shewa zone. The total area of Gimbichu woreda is about 75,071 hectares or 754.31km^2, of which 48916 hectares are cultivable land, 3753 hectares of grazing or pasture land, 10998 hectares of bush and forest land, 2268 hectares of settlement, 8348 hectares of hills and mountain land, and 788 hectares are for others (GWARDO, 2022).

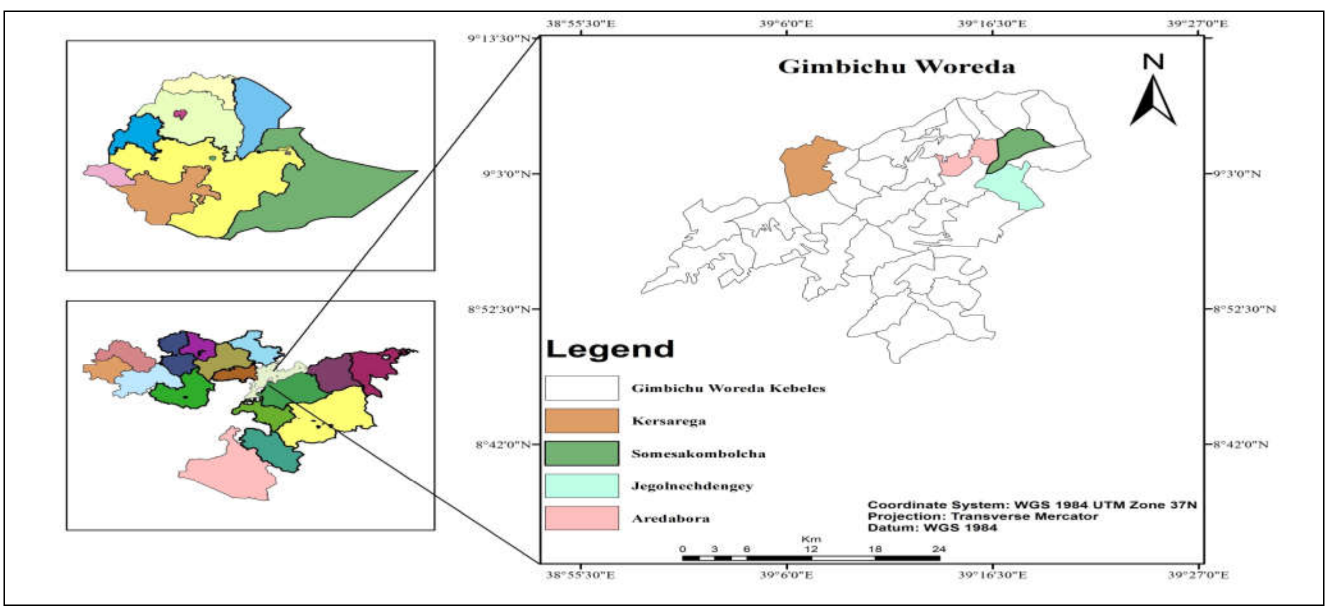

Figure 2: Location Map of the Study Area

Source: Developed by Investigator based on arc GIS

3.1.2. Topography , soil types and drainage

The altitude of Gimbichu woreda ranges between 1500m above sea level and 2700m above sea level. Garabokan is the highest mountain in this woreda. More than 85% of the Gimbichu woreda is found at an altitude of more than 1800 m.a.s.l. Gimbichu woreda consists of different soli types. Those are silt soil at 75%, sand soil at 15%, and clay soil at 10%. Vertisols are the most important soils, covering 79% of the total cultivated area. Wedecha and Belbela are main rivers, both tributaries of the Modjo (GWADO, 2022).

3.1.3. Climate

Gimbichu Woreda consists of three agro-climatic zones: Dega, Weyna Dega, and Kolla, which comprise about 52% (17 *kebeles),* 27% (9 *kebeles),* and 21% (7 *kebeles)* of the area of the woreda, respectively. The average annual temperature and rainfall are 13–21^{0} c and 800-1000 mm, respectively. Gimbichu has two rainy seasons: belg, or the small rain (January-May), and *Meher*, the big rain (June-September) (GWARDO, 2022).

3.1.4. Population characteristics

According to CSA (2017) projection, the total population of Gimbichu woreda was 104,722 with 54,162 (52.15%) were males and 50,560 (48.28%) were females. The total urban population was 8,871 (9.25%) and the rural population was 95,851 (90.75%). The average family size of the woreda is 5–6 people per household for rural and 4-5 people per household for urban. A large number of households live in rural areas. The two largest ethnic groups reported in Gimbichu were the Oromo (72.28%) and the Amhara (26.69%); all other ethnic groups made up 1.03% of the population. 72.62% spoke Oromiffa as a first language, and 27.29% spoke Amharic; the remaining 0.09% spoke all other primary languages reported. The majority of the inhabitants were Ethiopian Orthodox Christians, with 97.32% of the population reporting they professed that belief, while 1.33% of the population said they practiced traditional beliefs, and 1.02% was Muslims.

3.1.5. Socio economic activities

According to the Gimbichu Woreda agricultural and rural development office report 2022, the major source of income and way of life of the Gimbichu woreda population is agriculture. The agricultural sector of Gimbichu is composed of mainly crop production, livestock and poultry, and a few farmers also do beekeeping. All farmers in woreda produce wheat, *teff*, lentils, and grass peas. The woreda is also known for its production of vegetables and fruits. The woreda is also known for its animal products like cattle, goats, sheep, poultry, horses, mules, donkeys, and camels. So, Gimbichu woreda is characterized by a subsistence mixed farming system.

3.2. Research Design and Approach

In order to conduct this study, the researcher employed a descriptive research design. According to Kothari (2004), descriptive research design provides a deep understanding of the events being studied and its instruments are helpful in getting first-hand experience as well as in-depth coverage of the study. The objective of this study required the use of both quantitative and qualitative approaches. As a result, a concurrent (triangulation) mixed approach was used for this study. The reasons why concurrent mixed research approaches apply in this study are firstly, it gives equal priority to both quantitative and qualitative data. This means that the researcher valued both quantitative and qualitative data and saw them as approximately equal sources of information for this study. Secondly, it enabled the researcher to compare the results of quantitative and qualitative analyses to determine if the two databases yield similar or dissimilar results. Thirdly, this approach enables the researcher to gather information that uses the best features of both quantitative and qualitative data collection methods. Creswell also argues that a concurrent mixed method approach is a design in mixed methods in which the researcher collects both quantitative and qualitative data concurrently, analyzes them separately, and then compares the results to see if the findings confirm or disconfirm each other (Creswell, 2017). This method allows the simultaneous collection of quantitative and qualitative data. The choice of mixed methods is premised on the assumption that a social phenomenon like climate change and climate variability requires a combination of quantitative and qualitative approaches to have a deeper understanding of the subject matter.

3.3. Data types and sources

The investigator used both primary and secondary data type to conduct this research. Primary data were collected from respondents and participants using questionnaires and semi-structured interviews. Secondary data was obtained from a variety of sources, including published and unpublished documents identified by government offices; climate data for 28 years (1994 to 2021) from the National Meteorological Service Agency (NMSA), the Central Statistical Agency, reports from woreda development agents and academic publications on climate change and variability.

3.4. Sampling Technique and Sample Size

In order to assess the overall activities, the researcher employed a multiple stage sampling technique, where a combination of purposive and random sampling techniques was applied for selecting study area and sample households, respectively. In the first stage, Gimbichu District was selected purposively. The main reasons behind this choice were the familiarity and convenience of accessing information relevant to the study. The Gimbichu woreda represent most frequently affected by climate variability in the East Shewa Zone. Gimbichu woreda also represent the three important agro-ecological zones in the country, that is, the Dega , Woina Dega and Kolla. In the second stage, house hold heads of the study area were selected by using simple sampling technique and then in the third stage, out of the total 33 rural *kebeles* in the woreda, four *kebeles,* from three agro-ecology (Areda Gora and Qersa Rega from dega, Jegol Nechidingay from weina dega, and Somsa Kombolcha from kolla) were selected purposively based on their dependence on rain fed agriculture and represent different agro-climatic zones. The total household heads in four *kebeles* is 1644; from those household heads, the researcher selected 322 household heads by using Yemane's (cited in Neuman, 2006) sample determining formula. The researcher used a 95% confidence level and a level of precision of 5% error. In the fourth stage, 322 household heads were selected using probability proportional to the size of population in each village. The sample size for the quantitative study was determined through the mathematical formula used by Yamane (1967) expressed as follows.

The equation is $n=N/1+N(e^2)$

Where

N=Total population

n= the required sample Size

e= Standard Error

1= Constant

$n= 1644/1+1644(0.05)^2$

n=1644/1+1644(0.0025)

n=1644/1+4.11

n=1644/5.11

n= **322** sample size

322/1644* 100= 19.6%. This is the proportion to be multiplied by the household heads so as to get the proportional size.

Table 1: Sample size of household heads (HHHs) in the study area

No	Sample kebeles	Agro ecological zone	Total No of HHHs	Sample size HHH No
1	Areda bora	Dega	340*.196	67
2	Qarsarega	Dega	592*.196	116
3	Jegol Nechidingay	Weyna dega	346*.196	68
4	Somsa Kombolcha	Kola	366*.196	71
	Total		**1644**	**322**

Source: Field Survey, 2022

3.5. Instruments of Data Collection

In order to obtain adequate information on the issues of the study, the researcher employed the following data-gathering instruments: questionnaire, focus group discussion, key informant interview, and field observation. Data was collected from interviews which were conducted with different officials and experts of Gimbichu woreda and some model farmers. Focus group discussion and a structured questionnaire have been administered from the four selected *kebeles*. To collect both qualitative and quantitative data from 322 household heads.

3.5.1. Questionnaire

In order to gather facts and relevant information, the researcher prepared both open-ended and closed-ended questions in order to gather quantitative and qualitative data. Close-ended and open-ended questions were prepared for 322 sample household heads to generate the required data about climate variability's impact on crop production and adaptation strategies. Questionnaires were prepared based on the language status of the respondents

3.5.2. Focus group discussion

Focus Group Discussions (FGDs) were used to learn about the communities' perspectives on climate change and variability, as well as their impact and adaptation strategies. The main purpose of focus group discussion is to get insight on and to make the data more reliable and to collect the facts. The discussions was conducted with male, female, elder household heads, experts and DAs who likely represent the opinion of the community and to avoid specific group‘s idea dominance and to capture disaggregated data. There were a total of four FGDs and each group has involved 5 individuals and attended a total of 20 respondents. To guide the discussions, semi-structured checklist was designed specific to the research issues. For each *kebele,* one focus group discussion has been held with five members of the respondent. As a result, the researcher consulted with the following respondents.

Table 2: Focused group discussion

No	Focused group discussion	Sample size
1	Local elder	4
2	Agriculture office workers	4
3	Farmers	12
	Total	20

Source: Field Survey, 2022

3.5.3. Key informants interview

In order to conduct this research, the researcher also used interviews to obtain factual data and basic information from respondents. The researcher was to gather qualitative data and prepare for both structured and semi-structured interviews. Interview was used as a data collecting instrument to get the views and opinions of the respondent s for cross checking the data collected through other instruments. Interview was prepared and communicated to the interviewees. To gather additional data on the overall condition of farmers' adaptation strategies of climate variability and its impacts on wheat production, a semi structured interview was prepared to interview selected farmers and key informants like Gimbichu woreda agricultural office experts and DAs. The interview has given the needed information verbally in face to face situation. Therefore, individual interview was conducted by the investigator on the research issue to obtain specific information for the study. The researcher was asked questions by 12 respondents from four *kebeles*. Those questions are climate variability, its impact, and local knowledge and adaptation strategies.

