MEKELLE UNIVERSITY

College of Dryland Agriculture and Natural Resources

Department of Agricultural and Resources Economics

Ph.D. Program in Climate Change and Rural Development

Food Insecurity in the Drought-prone Rural Areas of Tigray, Ethiopia: Associated Precipitation Variability and Response Mechanisms

Tewelde Gebre Berhe

21 March 2025

Dissertation Supervisors:

Zenebe Abraha (PhD), Mekelle University, Mekelle, Tigray

Amanuel Zenebe (PhD), Mekelle University, Mekelle, Tigray

Woldegebrial Zeweld (PhD), Mekelle University, Mekelle, Tigray

This research was conducted under the auspices of the Department of Agricultural and Resources Economics, College of Dryland Agriculture and Natural Resources, Mekelle University, Ethiopia.

Food Insecurity in the Drought-prone Rural Areas of Tigray, Ethiopia: Associated Precipitation Variability and Response Mechanisms

Tewelde Gebre Berhe

Dissertation Submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in Climate Change and Rural Development at Mekelle University, Ethiopia.

Tewelde Gebre Berhe

Food Insecurity in the Drought-prone Rural Areas of Tigray, Ethiopia: Associated Precipitation Variability and Response Mechanisms, PhD Dissertation, Mekelle University, Mekelle, Ethiopia (2025)

DECLARATION

I, Tewelde Gebre Berhe, Registration Number/I.D. CDANR/163200/11, do hereby declare that this dissertation, entitled "*Food Insecurity in the Drought-prone Rural Areas of Tigray, Ethiopia: Associated Precipitation Variability and Response Mechanisms",* is my original work and it has not been submitted partially, or in full, by any other person for an award of any degree in any other university/institution and, to the best of my knowledge and belief, this dissertation contains no material previously published or written by another person, except where due reference has been made.

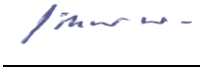
Name of Participant: Tewelde Gebre Berhe

Signature: _____

Date: 19 March 2025

APPROVALS

We, the undersigned, members of the dissertation examination committee, hereby certify that we have read the dissertation submitted by Tewelde Gebre Berhe entitled "*Food Insecurity in the Drought-prone Rural Areas of Tigray, Ethiopia: Associated Precipitation Variability and Response Mechanisms"* and recommend to the Mekelle University, College of Dryland Agriculture and Natural Resources, Department of Agricultural and Resources Economics, PhD Program in Climate Change and Rural Development to accept the dissertation in partial fulfillment of the requirement for the award of the Degree of Doctor of Philosophy in **Climate Change and Rural Development**.

Name of the External Examiners	**Signature**	**Date**
Professor Tassew Woldehanna		19 March 2025
Dr. Fitsum Hagos		19 March 2025

Name of the Internal Examiner	**Signature**	**Date**
Dr. Kidanemariam Gebreegziabher		19 March 2025

Name of the Chairperson	**Signature**	**Date**
Dr. Melaku Berhe	_____	19 March 2025

Dissertation Supervisors	**Signature**	**Date**
Dr. Zenebe Abraha	_____	19 March 2025
Dr. Amanuel Zenebe	_____	19 March 2025
Dr. Woldegebrial Zeweld	_____	19 March 2025

ACKNOWLEDGMENTS

Above all, I am thankful to the almighty God for all those wonderful things in my life! Next, I would like to sincerely thank my advisory committee: Dr. Zenebe Abraha, Dr. Amanuel Zenebe, and Dr. Woldegebrial Zeweld. I could not have reached this goal without their help in my study. I would like to take this opportunity to thank them for their continuous and unwavering support throughout my study.

I am also thankful to my family, colleagues, and friends for their encouragement and support. I am deeply indebted to my intimate friend, Tuem Birhane, for his unconditional overall support. All I can say is “May God bless you!”.