Table 3: Key informant interview

No	Key informants	Sample size
1	Local elder	3
2	Agriculture office workers	3
3	Development agents	3
4	Model farmers	3
	Total	12

Source: Field Survey, 2022

3.5.4. Field observation

Field observation was a way of gathering data by watching events and noting physical characteristics in their natural setting. It can be overt (everyone knows they are being observed) or covert (no one knows they are being observed and the observer is concealed). Robson (1995) indicates that field observation is used as a supportive technique to collect data that may complement or set in perspective data obtained by other means. During the time of staying in the study area, the researcher observes vegetation cover, topography, major development interventions, and other related things.

3.6. Methods of Data Analysis and Presentation

Quantitative data obtained from survey were analyzed using descriptive statistical methods such as frequencies, percentiles, tables, line graph, and histogram with the help of Microsoft Excel. The Microsoft Excel function of linear trend as well as line chart was used to analyze the trend of climate variability in the area. The line chart, trend line, trend equation and the degree of variation, that is, within the excel function was used to determine the nature and direction of the trend of the variables under investigation, that is, annual temperature and rainfall data (temperature and rainfall) were calculated using the Microsoft Excel to assess the year to year variability of the climate variables over past a 28 year period (1994 to 2021) in the area. Microsoft Excel is used for trend significant test. Hence, Mann- Kendall trend test was used to detect the trend.

3.6. 1. Rainfall and temperature analysis

The NMSA provided quantitative daily weather data from 1994 to 2021. Total rainfall, maximum and minimum temperatures were adjusted each month in a series of steps before being published. Computed into seasonal and annual parameters. Finally, the data was analyzed using Microsoft Excel 2010 software for descriptive and inferential statistical analysis by using the Mann-Kendall statistical Test method. Analysis Concerns with climate variability and trend, monthly, annual, kiremt and belg temperature and rainfall trend were analyzed. Additionally, Coefficient of Variation (CV), standard deviation (SD) and mean were used to determine the variability.

Coefficient of variation used to measure the variability of rainfall and temperature. A better value of CV is that the indicator of larger variability and vice versa which is computed as.

$$CV = \sigma / \mu \times 100 \quad \text{equation (1)}$$

Where CV is coefficient of variation, σ is standard deviation and μ is that the mean precipitation. CV is employed to classify the degree of variability of rainfall events as, less when CV < 20, moderate when between 20 < CV < 30, and high when CV > 30 (Hare‟s, 2003), and higher CV value indicate that higher variability, moderate value indicate moderate and less values indicate low variability.

On the other hand, the standard deviation is calculated as the square root of variance. Using the classification stated by Reddy (1990), the stability of rainfall is computed as

$$SD = \sqrt{[\sum_{i=1}^{n} 1(xi - \bar{X})^2]}$$ ……………………………………………………………………………………equation (2)

When SD is standard deviation, SD <10 means very high stability, 10<SD< 20 high stability, 20<SD<40 as moderate stability and SD>40 indicates less stability (Reddy, 1990).

To determine rainfall and temperature trend, Mann-Kendall test was used. It detects the presence of monotonic (increasing or decreasing) trends within the study area and whether the trend is statistically significant or not. MK test is beneficial because its measurement to predicated on the (+or -) signs, instead of the values of the variety, and thus, the trends determined are less suffering from the outliers (Birsan et al., 2005).

Sen (1968) reported that, based on the earlier procedure trends of annual, seasonal, and monthly trend the Sen‟s estimator of slope also calculated. Hence, the magnitude is usually determined by Sen‟s test which is also a nonparametric technique calculated. MK test with Sen's slope estimator was functional for nonparametric test and simple linear regression for parametric test. The non-parametric Mann-Kendall test is widely used in meteorology and hydrology to detect variable trends. Mathematically Mann-Kendall‟s test measured by;

$$S = \sum_{i-1}^{N-1} \sum_{j=i+1}^{N} sgn(x_j - x_i).$$ ……………………………………………………equation (3)

Where S is the Mann-Kendal‟s test statistics; xi and xj are the sequential data values of the time series in the years j and I (j > i) and N is the length of the time series.

$$\operatorname{Sgn}(X_j - X_i) = \begin{cases} +1 & \text{if } (X_j - X_i) > 0 \\ 0 & \text{if } (X_j - X_i) = 0 \\ -1 & \text{if } (X_j - X_i) < 0 \end{cases}$$

……………………………… equastion (4)

Where, Xi and Xj are the annual values in years i and j (j > i) respectively.

$$\operatorname{Var}(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i - 1)(2t_i + 5)}{18}$$

.... equastion (5)

Where n is the number of observation and ti are the ties of the sample time series.

The test statistics Zc is as follows:

$$Z = \begin{cases} \frac{S-1}{\sigma} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sigma} & \text{if } S < 0 \end{cases}$$

.... equastion (6)

Where, Zc follows a normal distribution, a positive Zc and a negative Zc depict an upward and downward trend for the period respectively.

If Z > 0, an upward trend is present, and vice versa. If |Z| > Z (1- α /2), where Z (1- α /2) is the standard normal distribution's corresponding value of P = α /2, then the sequential data should be expected to show a statistically significant trend at confidence levels of 0.05 and 0.01. Additionally, Sen's straightforward non-parametric method (7) was used to assess the amplitude of a time series trend. The trend is calculated by

$$\beta = Median \frac{(xj - xi)}{(j-i),\ j > i} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\text{equation (7)}$$

Where β is Sen's slope estimate. β>0 indicates upward trend in a time series. Otherwise the data series presents downward trend during the time period.

3.6.2. Correlation and regression analysis

Correlation and linear regression models were used to establish the relationship, cause, and effect of annual rainfall and temperature on crop production. Annual bread wheat yield total and per hectare were obtained in quintal from GWARD and metrological data was analyzed by using personal matrix correlation and regression in order to measure the relationship among these variables. Personal correlation and linear regression methods were applied to determine the relationship and impact of rainfall and temperature characteristics on wheat yields. The climate data was further correlated to crop production for which crop data was available to show any attribution of rainfall and temperature with crop production by correlation and linear regression models by the following formula.

Coefficients of multiple determinations (R^2); were used to determine the percentage of variation explained jointly by the rainfall and temperature characteristics. R-Square tells us what percent of the variability in the dependent variable is accounted for by the regression on the independent variable.

Pearson correlation coefficient (r); analyses were used to analyze the correlation between crop yields (wheat yield in qui/ha with rainfall and temperature feature value of r' ranged between-1 to +1, a correlation coefficient close to +1 indicates a strong positive correlation, a correlation coefficient close to -1 indicates a strong negative correlation, while correlation coefficient of 0 indicates no correlation.

Beta-coefficient (Slope); tells the change in dependent variable with respect to change in independent variables.

3.6.3. Data analyzing methods of adaptation strategies

In this study, SPSS version 25 and descriptive survey statistical analysis methods were employed to analyze collected data for indigenous and adopted adaptation strategies being practiced by local wheat yield farmers as well as adopted methods of adaptation measures and challenges that hinder the adaptive capacity of farmers in the study area. Finally, all of the analyzed data was summarized using mean, standard deviation, tables, frequencies, percentiles, histograms, cross tabulations, leaner line charts, and bar graphs, which allowed for easier comprehension and interpretation.

Linear Regression Model: The regression equation for the study was in the form of:

$Y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \ldots\ldots\ldots\ldots\ldots\ldots \beta_n x_n$ Equation (8)

where; Y = the value of the dependent variable (wheat yield in qt/ha); a = Y intercept and $\boldsymbol{\beta}_1$, $\boldsymbol{\beta}_2$, $\boldsymbol{\beta}_3$, $\boldsymbol{\beta}_4$,… $\boldsymbol{\beta}_n$ = regression coefficients, X_1, X_2, X_3, X_4,⋯,X_n = the independent variables are rainfall features such as rainfall; total kiremt and annual rainfall and temperature variability (minimum and maximum) and e = th e error of estimate or residuals of the regression. For performing the analyses, Statistical Package for Social Sciences (SPSS) version 25 Software with Microsoft Excel sheet was used.

Generally, descriptive statistics of climate variability analyzed by XLINSTAT software version +3.36 and climate trend was analyzed by XLSAT 2014, while other quantitative data analyzed by SPSS V25 and Microsoft Excel 2010, and information generated from key informant interview, focus group discussion and personal observation was analyzed qualitatively, and finally the results presented by table and figures.

3.7. Description of Variables

Dependent Variable

The dependent variable is the variable that is being measured or tested in the study. Therefore, in this study, the dependent variable is climate variability. The nature of dependent variable is dichotomous or dummy variable. The dependent variable (wheat crop production and adaptation strategies) has two values. The values 1 represents climate variability is increased and 0, otherwise.

Independent Variables

Predictors or explanatory variables are the variables that influence the predicted or dependent variable. In this study, the independent variables were assumed that determine the climate variability both rainfall and temperature. Therefore, the main task is assessing the negative and positive influence of the explanatory variables on the dependent variable.

3.8. Ethical Considerations

To legalize their every movement for research work, the researcher uses a formal letter from the research office, and in their every activity, social norms should be kept. The researcher introduces themselves before putting forward the reasons for the research. The researcher starts asking open-ended questions and replying to questions depends fully on the consent and willingness of informants. Informants were informed that the information they provided could be kept confidential if necessary. The questions were prepared first in English, and then they were translated into the local language. The researcher was able to use local languages depending on the language ability of informants. The investigator is considered to give informed consent before the interview begins and be serious about not exploring sensitive issues before the establishment of a good relationship. The rapport are; clarification of the purpose; telling them the provision of information was totally dependent on their willingness; assuring confidentiality of their shared information; guaranteeing that every response which came from them was highly respected; and by telling them there was no need to write their names. This strong rapport helped the investigator to get the consent and willingness of the participants, which was very crucial to getting the necessary information, which in turn greatly contributed to the validity and reliability of the work.

4. RESULTS AND DISCUSSION

4.1. Climate Variability and Trend of Rainfall and Temperature

4.1.1 . Annual, seasonal and monthly total rainfall variability

Gimbichu district had an average of 847.0mm of precipitation annually, with an SD of 146.7mm and a CV of 17.3%. Annual rainfall varied from 591.1 to 1080.9mm. This indicates rainfall has less stability and less variability. The area received lowest and highest annual rainfall amount at 2015 and 2020year respectively. Abreham *et al (2021) report,* annual rainfall had less coefficient of variation, shown that inters annual rainfall (13.94%) variability was observed during 1983–2016 in the study area. The study is disagreement with Bekele *et al.,* 2017 report, Coefficient of variation of the rainfall characteristics for Robe meteorological station clearly demonstrates that *kiremt* (JJAS) rainfall total has the highest coefficient of variation (16.3%). Therefore, both seasonal and annual rainfall high variability in Ethiopia.

The mean of *belg* season total rainfall was 153.0 mm and the highest total rainfall amount was 289.3 mm in 2005 year, whereas the lowest being 37.9mm in 1999 year, with less stability (SD of 67.7 mm), and highly variable condition (CV of 44.2%) then *kiremt* rainfall, which indicates that extreme rainfall variability observed in *belg* season. The same result was also reported by (Mohammed, 2021; Bewket, 2009; and Bewket and Conway, 2007).

In *kiremt* season, the mean rainfall amount is 659.9 mm and the highest total rainfall amount is 828.2 mm in 2020, whereas the lowest being 423.1mm in 1997 with less stability (SD of 108.4 mm), and less variable condition (CV of 16.4%). Table 3 indicates that the CV of belg season was much higher (44.2%) and more variable than kiremt season (16.4%). The result agrees with the findings of Alemayehu and Bewket. 2017, where more variability in *belg* rainfall than the *kiremt* rainfall in most parts of Ethiopia was disclosed. Farmers of our countries very dependent on *kiremt* rainfall amount for their crop production and a small fluctuation in the rainfall amount directly affect crop productivity (NMA, 2007).

Furthermore, the monthly total rainfall amount was lowest for January, February, November and December, while highest rainfall observed in the month of June, July, August and September. September to October months of crop maturation and harvesting. Therefore, high amount of rainfall may have negative impact. Monthly SD of rainfall varied from high stability

(7.0 mm) to less stability (63.2 mm) with CV of ranged from less (19.9 %) to high variability (68.7%) (Table 4), which indicates unpredictable nature of rainfall in the study area). There is a significant relation between climate and agricultural production in terms of the timing, variability, and quantity of seasonal and annual rainfall in Ethiopia. As a result, farmers during unexpected break in rainfall in early growing season may be able to recover and resume production despite the loss of some of their crops (Cheung *et al.,* 2008).

Table 4: Descriptive statistics of annual, seasonal and monthly rainfall in Chefe Donsa station

Parameters	Min	Max	Mean	Std. Deviation	CV(%)
January	0.0	62.2	31.1	19.3	62.1
Feb	0.0	48.7	24.3	16.7	68.7
March	0.0	110.9	55.5	23.1	41.6
Apr	0.2	151.8	76.0	42.3	55.7
May	0.3	163.1	81.7	36.6	44.8
June	40.6	177.6	109.1	37.9	34.7
July	139.3	346.3	242.8	48.2	19.9
August	106.2	334.3	220.2	63.2	28.7
Sep	47.4	188.6	118.0	33.1	28.1
Oct	0.0	67.4	33.7	16.9	50.1
Nov	0.0	29.7	14.9	7.0	47.0
Dec	0.0	24.2	12.1	7.4	61.2
Belg	37.9	289.3	153.0	67.7	44.2
Kiremt	423.1	828.2	659.9	108.4	16.4
Annual	591.1	1080.9	847.0	146.7	17.3

Source: Computed based on statistical raw data of NMSA 2022, for the period 1994-2021

4.1.2. Annual, seasonal and monthly rainfall trend

Belg and *kiremt* seasonal rainfall of the study area had a decreasing trend by a factor of -20.89, and -7.39mm per year, respectively for the past 28 years (Table 5). However, the trend was not statistically significant for *belg* and *kiremt* seasonal rainfall, but significant for annual rainfall trend. Sen‟s Slope of both seasonal rainfalls shows a decreasing trend by a factor of -20.89 mm per annual with -208.9 mm/decade for *belg*, -7.39 mm per annum with -73.9 mm/decade for *kiremt* (Table 5). Moreover, except March, all months had a decreasing trend during the study period. Because of the decline in rainfall amount, the rainfall dependent agricultural activities of the area suffer from water shortage. These results are consistent with Mohammed (2021) report that state annual, *belg* and *kiremt* seasonal rainfall of the study area had a decreasing trend by a factor of -20.81, -0.36 and -4.49 mm per year, respectively for the past two decades in Chiro Woreda. Rainfall variability is the major source of risk for farmers who depend on crop production. There are two important rains in Ethiopia- the '*Kiremt'* and '*belg'*. The *Kiremt* rains usually begin in March and May in South West and advancing northwards affecting most of the country from July through September. The *kiremt* rain constitutes about 90% of the crop production harvested during October–December (CSA, 2011). Gebrechorkos e*t al*. (2019) have also reported a non-significantly decreasing (increasing) trend in rainfall in the eastern (western) parts of Ethiopia during the main rain season from 1981 to 2016.

Table 5. Mann-Kendall statistics of annual, seasonal, and monthly rainfall trend

Parameters	Sen's slpoe	Kendall" s Tau	Mk	Trend
January	-17.6	0.037	0.34	Decrease
Feb	-16.89	0.021	0.33	Decrease
March	0.428	-0.205	0.008	Increase
Apr	-17.6	0.072	0.34	Decrease
May	-15.4	0.205	0.3	Decrease
June	-14.7	0.061	0.29	Decrease
July	2.85	0.157	0.056	Increase
August	-6.57	0.215	0.12	Decrease
Sep	-16.32	0.178	0.31	Decrease
Oct	-16	-0.045	0.316	Decrease
Nov	-21.25	0.179	0.419	Decrease
Dec	-20.5	-0.005	0.405	Decrease
Belg	-20.89	0.4	0.412	Decrease
Kiremt	-7.39	0.258	0.146	Decrease
Annual	2.9	0.217	0.06	Increase

Source: Computed based on statistical raw data of NMSA 2022, for the period 1994-2021

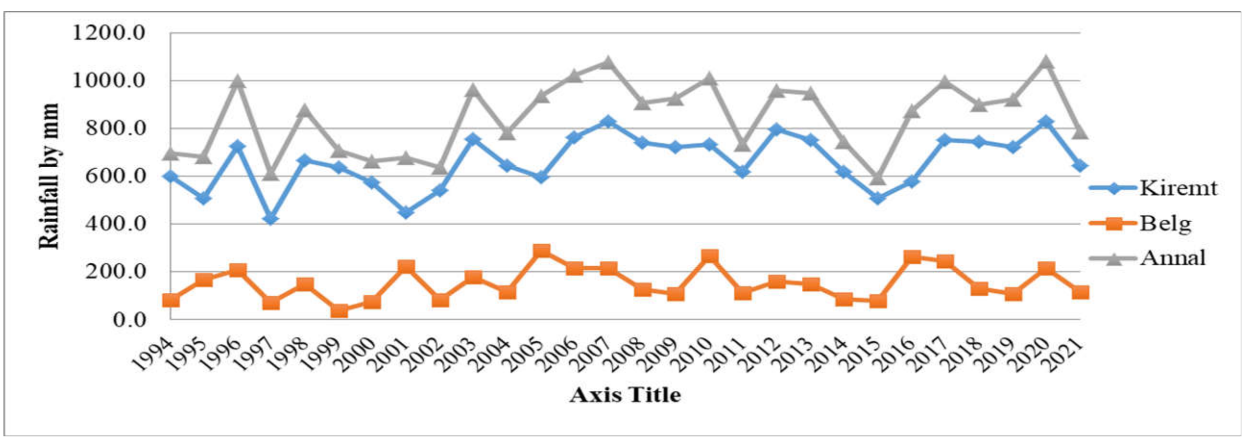

Figure 3: Annual, seasonal and monthly rainfall trend at Chefe Donsa station (1994-2021)

Source: Computed based on statistical raw data of NMSA 2022, for the period 1994-2021

4.1.3. Annual, seasonal and monthly maximum temperature variability and trend

Annual maximum temperature ranged from 23.9 to 27.9°C over the study area during the study period. From the analysis, the mean annual average maximum temperature over the study area was 26.0 °C with a CV of 4.5% and a SD of 1.2 °C, which implies less yearly temperature variability and very high stability respectively. In *belg* season, mean maximum temperature was 27.1 °C with a very high stability (SD of 1.0 °C), and less variability (CV of 4.2 %) temperature condition. The lowest *belg* maximum temperature occurred in 2001 whereas the highest maximum temperature was recorded in 2019.

In *kiremt* season, maximum temperature quantity extended from 21.0 to 24.7 °C with very high stability (SD of 1.0 °C) and a less variability (CV of 4.6%). As a result, there was less variation in the maximum temperature during both seasons, which indicates that the study area's food security was determined primarily by climate variability during the seasons for plant cultivation, growth, and harvest. The monthly maximum temperature varies between 19.4°C with SD 1.0°C and CV of 4.7% in August to 27.9°C in March with SD 1.6°C and CV of 6.5%. This higher SD and CV indicate that variation of minimum and maximum temperatures were found in every month in the study area. According to Mohamed (2021) report, annual, *Belg* and *Kiremt* maximum temperature over Chiro woreda was less variable and very high stable. The lowest maximum temperature amount August (19.4 °C) was recorded in 2000, March and April (27.9 °C) temperature were being in 2019, whereas highest maximum temperature recorded in 2019 and 2020. The highest maximum temperature in March and April were observed.

The result from the Mann-Kendall trend test annual maximum temperature showed an increasing trend by a factor of 0.089°C per year or 0.89°C per decade and statistically significant at 0.05 significance level in the study area. The *belg* and *kiremt* maximum temperature trend increased by a factor of 0.89°C/years, but it was statistically significant at Gimbichu woreda (Figure 4). According to Mekasha *et al.* (2013) report; annual maximum temperature, significant increasing trends were observed at Werer, Ziway, Nazret and Asela whereas a significant decreasing trend was observed only at Mieso. On the other hand, trends of maximum temperature were not significant at Metehara, Negele-Borana, Koka, Yavelo, Kulumsa and Kofele stations. Except a decreasing trend at Werer, the maximum temperature values were not significantly changing over time at almost all the stations.

Generally, rising maximum temperature can adversely affect physiological processes of major crop plants and reduce yield. Furthermore, evapotranspiration enhanced by rising temperature can induce moisture loss from the soil, which in turn can influence crop yield and thus interfere with food security status of the study district. The finding was linked with results in NMA (2007); Desta (2019); Mekasha *et al.* (2013) and Mohamed (2021) that stated a warming trend of annual maximum temperature in Ethiopia. Ethiopian case, annual temperature has rapidly increased in the last five decades. The mean annual temperature rose by 1.3^{o}C or by 0.28 ^{o}C per decade during 1960-2006. The frequencies of hot days and nights have also showed an increasing trend during these years. While the average number of 'cold days' has decreased by 5.8% between1960-2003, the average number of 'cold' nights per years has decreased by 11.2% (UNDP, 2008). In the coming 100 years, the average temperature in Ethiopia has projected to increase from 23.08^{o}C during 1961-1990 to 26.92^{o}C in 2070-2099 (WB, 2008).