I would also like to thank my home university, Mekelle University, for hosting and providing me with the opportunity to pursue my study. Lastly, I am incredibly grateful to the Head of the Tigray region PSNP office, district-level PSNP officers, heads of health offices of *Atsbi-wenberta (Atsbi,* following the recent administrative structure), *Irob*, and *Hintalo-wejerat (Wejerat,* following the recent administrative structure) districts, food security experts of these respective rural districts, and the general study population for their consent and support during the data collection phase of the study.

Tewelde Gebre Berhe

Mekelle University, Mekelle

March 12, 2025

OUTLINE OF CONTENTS

Contents **Pages**

LIST OF TABLES

Tables **Pages**

LIST OF FIGURES

Figures **Pages**

LIST OF ACRONYMS

CCA	Canonical Correlation Analysis
CFSR	Climate Forecast System Reanalysis
CPT	Climate Predictability Tool
CSI	Coping Strategies Index
ENSO	El Niño Southern Oscillation
FCS	Food Consumption Score
FIES	Food Insecurity Experience Scale
GAM	Global Acute Malnutrition
HDDS	Household Dietary Diversity Score
HFIAS	Household Food Insecurity Access Scale
JJAS	June, July, August, September
MAM	March, April, May
MAM	Moderate Acute Malnutrition
MUAC	Mid-Upper Arm Circumference
NMA	National Meteorological Agency
NOAA	National Oceanic and Atmospheric Administration of the United States
ONI	Oceanic Nino Index
PCA	Paired Comparative Analysis
PLW	Pregnant and Lactating Women
PSNP	Productive Safety Net Program
rCSI	Reduced Coping Strategies Index
SAM	Severe Acute Malnutrition
SLA	Sustainable Livelihood Approach
SST	Sea Surface Temperature

EXTENDED ABSTRACT

Tigray is one of the food-insecure regions in Ethiopia with many people living under the condition of chronic hunger. Rigorous food security studies are vital for proper intervention mechanisms. Yet, previous food security studies have rarely addressed the four pillars of food security: availability, access, utilization, and stability. On the other hand, the impact of precipitation variability on food security is very significant. For food-insecure rural areas, understanding the nature of precipitation variability and its teleconnection has paramount importance in guiding regional and local-level decisions. However, there is a lack of information regarding the nature of precipitation variability and the degree of impact the climate factors have on the precipitation pattern of the study areas. In addition, there is limited knowledge regarding how vulnerable rural households deal with food insecurity. Furthermore, food security intervention mechanisms applied by various governmental and non-governmental agents is not studied well. Thus, this study aims to investigate the food insecurity status of the drought-prone rural areas of Tigray in relation to the associated precipitation variability, coping, adaptation, and intervention mechanisms.

This study has employed a cross-sectional study design based on a mixed research approach with primary and secondary data. For this, 363 households from three selected drought-prone rural districts, i.e. Atsbi-wenberta, Irob, and Hintalo-wejerat were studied. Primary data were collected using questionnaires, key-informant interviews, Focus Group Discussions, and observations. And, secondary data were collected from relevant archives and policy documents. Questions from Household Food Insecurity Access Scale (HFIAS) and Food Insecurity Experience Scale (FIES) were adapted to measure the food availability, access to food, and stability components of food security. And, Household Dietary Diversity Score (HDDS), Food Consumption Score (FCS), Mid-Upper Arm Circumference (MUAC), and Bitot's spot were used to analyze the food utilization aspect. Besides, the precipitation, sea-surface temperature (SST), and El Niño Southern Oscillation (ENSO) indices data for the study were used from 1979 to 2019. A Summary of descriptive statistics and Mann-Kendall tests were used to detect trends; Sen's Slope and coefficient of variation were used to analyze the magnitude of the trend and degree of variation in the precipitation pattern. Further, Pearson's correlation is used to determine the effect of ENSO, and SST variations on the precipitation using the Canonical Correlation Analysis (CCA). Data analysis techniques consisting of descriptive statistics, Coping Strategies Index (CSI), and Paired Comparative Analysis (PCA) were used to analyze the household's coping and adaptation strategies. Data regarding food security intervention mechanisms were analyzed content-wise.