Table 6: Descriptive and Mann-Kendall statistics of annual, seasonal and monthly maximum temperature in Chefe Donsa station (1994-2021)

Parameters	**Max**	**Min**	**Mean**	**SD**	**CV (%)**	**MK**	Kendall''s Tau	**Trend**
Jan	25.5	21.0	23.0	1.3	5.8	0.2	0.496**	Increased
Feb	26.5	22.7	24.4	1.1	4.5	0.2	0.425**	Increased
Mar	27.9	22.0	25.1	1.6	6.5	0.2	0.553**	Increased
Apr	27.9	22.8	25.0	1.3	5.2	0.2	0.433**	Increased
May	27.0	23.5	25.4	1.0	3.8	0.2	0.195	Increased
Jun	27.8	20.9	24.6	1.6	6.5	0.2	0.75**	Increased
Jul	24.6	19.7	21.6	1.1	5.1	0.2	0.534**	Increased
Aug	23.7	19.4	21.3	1.0	4.7	0.2	0.398**	Increased
Sep	24.5	20.8	22.6	1.1	5.1	0.2	0.497**	Increased
Oct	24.6	20.7	22.4	1.0	4.6	0.2	0.450**	Increased
Nov	24.8	20.2	21.9	1.1	5.2	0.2	0.527**	Increased
Dec	24.5	20.4	21.9	1.1	5.1	0.2	0.467**	Increased
Belg	27.1	23.1	25.0	1.0	4.2	0.2	0.531**	Increased
Kiremt	24.7	21.0	22.5	1.0	4.6	0.0	0.512**	Increased
Anuall	27.9	23.9	26.0	1.2	4.5	0.0	0.589**	Increased

Source: Computed based on statistical raw data of NMSA 2022, for the period 1994-2021

Monthly maximum temperature trends of January, March, June and July showed an increasing trend, while February, April, May, September, November, and December showed decreasing trend but the trends had no statistical significance for all months. Mieso district is one of the neighboring district with Chiro district were the maximum temperature on district reaches lowest level in December, but increases again in June and start to decline as of July and, the maximum temperature follows a decreasing trend from July to December and an increasing from January to June (Tamiru, 2015). General temperature rise can be attributed to ongoing global warming (Worku *et al.,* 2019).

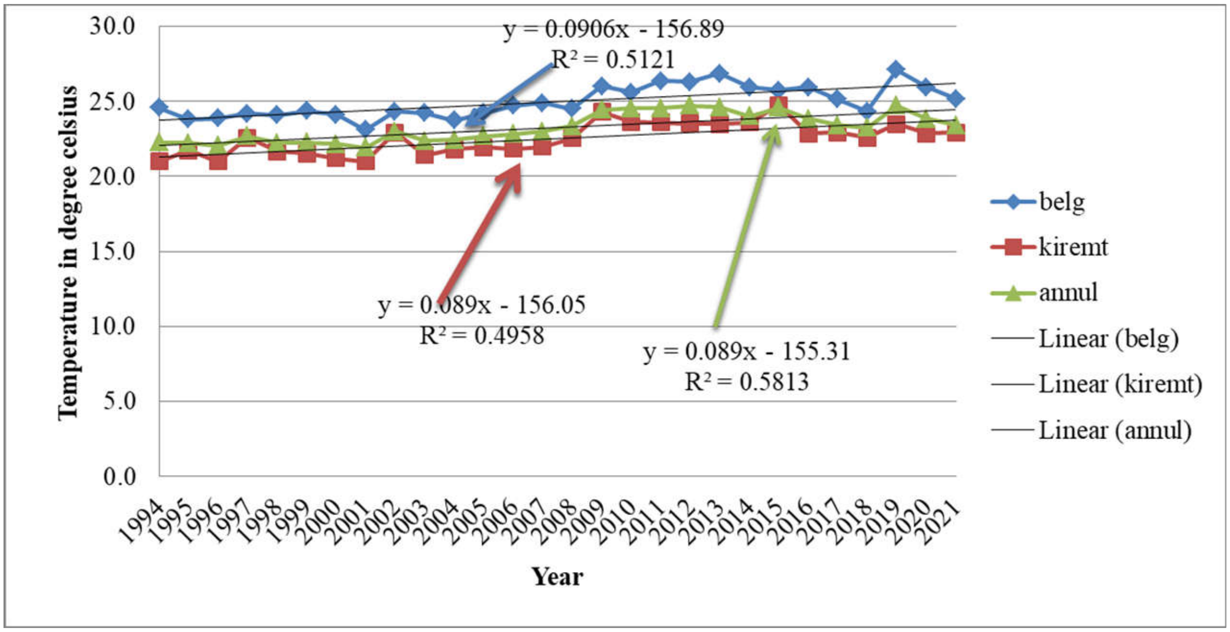

Figure 4: Annual, seasonal and monthly maximum temperature trend at Chefe Donsa (1994-2021)

Source: Computed based on statistical raw data of NMSA 2022, for the period 1994-2021

4.1.4. Annual, seasonal, monthly minimum temperature variability and trend

Annual minimum temperature of the Chefe Donsa station were extended from 9.5 to 13.2 °C with mean value of 11.5 °C respectively, where the quantity of minimum temperature value indicates less variable (CV of 7.8%) and a very high stability (SD of 0.9 °C). Minimum mean temperature of belg season was 12.3 ^{0}C, while lowest 9.6 and highest 14.6 °C belg season minimum temperature were recorded in 1998 and 2016 respectively, with very high stability (SD of 1.1°C) and less temperature variability. In kiremt season, 13.1°C was mean of minimum temperature, whereas lowest and highest minimum temperature were 11.9 and 14.1 °C respectively. According to Wasihun *et al.* (2019) report, annual minimum temperature over Habro District was less variable and stable. The average annual minimum temperature ranged between 5.08°C and 17.10°C and annual average of minimum temperature at Gelemso station was 13.18°C with a CV of 11.02% and SD of 1.33°C for the study period (1988-2017). This indicates that annual, *Kiremt* and *Belg* minimum temperature over the study period was less variable and stable in the study period.

On the other hand, the smallest monthly minimum temperature was recorded in December and January (3.9 °C), then followed by November (5.5 °C) and February (5.7 °C), while highest monthly minimum temperature amount occurs in the month of April (15.2 °C), then followed by March (14.7 °C). Monthly SD of monthly minimum temperature amount varied from 0.5 to 2.4, and monthly CV between 3.5 to 27.9%, which is indicated that all monthly minimum temperature very high stability and less and moderate variability respectively. December has moderate variability than other months with a CV of 27.9%, while July has lowest minimum temperature variability with a CV of 3.5 %. Months of December, January, November and October were coldest months, whereas, April, March, June and July months were warmest months. According to Wasihun *et al.* (2019) report, minimum temperature was less variable for all month except for January and February.

Table 7: Descriptive and Mann-Kendall statistics of annual, seasonal, and monthly minimum temperature in Chefe Donsa station (1994-2021)

Parameters	Min	Max	Mean	SD	CV (%)	MK	Kendall‟s Tau	Trend
Jan	3.9	12.8	8.6	2.4	27.3	0.4	0.552**	Decreased
Febr	5.7	14.1	10.4	1.7	16.5	0.4	0.535**	Decreased
Mar	8.2	14.7	12.4	1.6	12.7	0.4	0.646**	Decreased
April	11.9	15.2	13.5	1.0	7.7	0.4	0.568**	Decreased
May	9.9	14.5	13.1	1.0	7.3	0.4	0.370**	Decreased
June	11.9	14.2	12.8	0.7	5.4	0.4	0.410**	Decreased
July	12.4	14.5	13.7	0.5	3.5	0.4	0.451**	Decreased
Aug	11.9	14.5	13.5	0.6	4.1	0.4	0.569**	Decreased
Sept	10.2	13.7	12.4	0.8	6.4	0.4	0.563**	Decreased
Oct	7.0	13.3	10.2	1.7	17.1	0.4	0.382**	Decreased
Nov	5.5	12.6	9.0	1.6	18.0	0.4	0.543**	Decreased
Dec	3.9	12.6	8.1	2.3	27.9	0.4	0.562**	Decreased
Belg	9.6	14.6	12.3	1.1	8.94	0.4	0.638**	Decreased
Kiremt	14.1	11.9	13.1	0.5	3.9	0.2	0.638**	Decreased
Annual	9.5	13.1	11.5	0.9	7.8	0.5	1.000	Decreased

Source: Computed based on statistical raw data of NMSA 2022, for the period 1994-2021

Mann-Kendall trend test revealed that *belg*, *kiremt* and annual minimum temperature trend decreased by factor of -0.0573, -0.0275 and -0.0673 °C/year respectively (Figure 5). This result agrees with the report of Desta (2019) that means *kiremt* minimum temperature is decreased by 0.004°Cper year and 0.04°C per decade. The result differs from findings in Mieso district by Tamiru (2015) that showed an increasing trend of average annual minimum temperature for the period 1990-2009. Both annual minimum and mean temperature trends were statistically non-significant at α= 0.05, while both *kiremt* and *belg* minimum temperature showed a statistically significant increasing trend by a factor of by 0.13 °C and 0.2 °C/year respectively.

Moreover, all months had a decreasing trend during the study period. Statistically, minimum temperature trends of all months were significant at α = 0.05. Mekasha *et al.* (2013) reported no significant trend for minimum temperature in central, eastern, and southern parts of Ethiopia. Although 7 out of the 11 stations tend to show a negative minimum temperature trend, only one station (Mieso) had a significant decreasing trend, whereas two stations (Negle-Borana and Ziway) had a significant increasing trend in minimum temperature. Generally, most of the study results revealed that minimum temperature has been faster increased than maximum temperature.

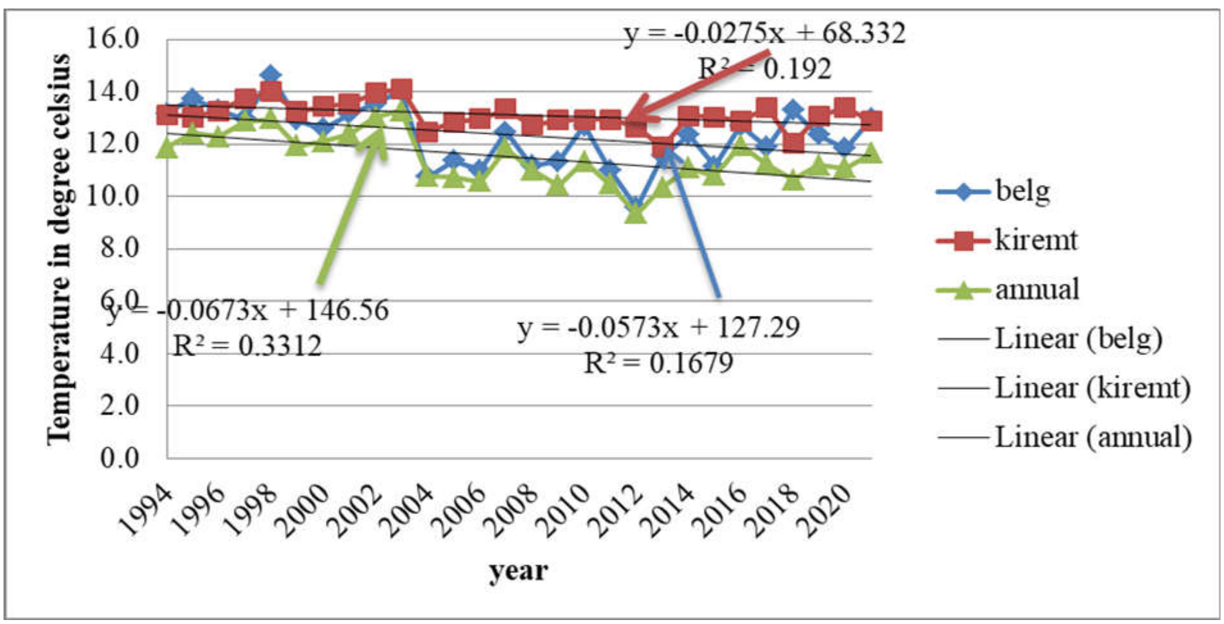

Figure 5: Pattern and change trend of monthly temperature at Chefe Donsa station (1994-2021)
Source: Computed based on statistical raw data of NMSA 2021, for the period 1994-2021