Findings show that 68 percent of the studied community frequently ate less food than they felt they needed and 82.1 percent of the households have experienced hunger because of lack of food. The study showed that rural districts were poorly connected to the road networks; 87.9 percent of the elderly and 20.4 percent of the women and girls had no access to food markets. Regarding food utilization, 81.5 percent of the studied households had poor FCS; the average HDDS and FCS for the study areas were 2.47 and 18.9, respectively. In the study areas, the prevalence of Global Acute Malnutrition (GAM), Severe Acute Malnutrition (SAM), and Moderate Acute Malnutrition (MAM) for children aged 6-59 months were 50.3, 4.2, and 46.1 percent, respectively. More notably, the prevalence of SAM for children from the food-insecure households was 21.2 percent. The prevalence of MAM for pregnant and lactating women (PLW) in the study areas was 59.5. Further, the prevalence of Bitot's spot among 6-59 months of age children was 1.9 percent. On the other hand, all the rural households had anxiety about their future food demands. Meanwhile, the average annual precipitation for Atsbi, Irob and Hintalo was 542.5, 318, and 520.7, respectively.

Hintalo's average precipitation for March-May was declining by 16.3mm per annum (P<0.01) and its average annual precipitation was declining by 4.1mm per annum (P<0.05). The SST of central and eastern equatorial Pacific Ocean and northeast and northwest equatorial Atlantic Ocean was strongly correlated with the April average precipitation of the three districts. In addition, SST of the South, West, and southwest of the equatorial Indian Ocean, and West equatorial Pacific Ocean was associated with July-September average precipitation with greater variation in strength among the three districts. Moreover, July's average precipitation of the three districts, April's average precipitation of Atsbi and Irob, and May's precipitation of Hintalo are found significantly associated with the ENSO indices of JFM and FMA (P<0.01); MJJ and MAM (P<0.05). Regarding the coping strategies, 74.4, 74.1, and 73.8 percent of the studied households were frequently limiting the portion of household's meal size, depending on aid, and consuming less quality and cheap food, respectively to cope with food insecurity. About 70 percent of the food-insecure rural households were relying on the most severe coping strategies. The average CSI score was 148.5 out of 301 with the highest result of 268 implying severe food insecurity status. Further, 77.1 and 69.5 percent of the studied households have never practiced the adaptation strategies of preparing alternative wetting and rainwater harvesting, respectively. Livestock production, cultivating drought-tolerant crops, and shorter-duration crops were the first three prioritized adaptation strategies of the households. There were several international interventions intended to halt food insecurity sustainably through financial aid, but many of the interventions were found to be responding to humanitarian crises mainly the food shortages. Ethiopia's Food and Nutrition Policy, Food Security Program, Food Security Strategy, and Food Security Pack program were the food security intervention mechanisms at the national level. These interventions were found to be inconsistent with each other in achieving their intended goals. Regionally, no food security strategy or program was found intervening in the prevailing food insecurity of Tigray. More notably, apart from the PSNP office, no specific food security office was found in Tigray during the study period. Food aid and PSNP transfers have been the usual food security intervention mechanisms at a community level. 35.6 percent (77,010) of the population in the study rural districts were found to be rural PSNP beneficiaries. The food aid and PSNP transfers were outrageously insufficient for the recipients to cope with food insecurity.

The rural households living in the studied areas were found to be critically food-insecure. All the measurements implied that the food insecurity situation was unacceptably worrisome and life-threatening. This calls for an instant action to avert the occurrence of famine and starvation in the drought-prone rural areas of Tigray region. Thus, interventions should primarily target the vulnerable rural people and need to be planned based on attaining food availability first rather than concurrently addressing all components of food security. The limited amount of precipitation, exacerbated by a higher degree of variability, makes the food production in the three districts more uncertain. Therefore, the task of achieving food security should incorporate the design of informed food production strategies that can adapt to the limited and variable precipitation based on these SST and ENSO indices. Most of the food-insecure households were using severe coping strategies, and the mostly applied adaptation strategies were barely recommended to deal with the varying and short precipitations. Therefore, relevant organizations should focus on enhancing these households' coping and adaptive capacities to deal with the problems. In this regard, all the food security intervention mechanisms of various levels should be integrated into the common goal of achieving food security.

Keywords: nutrition, climate change, sea-surface temperature, El Niño, food policy

CHAPTER ONE

INTRODUCTION

1.1 General Background of the Study

Food security is the condition in which all people, at all times, have physical, economic, and social access to sufficient and nutritious food that meets their dietary needs for an active and healthy life (FAO, 2008). Achieving global food security has been a growing concern, prompting governments and humanitarian organizations to make it a priority agenda. In line with this, the Sustainable Development Goals (SDGs) seek to end all forms of hunger and achieve food security by 2030 (SDG 1: no poverty and SDG 2: zero hunger). This is because food is one of the vital necessities of life that profoundly determines the survival and prosperity of human beings.

While many strides have been made, the proportion of global people facing severe hunger has been increasing over time. FAO (2023) reported that the number of severely food-insecure world population increased from 623.8 million people (7.5%) in 2017 to 783.1 million people (9.2%) in 2022. In 2023, an estimated 2.33 billion people (28.9% of the global population) were moderately or severely food-insecure (FAO *et al*., 2024). In the 59 food-insecure countries listed by the Global Report on Food Crises (GRFC), about 282 million people (21.5% of the population) faced high levels of acute food insecurity in 2023, an increase of 24 million from 2022 (FSIN and GNAFC, 2024). More notably, it is projected that nearly 600 million more people will face chronic hunger by 2030 (FAO *et al.,* 2023), casting serious doubt on the likelihood of achieving the SDGs target to eliminate hunger and reduce poverty.

Food insecurity disproportionately affects rural communities. A World Bank (2016) report indicated that food insecurity is significantly more prevalent in rural areas than in urban ones, with rural residents facing more than three times the risk of experiencing food insecurity when compared to their urban counterparts. The report further reveals that the risk of food insecurity is over four times greater for those employed in agriculture than those working in other sectors of the economy. Globally, food insecurity affected 33.3 percent of rural people in 2022 compared to 26 percent in urban areas (FAO *et al.*, 2023).

Regionally, Sub-Saharan Africa (SSA) has the highest proportion of severely food-insecure people in the world with a total of 310.6 million people (22.5% of the total population) facing chronic hunger in 2022 (FAO, 2023). Ethiopia is one of the SSA countries with a significant number of

food-insecure people. In the last twenty years, Ethiopia has gained important achievements in food security. Nevertheless, food insecurity is still prevalent in many parts of the country. In 2023, an estimated 20.1 million people were facing chronic hunger across the country with 7.4 million severely undernourished children and women (WFP, 2023).

Tigray, one of the regions most affected by food insecurity in Ethiopia, has faced recurring food insecurity for decades (Endalew *et al.*, 2015). During 1984/1985, Tigray experienced severe food insecurity which caused the death of an estimated one million people (Reid, 2018). As such, food insecurity is still a pressing issue in the region. In June 2022, almost half of Tigray's population, a staggering 47 percent, were struggling with severe food insecurity (WFP, 2022a). That time was a dire humanitarian crisis in the region when compared to earlier times.

According to the Tigray Region Productive Safety Net Program (PSNP) Office (2024), only one rural district in western Tigray, named *Kafta Humera*, was classified as food-secure and, nearly ten rural districts from eastern, southeastern, and southern parts of the region were classified as severely food-insecure rural districts. In 2003, there were 16 food-insecure rural districts out of the then 34 rural districts in Tigray (WFP, 2009). This number increased to 31 (91% of the region) rural districts in 2019, as reported by the Tigray Region PSNP Office (2019).

Following the administrative boundary restructuring that took place in 2020, the food-insecure rural districts increased to 56 (98.2%). Of which, three drought-prone rural districts of Tigray namely: *Irob*, *Atsbi-wenberta* (*Atsbi*, after the new structure), and *Hintalo-wejerat* (*Wejerat*, after the new structure) were categorized as the most food-insecure rural districts in Tigray, as reported by the Tigray Region PSNP Office. Yet, there was very little information about the degree of severity of the food insecurity in general, and in particular, the status of food availability, access to food, utilization (nutrition), and stability in the food-insecure rural districts of the Tigray region.