4.3. Effect of Climate Variability on Wheat Crop Production

4.3.1. Correlation of wheat crop production on rainfall and temperature

The economy of the study area is mostly dependent on rain-fed agricultural production. It is directly related to the current weather conditions. Variability in temperature and rainfall would jeopardize the agricultural sector's productivity and put rural people in danger. Lack of rain is one factor negatively affecting the output of livestock and cereal crops. Additionally, unpredictable rainfall causes crop failures and, it would seem, lowers production. All the households in Gimbichu woreda, including the sample *kebeles,* were impacted by climate variability. As illustrated in Table 8, Pearson Correlation Coefficients for *kiremt* and annual minimum temperature against crop production shown negative and strong correlations for Wheat (r = -0.480) and (r = -0.492) respectively, whereas annual rainfall and annual mean maximum temperature against crop production revealed that positive and moderate correlations for Wheat (r = 0.266) and (r=0.673) respectively (Table 8). According Bekele *et al.* (2017) report , the correlation coefficients computed between wheat and rainfall characteristics for Robe meteorological station showed that *kiremt* (JJAS) rainfall total (r = 0.499) and annual total rainfall (r = 0.003) had positive moderate and weak correlation with wheat yields, respectively.

According to Table 8, the results of the Pearson method of correlation analysis showed that the maximum temperature at Chefe Donsa indicated significant strong positive values at P value 0.05 for the relationship between main cropping and growing seasonal temperature for wheat. Wheat crop production has a strong negative correlation (R = -0.480) with Chefe Donsa's *kiremt* minimum temperature at the P. value of 0.01 level (Table 8). The regression analysis results showed that there is relationship between climate variability and wheat crop production. Therefore, it is evident that rainfall and temperature variability had significant effects on crop production among household in the study area. Climate change reduced yield of wheat staple by 33% in Ethiopia (World Bank, 2006). According to Agricultural economists, rainfall variability greater than 30 is risky for farmers who depend on crop production which is prevalent in most parts of Ethiopia (NAPA, 2007).

Table 8: Correlation of annual rainfall, maximum, minimum temperature and wheat yield at Chefe Donsa

Correlations

Variable	Annual rainfall	Kiremt rainfall	Kiremt Tmin	Kirmt Tmax	Annual Tmax	Annual Tmin	wheat production per Ha
Annual rainfall	1						
Kiremt rainfall	.892**	1					
Kiremt Tmin	-.169	-.243	1				
Kirmt Tmax	.050	.132	-.343	1			
Annual Tmax	.233	.324	-.452*	.936**	1		
Annual Tmin	-.324	-.432*	.773**	-.552**	-.667**	1	
Wheat production per Ha	.266	.303	-.480**	.629**	.673**	-.492**	1

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Source : Computed result summary from Pearson correlation matrix based on raw statistical data of NMSA and GWARDO (1994-2021).

4.2.2. Effects of climate variability on wheat production by multiple Regression models

In order to compute the correlation coefficients that exist between major crop (wheat) and climatic parameters (rainfall and temperature) are mentioned below in the study area metrological stations. The identified descriptive variables were namely; total *kiremt* rainfall (JJAS), *kiremt* maximum temperature and *kiremt* minimum temperature. Wheat yield were regressed on these variables by employing regression procedure to see the variation in yield and the result is shown for Chefe Donsa station in Tables 9. The average grain yield of wheat is very low in Ethiopia as compared to other growing countries of the world. This is due to many constraints one of the major problem is climate change effects on the productivity of wheat crop. The actual impacts of climate parameters (average annual temperature, total annual and summer rainfall) on wheat were investigated using multiple regression models. The model also showed the relative contributions of the independent variables to productivity. The following table displays the effects of climate variability on wheat productivity in the study area.

Table 9: Regression analysis

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Mean square	F	Sign	Df
1	.695[a]	.483	.393	13.91761	1041.019	5.374	0.003[b]	4

a. Predictors: (Constant), annual max and min tem, annual and summer rainfall at chefedonsa,

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	T	Sig.
1	(Constant)	-117.432	70.416		-1.668	.109
	Annual rainfall	.007	.040	.061	.184	.856
	Maximum	7.303	2.551	.483	2.863	.009
	Minimum	-3.542	1.620	-.396	-2.186	.039
	Kiremt rainfall	-.022	.056	-.137	-.394	.697

a. Dependent Variable: Wheat production per ha

Source : Computed result summary from Pearson correlation matrix based on raw statistical data of NMSA and GWARDO (1994-2021).

From Table 9, the regression or prediction equation had been determined using the following equation by regressing wheat yield on some selected climatic variables mentioned above. Y (Wheat) = -117.432 + 0.077 +7.303 – 3.542 - 0.022 (Equation 8) Where, Y = wheat yield (qt/ha), X1 = Annual rainfall (mm), X2= maximum temperature (^{o}C) and X3= minimum temperature (^{o}C), X4= Kiremt rainfall(mm).

The result of the multiple linear regression analysis at Chefe Donsa Station showed that the coefficient of regression (R^2) was 0.483 that means (48.3%) of wheat production variations on study area caused by annual and summer rainfall, max tem and min tem temperature factors, whereas the remaining (51.7%) of the variation in above crop production could be explained by other climatic and non-climatic factors.

The above regression model represents that given a unit change in any of the rainfall and temperature variables included in the study above will brought a change in wheat yield. Annual rainfall and maximum temperature have positive effect on yield of wheat. The highest variation in yield of wheat in the area will be experienced by maximum temperature (7.303qt/ha) and lower variation of *kiremt* rainfall (0.022ql/ha). Maximum temperature has higher positive impact on wheat yield, meaning that there was higher yield of wheat under years of maximum temperature getting higher. The annual rainfall has positive effect on yield of wheat meaning yield of wheat was higher in the years with increasing annual rainfall. Also *kiremt* minimum temperature has negative effect on yield of wheat meaning yield of wheat was lower in the years with decreasing minimum temperature. According to Bekele (2017) in Sinana district, South Eastern Ethiopia, wheat yield was influenced negatively and positively by duration of the rainy season, *kirem*t rainy days and *kiremt* rainfall total, respectively.

Table 9 shows a significant correlation between wheat productivity and annual rainfall, summer rainfall, maximum temperature, and minimum temperature. This means that an increase of 1^0c in the minimum temperature is likely to cause a decrease of 3.542 quintals of wheat yields per hectare per year at study area. Increasing of 1 °C in annual maximum temperature causes increasing in 7.303quintals of wheat yields per hectare per year at the study area, whereas increased in 1 mm of annual rainfall was causes increasing by 0.007qut wheat and increased in 1mm of summer rainfall was causes decreasing by -0.022 quintal of wheat yields per hectare per year at the study area (Table 9). Lobell *et al.* (2012), using nine years of data from north-western India, found that crop models underestimate yield losses from high temperature as much as 50% for some sowing dates. These results imply that warming presents an even greater challenge to wheat than implied by previous modeling studies and that the effectiveness of adaptations will depend on how well they reduce crop sensitivity to very hot days.

On the other hand, the regression result also shows the effects of the maximum and lowest temperatures as well as the total yearly rainfall. The most important variables influencing the variability and decline of wheat productivity in the study area are maximum and minimum temperatures, summer rainfall, and total annual rainfall, even though Table 9 shows no evidence of a significant effect. Since the p value is less than 0.05 at a 5% level of confidence, yearly rainfall, summer rainfall, and mean annual temperatures all significantly affect the amount of wheat produced annually. Furthermore, only about 60.1 percent of the independent variables (predictors) or 43.4 percent of the dependent variable's adjusted R can be used to explain the independent variables (productivity).

Therefore, the p value for the total annual rainfall is 0.05, indicating that there is a substantial impact on the variation or drop in wheat production across the years taken in to account. The p value of annual rainfall, summer rainfall, mean average temperature, and mean annual temperature, however, is > 0.05, indicating that there is no discernible consequence to the variation or drop in wheat production over the years taken into consideration. Therefore, the findings of this research agreed with Aliyi (2017) that climate variability can affect wheat production through the direct effects on yield via physiological processes, through changes in sowing dates or increased rainfall, and through changes in the areas under production and as regions become more or less unsuitable for wheat due to climate variability.

According to the survey result of this study, respondents suggested that some climate related factors in the study area as having a significant impact on wheat yield found to be presented in a descending order. Erratic rainfall, increasing temperature, excess rainfall and flood and low temperature were the major factors in the study area. The fluctuation of climatic variables has a great impact on timing of farming activities (land preparation to sowing) and on growth and development of plants and yield become reduced as a result of drought or excess rainfall/flood or unpredicted rainfall during harvesting time. This erratic rainfall and increasing temperature during the rainy season influenced productivity of farmers in wheat production. This unpredictable rainfall characteristics and increasing temperature associated with drought and flood results in loss of the upper most fertile soil and decrease soil fertility through soil erosion and this eventually leads to reduction in crop yield and then to food insecurity of farmers in the study area.

4.3. Major Adaptation Strategies to Climate Variability Effects on Wheat Crop Production

Model fitness was assessed using the chi square statistic. The chi- square value 36.846 and P-value was less than 0.05. This proves that there is a significant relationship between dependent and independent variables the final model. The Pseudo R - square measures are Cox and Snell (0.108), Nagelkerke's (0.170) and Mc Fandden (0.114). The model accounts for 10.8% to 17% of the variance and represents relatively decent- sized effects. In addition, the model summary revealed that Nagelkerke R-square (Pseudo R^2= 0.170), which means that the outcome variable explained by 17% via independent variables (Table 10).

Table 10: The result of Multi- nominal Logistic regression analysis

Model Fitting Information				
	Model Fitting Criteria	Likelihood Ratio Tests		
Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept only	58.507			
Final	21.660	36.846	5	.000

Pseudo R-Square		
Cox and Snell	Nagelkerke.108	McFadden
.108	.170	.114

Parameter Estimates						
Variable	B	Std. Error	Wald	Df	Sig.	Exp(B)
Intercept	1.179	.572	4.249	1	.039	
Practicing crop diversification	-.507	.627	.656	1	.418	.602
Using mixed farming	1.375	.693	3.933	1	.047	3.956
Improve agronomic	.306	.632	.234	1	.629	1.357
Practicing small scale irrigation and water conservation	-2.565	.976	6.911	1	.009	.077
Agroforestry	.495	.724	.467	1	.494	1.641
Using diversified income source	0^b	.	.	0	.	.

Source: survey, 2022

According to the survey result, various adaptation strategies were being employed by farmers in response to climate variability in the study area. The surveyed household heads who have observed climate variability in the previous years were asked about their adaptation strategies in face of climate variability in the study area. The sample household heads in the selected three agrological zones of *Dega* (Qersa Rega kebeles), *Weynadega* (Areda Gora and Jegol Nechidigay kebeles) and *Kolla* (Somsa kebeles) were asked either they were using adaptation measures or not against variable climatic conditions and they were requested to respond Yes' or No' with their explanation through questionnaire (Table11).