Food insecurity, in many parts of the developing world, is associated with climate change, particularly with precipitation variability (Darwin, 2001; Schmidhuber and Tubiello, 2007; Wheeler and Braun, 2013; Afifi *et al.*, 2014 and Muluneh, 2021). According to Von Braun (1991), a 10 percent decrease in average precipitation had a notable impact on food production, resulting in a 4.4 percent decrease. A similar study by Kinda and Badolo (2019) showed that precipitation variability has reduced food availability and increased fluctuation in food production for 71

developing countries. It is projected that nearly 100 million global people will need food assistance in 2024, mainly because of the ongoing strong El Niño event (World Bank, 2023a).

Ethiopia's economy is heavily reliant on agriculture, with over 80 percent of the population depending on it. More importantly, nearly 90 percent of smallholder farmers mainly depend on rain-fed agriculture (Alhamshry *et al.*, 2020). For this reason, Ethiopia is listed as the most vulnerable to adverse impacts of climate change (World Bank, 2010). However, not all parts of the country are equally vulnerable to the impacts of climate change. Subsistence farmers were relatively the most susceptible to climate change in Ethiopia (Asfaw *et al.*, 2018). Further, an overdependence on rain-fed agriculture was one of the reasons for the pervasiveness of food insecurity in rural Ethiopia (Mekonnen and Gerber, 2017). Correspondingly, because of dependence on erratic precipitation and limited livelihood strategies, rural communities in the Tigray region are more vulnerable to acute malnutrition (Weldemariam *et al.*, 2023).

The intensity and variability of precipitation have been the important determinants of food security in rural areas of Ethiopia (Demeke, 2011; Alemayehu and Bewket, 2016; Lewis, 2017 and Agidew and Singh, 2018). Between 2015 and 2016, an El Niño induced drought took place mainly in the lowlands of the country (Singh *et al.*, 2016). Likewise, the history of food crises in Tigray in the last three to five decades has been associated with recurrent droughts (Endalew *et al.*, 2015). In addition, Demeke *et al.* (2011) and Weldearegay and Tedla (2018) reported that precipitation variability was the major cause of food shortage in the Tigray region. The average precipitation in Tigray is very short and variable as compared to the southern and western parts of Ethiopia (Seleshi and Demaree, 1995; Woldehanna, 2000 and Weldearegay and Tedla, 2018). However, there is a lack of information about the degree and intensity of precipitation variability and detailed knowledge-based evidence about its drivers in the drought-prone rural areas of the region.

Food-insecure rural households have adopted a range of coping and adaptation mechanisms to deal with their food insecurity. In the Tigray region, consumption of less-quality or less expensive foods, remittance, reduction of food portion size, selling of assets, daily labor, and borrowing money or grain were used as a means of coping strategies for food insecurity (WFP, 2022a and Weldemariam *et al.*, 2023). Besides, crop diversification, planting date adjustment, soil and water conservation, use of agricultural input, integrating crop production with livestock, and tree planting were the agricultural adaptation strategies adopted by rural communities in Tigray (Belay *et al.*,

2017). Nonetheless, the coping and adaptation mechanisms that are being specifically used in the drought-prone rural areas of Tigray have not yet been studied well. Besides, which of these coping and adaptation strategies are mostly preferred by the vulnerable communities is not well studied.

Recognizing the need for action, a range of interventions aimed at achieving food security have been implemented across different sectors and levels of governance in Ethiopia and Tigray, in particular. Nevertheless, only the PSNP and agricultural interventions were repeatedly mentioned in studies (Wordofa and Sassi, 2020 and Cordonnier *et al.*, 2022), and other food security intervention mechanisms of various levels are not scientifically reported. Besides, why these interventions have failed to address food insecurity is the question that needs to be answered.