The table shows that about 94.8% from *Dega* agro ecological zone had been taken different adaptation measures against changing climate and the remaining 5.2 % respondents had not taken any adaptation options to climate variability respectively in the study area. While 93.4% and 94.3(%) of respondents from *Weynadega* and *kola* agro ecological zone had been taken adaptation measures and the remaining 6.6% and 5.7(%) of the respondents had not taken an adaptation options to climate variability respectively in the study area. In general, *Dega, Weynadega* and *Kolla* agro ecological zone respondents of 94.1% had taken an adaptation measures like crop diversification, changing planting date, using improved/ selected crop varieties, using chemical fertilizers, practicing soil and water conservation practices and other agronomic practices.

However, farmers were practicing different adaptation mechanisms; they are less productive in crop production particularly in wheat because their adaptation mechanism was mostly based on their indigenous knowledge and not integrated with new technologies. The remaining 5.9% respondents had not taken any adaptation options to climate variability effects and they were more vulnerable to food insecurity problem in the study area. When compared to the farmers between the three agro ecological zones, the respondents who perceived and take adaptation measures from *Dega, Weynadega* and *Kolla* agro-ecological zone are relatively similar in the study area. Hence, about 5.2%, 6.6% and 5.7% of the respondents did not yet perceived and taken any adaptation measures to climate variability from *Dega, woyinedega* and *kolla* agro-ecological zone respectively. Therefore, *Weynadega* farmers had taken less adaptation strategies as compare to *Dega* and *Kolla* agro-ecological zones.

Table11. Adaptation options of farmers to climate variability across agrological zones

No	Agro ecology	Adaptation options taken by HHHs in (%)	
		Yes (%)	No(%)
1	Dega	94.8 (%)	5.2(%)
2	W/Dega	93.4(%)	6.6(%)
3	Kolla	94.3(%)	5.7(%)
	Total	94.1(%)	5.9(%)

Source: survey, 2022

However, these adaptation options are employed very small in amount and area coverage thus it is advisable to introduce and expand new technologies for all farmers to adapt climate variability effects in the study area. According to information from respondents, lack of weather and climate information for the farmers' to adapt to climate variability was another hindrance for climate variability adaptation in the study area. An agronomic adaptation measures most commonly used by farmers in the study area were using chemical fertilizers, fallowing, crop rotation, pest and weed control and other agronomic practices.

According to the survey result from (Table12) most of the farmers (78.3) used chemical fertilizers for adapting climate variability impacts by improving soil fertility to increase productivity. According to the survey result of the respondents, using chemical fertilizer is the most commonly practicing adaptation measure in the study area. Accordingly, most of the farmers had been used chemical fertilizers (DAP and Urea) to increase productivity in crop/wheat production in the area. But due to improper way of using, lack of knowledge and high price of fertilizer coupled with low awareness of farmers in use of agricultural technologies is hindering to get the expected high yield per a plot of land in the area. As a result productivity of farmers in wheat become declining from time to time. Also 9.9(%), 8.4(%), 2.5(%) and 0.9% used crop rotation, pest and weed control, agronomic practices and fallowing respectively to adapt climate variability in the study area.

Table 12. Land and wheat crop management adaptation measures used by farmers

No	Adaptation measure	No of HHHs used adaptation measure in (%)
1	Manuring /using chemical fertilizers	78.3
2	Crop rotation	9.9
3	Pest and weed control	8.4
4	Fallowing	0.9
5	agronomic practices	2.5
	Total	100

Source: survey, 2022

As a result, adopted or recently developed adaptation strategies can be included into more comprehensive and sustainable adaptation plans that also incorporate practices based on local knowledge. From the survey result (Table 13) majority of the farmers (85.7%) adapt climate variability by using both modern and local adaptation strategies.

Table13: types of adaptation strategies farmers used to respond effect of climate variability

No	Types of adaptation strategies	No of HHHs used types of adaptation strategies in (%)
1	Local adaptation strategies only	8.1
2	Modern adaptation strategies only	6.2
3	Both adaptation strategies	85.7
	Total	100

Source: survey 2022

According to the survey result, 20.8%, 21.7%, 20.9% and 14.8% of Qersa Rega, Jegol Nechdingay, Areda Gora and Somsa Kombolcha kebeles farmers respectively were used mixed farming in the four sample *kebeles.* Finally, about 78.2% of respondents confirmed that some farmers have been practicing mixed farming to adapt the changing climate; both crop production and livestock production in combination to adapt adverse impact of the changing climate. This is because to increase income level and also they might be productive either of the two at the time of climatic shocks or hazards (drought, flood, famine).

The survey result showed that about 8.55% of respondents were used crop diversification and improved wheat seed to adapt to climate variability in the study area (Table14). Most of the farmers adapting rainfall and temperature variability impacts by diversifying crop types; producing more than one crop or producing different types of crops in their plot of lands. This is because of different crops have different adaptation capacity in adapting ever changing climatic conditions. For example, maize can adapt in shorter rainfall condition more than wheat as wheat requires maximum amount of rainfall, in this case farmers might be more productive in maize production than wheat. Based on this fact, farmers have been practicing producing wheat, *teff,* barley, maize and sorghum in combination rather than depending on a single crop in the study area. This is more common in midland (*Weynadega)* agro-ecological zone *kebeles* than *kebeles* found in *dega* (highland) in the study area.

According to respondents, diversifying crop types are more common in midland *(Weynadega) kebeles* of Jegol Nechdingay and Areda Gora than the highland *(dega) kebeles* of Qersa Rega because midland (*Weynadega)* is more suitable to diversify and produce different types of crops as having moderate temperature condition. According to the respondents, many crop varieties have been introduced from these (*Dendea* and *Qeqeba)* improved wheat varieties were widely introduced and better accepted because of matching to some extent with the current climatic situation in the area. Key informants from the Woreda agriculture office also suggested that the government is supplying new varieties of crop seeds (improved wheat) and chemical fertilizers (DAP and Urea) to increase productivity of farmers in their field. Nevertheless, the high price of seeds and fertilizer coupled with low awareness of farmers in use of agricultural technologies is hindering to get the expected high yield per a plot of land in the area.

When questioned, model farmers stated that "farmers employ enhanced wheat seeds, such as Qeqeba and Dendea wheat seeds, respectively, in the research area when the rain is late and early." Gimbichu Woreda's primary wheat crop products are Qeqeba and Dendea wheat seed.

Farmers are more likely to adopt new practices when they closely align with current ones and the social and environmental context, according to past experience with agricultural technologies and resource management (during the survey, HHHs were asked to differentiate between the listed strategies they adopted to adapt to the impact of climate variability and their response) (Table 14). In addition to the field observation study, a key informant interview with one agricultural expert revealed that some *kebeles* frequently use small-scale irrigation methods. Respondents were involved in small-scale irrigation practices directly from the streams (2.94%). In the study area, the main sources of this practice were the Kessem and Mojo Rivers. Farmers have used fruits such as mango, orange, and banana as well as vegetables like onions, tomatoes, potatoes, and cabbage in this adaptation strategy. Societies in the area benefited most from this practice for domestic purposes and in small amounts from cash sources (Field survey, 2022). Basically, people practiced eating vegetables as a coping mechanism to fend off the short-term negative effects of climatic fluctuations. Farmers stated during FGD that they have used crop diversification, pest and weed management, and modifying the planting date practice in the research area.

This result is relate with Desta (2019), report that farmers of Ethiopia practicing important adaptation options such as crop diversification, using different crop varieties, using short growing crop varieties, applying small scale irrigation, changing planting date and involving off farm activities against climate impacts. Another study found that the most common adaptation measures in the central highlands of Ethiopia included adjusting crop planting dates, soil and water conservation, crop diversification, tree planting and soil fertility management (Alemayehu and Bewket, 2017). Gebru *et al.* (2020) found that adaptation strategies in eastern Tigray include soil and water conservation, water harvesting, compost preparation to increase soil fertility, tree planting and changing the quantity of land under cultivation.

Table14. Major adaptation strategies of farmers in response to climate variability in the study area

No	Major adaptation strategies	Name of sample kebeles and No of HHH (%)				
		Qersa Rega (%)	Nechdin gay (%)	Areda Gora(%)	Somsa Kombolcha(%)	Total (%)
1	Practicing mixed farming	20.8	21.7	20.9	14.8	78.2
2	Modifying the planting date	0.8	1.3	2.33	0.6	5.03
3	Using improved variability of wheat and crop diversity	2.85	1.9	2.3	1.5	8.55
4	Using small scale irrigation	0.5	0.3	0.44	1.7	2.94
5	Soil and water conservation	0.64	1.24	1.75	1.65	5.28
	Total	25.59	25.85	27.72	20.84	100

Source: survey 2022

5. SUMMARY AND CONCULUSION

5.1. Summary

This section summarizes the study's findings and provides a brief justification for the key conclusions drawn from the investigated data. Finally, some possible recommendations were based on the discussion and main finding of the study.

Therefore, the goal of the study was to look at rainfall and temperature variability and trends as well as to evaluate how climate variability affects wheat crop production and adaptation methods using data from four sample *kebeles* in the Gimbichu woreda. Both the concurrent mixed research approach and the descriptive research design were used. 322HHHs were chosen as a sample of the population using a simple random sampling procedure. Data from both primary and secondary sources was used.

Primary data sources were 322 HHHs respondents for the survey questionnaire, 20 participants in four FGDs, and 12 participants in the key informant interview. To collect primary data, instruments such as FGD, key informant interviews, semi-structured survey questionnaires, and survey field observations were used. Government office records of socioeconomic demographics, wheat production in qt/ha, rainfall, and maximum and minimum temperature data were used as secondary data sources (1994–2021). NASA (1994-2021) collected data on daily rainfall, maximum temperature, and minimum temperature for the meteorological stations at Chefe Donsa.

The qualitative data collected were analyzed and narrated in words using the text analysis method. XLSTAT version 2014.5.03 and SPSS version 25 were used to analyze statistical results. The Mann-Kendall time series trend test method was used to assess trends of climate variability (rainfall and temperature). The Pearson correlation and linear regression analysis were used to determine the relationship and effect of rainfall and temperature on wheat yield.

The study area annual rainfall ranged from 591.1 to 1080.9 mm with mean rainfall amount of 847.0mm. The minimum annual rainfall total amount of 591.1 mm and the maximum annual rainfall amount of 1080.9 mm, which are recorded on 2015 and 2020year respectively. Furthermore, Mann-Kendall trend showed that annual rainfall trend was increased by factors of

2.29mm per year, while *belg* and *kiremt* seasonal rainfall where decreased by factors of -20.89 and –7.39 mm/year respectively, and seasonal and annual rainfall trend statistically significant.