An effective food security intervention demands proper information about the food insecurity situation, its associated climate factors, coping and adaptation strategies, and a description of the undergoing interventions. Therefore, this study has described the food insecurity situation clearly in reference to the fundamental components of the food security concept. In addition, the trend in the precipitation pattern of the study areas and its associated climate factors is duly described. Further, the various coping and adaptation mechanisms used in the study areas are identified. Moreover, the food security intervention mechanisms being undertaken at different levels are reviewed to guide the activities intended to seek sustainable solutions to food insecurity. These findings are believed to play a vital role in serving policy-makers, decision-makers, and other relevant state and non-state actors to make an evidence-based decision to address food insecurity in the vulnerable rural communities sustainably.

1.2 Research Problems

Globally, nearly nine million people die every year from hunger; losing one person to hunger every few seconds (UN, 2023). Ethiopia is among the leading countries in the total number of people facing hunger. Based on the Global Hunger Index (2023), Ethiopia was ranked 101st out of 125 countries with a "*serious*" hunger level. More notably, Ethiopia had the second-highest number of children (1.6 million) with acute malnutrition in 2023 (FSIN and GNAFC, 2024). In 2022, more than 26 million (nearly 22% of the population) were severely undernourished (FAO *et al.*, 2023). An updated projection by the World Bank (2023a) indicated that up to 13 million extra people in Ethiopia will be food insecure by March 2024. Similarly, WFP (2023) estimated that 20.1 million people in Ethiopia require food support.

In rural areas of the Tigray region, a very high prevalence of acute malnutrition was reported in August 2023 (FSIN and GNAFC, 2024). In addition, a research cited in the Associated Press News (2023) reports that nearly 1,400 people died because of hunger in Tigray between November 2022 and July 2023, and hunger was associated with about 68 percent of deaths, making hunger the main cause of death in the region. This implies the need to employ, in an improved and more robust manner, a scientific approach to answer why food insecurity is still an unresolved issue in developing countries, particularly in Ethiopia.

Although there are many suggestions associated with addressing food insecurity, having a dynamic and clear understanding about the concept of food insecurity and its underlying causes is vital for addressing the problem sustainably. Having a clear and pragmatic concept of food security is believed to be one of the preconditions needed to address food insecurity (Mock *et al.*, 2013). Yet, the concept of food security has been a complex one, subject to different meanings (Maxwell, 1996; Pinstrup-Andersen, 2009; Clay, 2002; Gibson, 2012 and Coates, 2013). As a result, there have been more than 200 separate definitions of food security in published materials (Napoli *et al.*, 2011 and Gibson, 2012). For this reason, decision-makers and various stakeholders are usually challenged with incomplete and contradicting information about food insecurity situations (FAO, 2015), which leads to deficient lessons and practices therefrom. This calls for a deconstruction of the concept into a more understandable and practicable concept which this study aims to achieve.

Food security, as indicated by the FAO (1996), is an aggregate measure of food availability, access to food, utilization, and stability. Thus, food security assessment reports are expected to reflect those food security components and their levels. In this regard, a significant number of food security assessment methods have been applied by different practitioners. However, it was difficult to understand which food security component those mechanisms were measuring and why.

A proper analysis of food insecurity is crucial for developing effective intervention strategies. Nevertheless, most of the previous researches have analyzed food security by considering only the food availability and access to food components (Manikas *et al.*, 2023); the utilization and stability aspects were seldom addressed when analyzing food security. Similarly, many food insecurity studies in Ethiopia used one or combined indicators of food security where the key components of food security were not fully addressed (Tora, 2023).

In addition, previous food security researchers like Asrat and Anteneh (2020); Eshetu and Guye (2021) and Getaneh *et al.* (2022) focused on identifying the proportion of food-insecure people in their study areas. Thus, there is no sufficient understanding about the degree of severity and general food insecurity situation within the food-insecure rural communities living in drought-prone rural areas. Therefore, this study fills the gap by explicitly pinpointing the food insecurity status in the drought-prone rural areas of the Tigray region by analyzing and capturing the four important components of food security.

Concerning the impact of climate change on food security, a substantial number of scholars support the significant influence of climate change on food security (Darwin, 2001; Schmidhuber and Tubiello, 2007; Wheeler and Braun, 2013 and Muluneh, 2021). Precipitation is one of the climate elements that highly determine agricultural production in rural areas. However, the nature of precipitation and its associated climate factors are not yet well known at a micro level. Hence, a significant number of rural farmers in the region are still at higher risk of food insecurity.

The most significant aspects of precipitation variability are the intensity and timing of precipitation patterns. According to Torres *et al.* (2019), variations in timing and intensity of precipitation are higher in an intra-year than inter-yearly. Intra-year precipitation variability matters most as many rural farmers keep months and seasons to do farming activities. In the Tekeze-Atbara river basin, Abebe *et al.* (2022) found that precipitation variability was higher in the other seasons than the summer and most of the precipitation was occurring in less than three months.

Precipitation variability is highly determined by global sea-surface temperature (SST) and El Niño/La Niña Southern Oscillation (ENSO). The SST is among the major drivers of precipitation variability (Dittus *et al.*, 2018), particularly for the Ethiopian precipitation (Alhamshry *et al.*, 2020). Besides, the ENSO is the other most important determinant of precipitation variability, particularly in the precipitation pattern of Ethiopia (Kasie *et al.*, 2019 and Tefera *et al.*, 2020). These two factors highly determine the intra-year and inter-year precipitation variability.

However, different areas have varying sensitivities to the SST and ENSO indices; the impacts of those indices greatly vary spatially. Hence, studies on precipitation variability and its associated climate factors should be conducted at the lowest possible geographical spaces. Furthermore, there is a lack of knowledge on how significant is the influence of SST and ENSO in determining local level precipitation variability in the food-insecure rural areas of the Tigray region.

Therefore, this study contributes to filling the knowledge gap by investigating the precipitation time-series trend on monthly, seasonal, and annual scales, its degree of variability, and the significance of the global SST and ENSO indices on the precipitation pattern of the food-insecure rural areas of Tigray. This is crucial for guiding local-level food production-related decisions and indicating feasible adaptation strategies to reduce risks in food production.

In dealing with food insecurity and associated precipitation variability, household's choice of coping and adaptation strategies plays a significant role in reducing and averting the risks of precipitation variability and the subsequent food insecurity. Researchers like Belay *et al.* (2017) and Teklewold *et al.* (2019), emphasized the factors that determine household's decision to choose from the different coping mechanisms. Likewise, Asesefa *et al.* (2018); Gebre *et al.* (2021); Yohannes *et al.* (2023) and Bahiru *et al.* (2023), studied the different coping strategies that have been used by rural households in Ethiopia to cope with food insecurity.

However, coping and adaptation strategies adopted by the food-insecure households living in drought-prone rural areas and their choices of strategies are less researched. Besides, food insecurity coping strategies were barely reported in line with adaptation strategies to the meteorological drought, which is vital for leading intervention mechanisms. Hence, this study contributes to the current literature by describing the food insecurity coping strategies and agricultural adaptation mechanisms in the study areas along with their ranked choices of strategies.

The role of food security intervention mechanisms applied by governments and NGOs of various levels is essential in enabling vulnerable rural communities to effectively deal with food insecurity and adapt to the varying precipitation. So far, there are very little and fragmented researches that examined intervention mechanisms intended to halt food insecurity. Therefore, this study produces new knowledge by critically describing and reviewing the existing food security intervention mechanisms at the international, national, regional, and community levels. The findings will help researchers in evaluating the impact of these interventions in the quest to address food insecurity.

Eventually, this study will add to the existing literature by informing academicians, practitioners, and policy-makers about the features of the prevailing food insecurity, its associated precipitation variability, food insecurity coping strategies, adaptation mechanisms for the variable precipitation, and food security intervention mechanisms. This will contribute to the tasks aimed at achieving food security in the drought-prone rural areas of Tigray and other susceptible areas in general.

1.3 Objectives of the Study

1.3.1 General Objective

The main objective of the study was to investigate the status of food insecurity in the drought-prone rural areas of Tigray region in relation to the precipitation variability, coping, adaptation, and intervention mechanisms undertaken by the vulnerable households and various relevant actors.