The result indicated that at the study area, annual maximum temperature ranged from 23.9 to 27.9°C with the average value of 26.0 °C showing upward increasing trend by a factor of 0.089 °C /year, while the annual minimum temperature ranged from 9.5 to 13.2 °C 13.48 to 16.05 °C with an average value of 11.5 °C. Mann-Kendall trend test revealed that *belg*, *kiremt* and annual minimum temperature trend decreased by factor of -0.0573, -0.0275 and -0.0673 °C/year respectively. The *belg*, *kiremt* and annual maximum temperature showed an increasing trend by 0.089 °C. Wheat crop output at the research area was considerably impacted by the minimum temperatures of meteorological stations throughout the duration of (1994–2021).

Monthly SD of maximum temperature varies between 4.5°C and 6.5°C with CV varying between 1% and 1.3%, while monthly SD of minimum temperature varies between 0.5 to 2.4 °C with their CV between 3.5 and 27.9 °C. Generally, maximum temperature increased means the district vulnerable to shortage of rainfall was critical problem for household on study area. The annual rainfall variability was characterized by fluctuation of wet and dry years.

Rainfall and temperature insatiability had effects on crop production on study area. Climate variability and wheat crop production show that year-to-year variability. Pearson Correlation Coefficients for annual minimum temperature against crop production shown negative correlations for Wheat (r = -0.480), whereas annual rainfall and annual mean maximum temperature against crop production revealed that positive correlations for Wheat (r = 0.266) and (r=0.673) respectively. According to Table 8, the results of the Pearson method of correlation analysis showed that the maximum temperature at Chefe Donsa indicated significant strong positive values at P value 0.05 for the relationship between main cropping and growing seasonal temperature for wheat.

Majority of the farmers (785.2%) adapt climate variability by using mixed farming (crop and livestock production) practice. According to the survey result from (Table11) most of the farmers (78.3) used chemical fertilizers for adapting climate variability impacts by improving soil fertility to increase productivity. From the survey result (Table 12) majority of the farmers (85.7%) adapt climate variability by using both modern and local adaptation strategies. These were some of the major adaptation strategies used by farmers in response to variable climate in the study area.

5.2. Conclusion

The overall inquiry outcome showed that there was significant long-term climate variability from 1994 to 2021, as evidenced by meteorological data and the responses from the farmers (house hold heads). The majority of the rural households indicated that they had observed increased temperatures and decreased rainfall amounts in distribution. This implies that the research area's community level is where climate variability has an effect. Analysis Concerns with climate variability and trend, monthly, annual, *kiremt* and *belg* temperature and rainfall trend were analyzed. Additionally, Coefficient of Variation (CV), standard deviation (SD) and mean were used to determine the variability. Pearson Correlation Coefficients for annual minimum temperature against crop production shown negative correlations for Wheat ($r = -0.480$), whereas annual rainfall and annual mean maximum temperature against crop production revealed that positive correlations for Wheat ($r = 0.266$) and ($r=0.673$) respectively. The findings showed that the research area's wheat production was negatively impacted by the yearly rainfall decrease, which was evident in *belg* in terms of intensity and amount. The local community was highly dependent on seasonal and annual rain-fed agriculture.

Farmers have devised a variety of tactics to deal with the effects of climate variability and to control future patterns of climate variability in response to long-term observed changes. Different adaptation techniques were used by farmers in the study area. The major adaptation strategies practicing important adaptation options such as crop diversification, using different crop varieties, using short growing crop varieties, applying small scale irrigation, changing planting date and involving off farm activities against climate impacts.

Finally, the objective obtained from the identified problem was successively achieved by the use of the research design, methodology, and instruments, as well as data analysis techniques. To identify negative effects of climate variability on wheat crop productivity, ownership and coordination of all these farmers' knowledge on climate variability, its impact on wheat crop production, and adaptation strategies are required.

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7. APPENDICES

HARAMAYA UNIVERSITY

POSTGRADUATE PROGRAM DIRECTORATE

Appendix 7.1. Questionnaire to be filed by Sample respondent Household Heads

Dear participants! The researcher is a graduate student in the College of Social Sciences and Humanities, School of Geography and Environmental Studies (MA in Climate Change and Disaster Risk Management Program) at Haramaya University.

Dear participant, this questionnaire is designed to gather data from household-headed farmers for the research entitled **" Effects of Climate Variability on Crop Production and Farmers' Adaptation Strategies: The case of Gimbichu Woreda, East Shewa Zone, Oromia Regional State, Ethiopia".** The information you provide will be used for research purposes only and kept strictly confidential. The researcher would like to kindly request that you give your credible response to each question, as your response is very helpful for the credibility of the research and the reliability of the implications. Also, the researcher would like to underline that there is no right or wrong answer. This means your idea is right by what you responded with. Thank you very much for your cooperation!

General Information

Questionnaire number: ____

Date: ____

Enumerator's name: ____

Thank you in advance!

Part I: Personal information

1. Full name ____
2. Sex ____________ Age__________Kebele______________________
3. Types of activities ____
4. Farming experience ____
5. Family size ____
6. Source of income ____

Part II: Information on climate variability

1. Is there climate Variability in your environment from 1994-2021G.C?

   1. Yes 2. No

2. What are indicators of climate variability on your area?
3. If there is climate Variability, which of the following climate variables affect your crop production status.

S/No.	Climatic variable	Please, tick (√)	
		Yes	No
3.1	Temperature variability		
3.2	Rainfall variability		
3.3	Pests and diseases caused by climate variability		
3.4	Frost		
3.5	Snow		
3.6	Flood		
3.7	Cupping glass		
3.8	Drought		

4. Have you seen any long-term variability of rainfall and temperature for the last 28 years? If you say yes, how do you detect, and what is the reason to variability?

   ____

   ____

5. If your answer for #4 is yes, did it affect your crop/wheat? Yes/No, if yes how much/to what extent?

   ____

   ____

6. Have you ever faced any hazard related to rainfall risk in your locality which altered your wheat production in the past 28 years? Yes /No
7. If #6 is yes, what type of climate related hazards?
   1. Excess Rainfall 2. Drought 3. Erratic Rainfall 4.All 5. Others_______________
8. If the answer to Q6 is yes, did it affect your wheat productivity? Yes / No
9. During which season you plant/produce wheat in your area?
   1. Belg season 2. Kiremt/Meher season 3. In both seasons
10. In which area or agro-ecological zone wheat mostly grown in your area?
    1. Dega 2. Weynadega 3. Kola
11. Have your wheat agricultural activity shifted due to risks associated with temperature variability? 1. *Increasing maximum annual and kiremt temperature*
    2. Decreasing maximum annual and *kiremt* temperature
    3. Increasing minimum annual and *kiremt* temperature
    4. Increasing minimum annual and *kiremt* temperature
12. At which growing stage of wheat did more climatic hazards happen?
    1. Initial growing stage 2. Vegetative stage 3. Flowering stage 4. Harvesting stage
13. What are the general adaptation practices of farmers towards climate variability and its impact on crop/wheat productivity in your area?

    ____

    ____
14. Did you take any Adaptation measures? Yes/No
15. What type of Adaptation measures did you practice? When did you start taking these measures?(year) How did you learn these methods?
16. What types of agricultural decisions/adaptation measures taken in response to variable climate?

    ____

    ____

    ____

    ____
17. Have you participated in any community based adaptation strategies to minimize the observed climate variability impact in your locality? 1. Yes 2. No

18. If your response for question # 19 is yes, in what strategies have you participated?

____

____

____

____

19. Which adaptation strategies have you applied in order to minimize the negative impacts of climate variability on wheat crop production?.

Modern only 2. Local only 3. Both strategies

20. Which adaptation strategies have you applied when the rainfall comes late and stop early

1. Early farming practice 4. Selecting adaptive seed
2. Late farming practice 5. Early harvesting practice
3. Changing date system

21. What activities are done by government and non-government institutions to cope with the impacts of climate variability at your area?

____

____

____

Appendix7.2. Check List for Key Informant Interview

My name is Itabezaw Mekasha. I am an MA student at Haramaya University and am studying for my Master's Degree in Geography and Environmental Studies. Conducting my master's thesis on **Effects of Climate Variability on Crop Production and Farmers' Adaptation Strategies: The case of Gimbichu Woreda, East Shewa Zone, Oromia Regional State, Ethiopia.** You have requested kindly to give responses based on the provided questions regarding the title. Consequently, your feedback has made a great contribution in constructing this thesis and made my study more fruitful.

Thank you in advance for your contribution!!!

1. Is there any variability in temperature and rainfall in Gimbichu woreda in the past 28 years?
2. What do you think are the causes of climate variability?
3. What are the effects of climate variability on the community livelihood that you have seen so far?
4. Have you ever faced any climate related hazard in this locality related to rainfall characteristic and temperature? Yes / No If yes what was the trend in the past 28 years?

   - ✓ Rainfall; increasing ____ decreasing ______
   - ✓ Temperature; Increasing _____ decreasing _____

5. If yes, did it affect wheat production? Yes / No how much is its extent? ____
6. What are the observed indicators of climate variability?
7. What are the main effects of climate variability on wheat crop production in your area?
8. What are the local coping mechanisms used to reduce the impact of climate variability?
9. How do you adapt to the impact of climate variability on wheat crop production in your area?
10. What adopted adaptive strategies did you apply to minimize the adverse impact of climate variability on wheat crop production?

Appendix7.3. Check List for Focused Group Discussion (FGD)

My name is Itabezaw Mekasha. I am an MA student at Haramaya University and am studying for my Master's Degree in Geography and Environmental Studies. Conducting my master's thesis on **Effects of Climate Variability on Crop Production and Farmers' Adaptation Strategies: The case of Gimbichu Woreda, East Shewa Zone, Oromia Regional State, Ethiopia.** Hence, I would like to express my thanks for your cooperation in giving me your time and being committed to the success of this study.

Thank you in advance for your cooperation

Part 1: Leading questions for FGDs

1. Have you observed any change in rainfall and temperature trend over the past 28 year?
2. Do you think there is climate variability in your area?
3. Have you ever noticed any kind of rainfall and temperature related hazard which affect the locality on wheat production? Yes / No If yes explain briefly its extent on wheat yield?
4. Do you use rainfall and temperature information? Yes / No If yes for what purpose?
5. What is your plan to flourish wheat agricultural productivity under variable rainfall and temperature
6. To adapt, what is the response of farmers, governments, and non-governmental organizations?
7. What effects have temperature and rainfall variability had on wheat crop production from 1994 to 2021?
8. What are the best adaptation strategies employed by farmers, governments, and non-governments?
9. What is your future plan in increasing wheat production under variable rainfall and temperature?

Appendix Table 1. Chefe Donsa Station Annual Rainfall Data (1994-2021)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994	0.0	12.0	12.1	31.6	25.4	94.1	247.0	166.8	92.6	1.3	10.5	3.6
1995	0.2	23.7	59.2	69.4	13.9	40.6	168.4	225.9	71.3	5.3	0.1	4.4
1996	62.2	2.0	81.5	32.7	91.5	174.1	252.0	230.2	71.0	0.2	3.6	0.0
1997	32.2	0.0	25.1	32.8	12.1	73.0	147.9	135.7	66.6	67.4	18.8	0.1
1998	19.1	46.1	48.4	27.5	28.3	87.3	218.1	264.9	98.2	38.3	0.0	0.0
1999	0.1	0.0	23.2	0.2	14.4	86.6	236.4	266.4	49.3	29.3	0.0	0.2
2000	0.0	0.0	23.5	30.3	19.9	96.8	166.4	228.0	83.5	13.1	2.7	0.3
2001	0.1	23.6	110.9	18.4	69.7	91.5	204.3	106.2	47.4	0.8	0.0	6.3
2002	0.8	1.2	42.6	19.8	18.2	61.2	158.6	267.0	55.6	0.1	0.0	12.3
2003	12.3	44.0	53.8	79.9	0.3	75.8	230.5	334.3	114.3	0.2	1.0	15.4
2004	14.0	1.5	37.6	74.0	4.2	122.0	224.2	189.5	107.7	1.0	5.2	0.7
2005	48.8	1.0	48.0	141.6	98.7	133.9	189.3	189.8	85.1	0.4	0.4	0.0
2006	2.4	11.7	29.9	147.6	28.1	96.7	346.3	170.6	147.8	22.3	0.2	19.2
2007	29.0	15.2	54.2	77.8	69.2	177.6	219.4	325.7	105.5	0.9	2.3	1.0
2008	0.2	0.0	0.0	41.5	85.1	72.9	313.6	265.0	87.5	11.4	29.7	0.0
2009	53.9	0.8	22.5	23.0	63.9	51.6	276.2	331.4	64.5	1.3	13.0	24.2
2010	0.1	47.3	28.3	101.6	90.0	144.6	250.4	180.4	159.4	0.5	0.2	7.5
2011	0.1	0.3	47.4	29.7	33.4	68.3	164.9	277.3	109.5	2.4	0.2	0.0
2012	0.0	0.0	11.4	89.2	61.1	136.4	239.6	314.1	104.3	0.0	0.6	0.4
2013	1.2	0.0	52.5	53.9	42.3	85.9	259.3	261.8	144.0	42.8	3.4	0.1
2014	0.3	24.7	21.1	5.8	36.4	62.1	203.0	268.1	83.6	39.0	1.8	0.0
2015	0.0	1.0	15.2	0.4	61.4	92.6	139.3	205.9	71.2	1.4	2.5	0.2
2016	18.8	0.8	30.2	151.8	79.2	109.8	230.6	155.6	82.0	4.9	10.6	0.1
2017	0.0	48.7	20.6	12.1	163.1	55.1	251.5	257.0	188.6	0.6	0.0	0.0
2018	1.2	35.8	10.0	58.4	28.0	113.8	279.6	280.4	71.9	8.0	12.0	0.0
2019	50.9	0.8	22.5	23.0	63.9	51.6	276.2	331.4	64.5	1.3	13.0	24.2
2020	32.0	15.2	54.2	77.8	69.2	177.6	219.4	325.7	105.5	0.9	2.3	1.0
2021	17.0	1.5	37.6	74.0	4.2	122.0	224.2	189.5	107.7	1.0	5.2	0.7

Source: NASA, 2022

Appendix Table 2. Chefe Donsa Station Maximum Temperature Data (1994-2021

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994	22.8	23.9	24.4	24.9	25.2	23.2	20.2	19.8	20.8	21.2	20.2	20.7
1995	22.1	23.9	23.8	23.1	24.4	24.4	20.5	20.6	21.5	20.9	20.7	21.0
1996	21.4	24.3	23.8	23.8	23.6	20.9	20.4	20.8	21.9	21.9	20.9	20.9
1997	21.7	23.1	24.9	23.3	25.5	23.8	21.2	21.7	23.6	21.6	20.3	21.3
1998	21.8	23.3	23.0	25.1	24.9	25.2	20.7	20.0	20.8	20.7	20.7	20.5
1999	21.7	24.0	22.7	25.1	25.7	24.9	19.7	20.4	21.2	20.8	20.4	20.5
2000	22.1	23.1	24.6	24.0	24.8	23.0	20.4	19.4	22.1	21.3	20.5	20.8
2001	21.3	22.7	22.0	23.9	23.8	21.8	20.7	20.0	21.5	22.4	21.7	21.2
2002	21.0	24.3	23.6	23.8	25.7	24.8	22.6	22.0	22.3	22.8	22.1	21.1
2003	22.1	24.3	23.7	23.2	25.8	23.7	20.2	20.6	21.2	21.9	21.5	20.4
2004	22.6	22.7	23.4	22.8	26.1	23.3	21.2	21.1	21.8	21.6	21.2	21.5
2005	21.7	24.3	24.5	24.6	23.5	23.2	20.9	21.7	21.9	22.5	21.9	21.6
2006	22.7	24.4	25.0	24.2	25.3	23.7	21.2	20.7	21.7	22.4	21.4	21.0
2007	22.8	24.3	25.2	24.2	25.9	23.1	20.9	21.4	22.6	22.2	21.5	21.7
2008	23.3	22.8	24.9	25.2	25.2	24.2	21.7	21.3	23.0	23.3	22.1	23.4
2009	22.9	24.1	26.9	26.2	26.8	27.8	22.6	22.6	24.3	22.9	22.7	23.5
2010	24.5	25.6	24.4	26.3	26.2	25.4	22.4	23.0	23.7	24.6	24.0	24.4
2011	25.1	26.2	25.4	27.1	26.8	26.3	22.7	22.2	23.3	23.3	23.7	22.7
2012	24.5	25.0	27.3	25.8	27.0	26.6	22.4	21.0	24.1	23.7	24.8	24.5
2013	25.5	26.5	27.4	26.9	26.7	25.8	21.9	21.9	24.5	23.4	22.5	22.5
2014	24.2	26.0	26.0	25.8	26.0	26.5	22.9	22.3	22.6	21.5	22.2	22.2
2015	22.9	25.5	25.4	26.2	25.8	26.3	24.6	23.7	24.4	24.3	23.3	22.3
2016	24.6	25.2	27.9	25.4	25.4	24.4	22.7	20.9	23.5	22.4	22.1	21.6
2017	22.7	24.2	26.5	25.6	24.3	26.5	21.4	21.5	22.4	22.3	21.9	21.8
2018	22.4	24.4	24.3	23.9	24.7	23.6	21.6	22.2	22.9	23.4	22.6	22.9
2019	25.5	26.5	27.4	27.9	26.7	25.8	21.9	21.9	24.5	23.4	22.5	22.5
2020	24.6	25.2	27.9	25.4	25.4	24.4	22.7	20.9	23.5	22.4	22.1	21.6
2021	22.7	24.2	26.5	25.6	24.3	26.5	21.4	21.5	22.4	22.3	21.9	21.8

Source: NASA, 2022

Appendix Table 3. Chefe Donsa Station Minimum Temperature Data (1994-2021)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994	8.0	10.8	13.5	14.4	13.9	13.1	13.7	13.3	12.4	10.3	9.8	9.1
1995	9.2	12.2	13.9	14.7	14.1	12.6	13.6	13.9	12.1	11.6	9.7	11.5
1996	11.8	11.4	14.3	13.7	13.7	13.7	13.2	13.7	12.5	10.7	9.8	8.9
1997	11.9	10.2	13.9	13.9	13.8	14.1	13.8	13.8	13.3	13.3	12.6	9.9
1998	12.8	14.1	14.7	15.2	14.5	13.8	14.5	14.3	13.5	12.2	8.4	7.6
1999	9.8	10.2	13.5	14.3	13.7	13.2	13.4	13.5	13.0	12.1	8.1	8.5
2000	9.0	10.3	12.5	14.3	13.3	13.0	13.7	13.7	13.4	11.6	10.5	9.9
2001	10.2	11.1	13.7	13.8	14.1	13.3	13.9	14.5	12.6	11.9	9.8	10.1
2002	11.4	11.8	14.3	14.4	13.7	14.2	14.3	14.1	13.3	12.2	10.8	12.6
2003	11.4	13.0	14.0	15.1	14.1	14.1	14.2	14.4	13.7	11.2	11.4	10.0
2004	10.8	10.7	10.5	11.9	9.9	11.9	13.1	13.0	11.9	8.4	7.3	8.3
2005	8.1	8.0	12.1	12.3	13.1	12.2	13.0	13.6	12.6	8.2	7.4	3.9
2006	7.9	10.3	10.5	12.1	11.2	12.5	13.5	13.8	12.2	10.6	8.4	10.5
2007	10.0	11.8	11.7	13.2	13.2	13.3	13.8	13.6	12.8	7.1	11.2	10.9
2008	9.0	10.1	9.3	12.7	12.5	13.2	12.9	12.9	12.0	9.0	7.8	5.1
2009	8.4	9.2	11.5	12.6	12.1	12.4	13.7	13.8	11.8	9.2	5.5	10.0
2010	7.8	12.2	11.9	13.3	13.4	12.0	13.6	13.8	12.3	8.9	6.9	5.9
2011	7.5	7.8	10.6	12.5	13.3	13.1	13.4	13.6	11.7	7.4	9.1	4.7
2012	5.3	5.7	8.2	12.8	11.6	13.1	13.1	13.0	11.6	7.0	6.1	6.3
2013	6.6	7.8	12.5	12.9	13.0	12.7	12.4	11.9	10.5	8.8	8.8	5.7
2014	7.7	10.9	12.5	13.0	13.0	12.3	14.1	13.2	12.7	9.5	8.5	6.5
2015	6.0	8.5	11.3	11.9	13.0	12.6	13.7	13.6	12.3	10.4	10.0	10.3
2016	10.5	9.9	13.3	15.1	12.6	11.9	14.1	13.4	12.2	12.3	8.0	8.1
2017	4.5	9.9	11.5	12.7	13.4	12.6	14.0	14.0	13.0	10.5	10.5	5.4
2018	3.9	11.8	13.4	14.4	13.6	11.9	13.7	12.4	10.2	8.2	8.9	7.0
2019	7.7	10.9	12.5	13.0	13.0	12.3	14.1	13.2	12.7	9.5	8.5	6.5
2020	4.5	9.8	11.5	12.7	13.4	12.6	14.0	14.0	13.0	10.5	10.5	5.4
2021	10.5	10.9	13.3	15.1	12.6	11.9	14.1	13.4	12.2	12.3	8.0	8.1

Source: NASA, 2022

Appendix Table 4. Gimbichu Woreda Data on Farm land in ha and Wheat Production in Quintal (1994-2021)

Year	Total farm land size for wheat production per hector	Trend of wheat production	Total wheat in Quntal
1994	19585.25	24	470046
1995	25,532.50	32	817040
1996	19585.25	30	587557.5
1997	24401	17	414817
1998	26405	18	475290
1999	27645	18	497610
2000	25777.8	22	567111.6
2001	25589.75	22	562962.4
2002	21075	20	421,500
2003	21876.2	25.75	563,312.15
2004	21984.3	26	571,591.80
2005	22345.8	29.5	659,201.10
2006	20889.5	28	584,906
2007	25,532.50	30.75	785127
2008	25,045.90	30	751377
2009	25801	34.7	895,294.70
2010	25047	34	851,598
2011	20671	36.5	754,491.50
2012	19585.25	45	881,336.25
2013	22274	64.5	1,436,673
2014	23687.5	63	1,492,312.50
2015	22629	61.5	1,403,983.50
2016	24401	62	1,512,862.00
2017	25137	62	1,558,494.00
2018	27474	62.5	1,717,125.00
2019	28753	63	1,811,439.00
2020	29350	64	1,873,400.00
2021	29351	64	1,873,409.00

Source: GWARDO, 2022