1.3.2 Specific Objectives

The specific objectives of the study were:

1. To describe the **food insecurity status** in the selected drought-prone rural areas of Tigray.
2. To analyze the **nature and associated climate factors of precipitation variability** in the selected drought-prone rural areas of Tigray.
3. To explain the rural **household's coping and adaptation mechanisms** to food insecurity and associated meteorological drought in the selected drought-prone rural areas.
4. To explore the **food security intervention mechanisms** used by various actors of different levels in the selected drought-prone rural areas.

1.4 Research Questions

Research questions on specific objective 1:

Food insecurity in this study is described in terms of the four pillars of food security. Accordingly, the study answers the following questions:

i. What is the food availability situation in the drought-prone rural areas of the study areas?
ii. Does the study population have physical, social, and economic access to food?
iii. What is the nutritional status of the vulnerable households living in the study areas?
iv. How stable are the food availability, access to food, and nutrition in the study areas?

Research questions on specific objective 2:

Regarding the nature of the precipitation variability in the drought-prone rural areas and its associated climate-related factors, the study answers the following questions:

i. Is there any trend in the monthly, seasonal, and annual precipitation variability in the study areas?

ii. Is there any correlation between the monthly precipitation of the study areas and the global SST?

iii. Is there any correlation between the precipitation variability of the rainy months of the study areas and the ENSO indices?

Research questions on specific objective 3:

The study answers the following research questions in relation to household's coping and adaptation mechanisms to food insecurity:

i. What are the coping strategies for food insecurity adopted by the food-insecure rural households?

ii. What coping strategies are mostly chosen to cope with food insecurity?

iii. What are the adaptation mechanisms to meteorological drought adopted by the food-insecure rural households?

iv. What adaptation mechanisms are mostly chosen to cope with the meteorological drought?

Research questions on specific objective 4:

In addition to the above-mentioned questions, this study answers the below-listed research questions related to the different food security intervention mechanisms:

i. What are the intervention mechanisms at the international level?

ii. What are the intervention mechanisms at the national level?

iii. What are the intervention mechanisms at the regional level?

iv. What are the intervention mechanisms at the community level?

1.5 Conceptual Framework

As illustrated in Figure 1.1, food insecurity is an aggregate measure of food availability, access to food, nutrition (utility), and stability at a household or a higher level (FAO, 1996). This study assumes that food security in rural areas can be achieved gradually in which these four pillars of

food security can be attained through a step-by-step process. In addition, these pillars of food security do not have the same weight as food availability is the most important aspect that should be addressed first, followed by access to food. Nutrition and stability are the issues that can be addressed once the food availability and access are secured.

The entitlement, capability, and livelihood approaches to food security offer distinct but interconnected frameworks for understanding and addressing food insecurity. The entitlement approach focuses on individuals' legal and economic access to food, arguing that starvation results not from a lack of food availability but from failures in people's "entitlements" to acquire it (Sen, 1982). The capability approach broadens this perspective by emphasizing people's freedoms and opportunities to achieve food security, highlighting the importance of education, health, and agency as critical factors that enable individuals to live nourished lives (Dreze and Sen, 1990). The livelihood approach builds on these ideas by examining how people sustain access to food through diverse strategies like farming, employment, or social networks while considering the resilience of these strategies against shocks like droughts (Chambers, 1988). Together, these approaches shift the focus from mere food supply to the stable physical, social and economic access of food.

Although many factors affect food insecurity in rural households, the intra-year and inter-year precipitation variability are the major determinants of food insecurity (Weldearegay and Tedla, 2018). This variability, in turn, is highly determined by the global SST and ENSO (Alhamshry *et al.*, 2020). Although the food availability and the stability components of food insecurity are under the direct influence of the precipitation variability, the access and nutrition aspects can also be indirectly influenced by it.

Food security intervention mechanisms are crucial in achieving food security; the intervention mechanisms should be guided based on information about the prevailing food insecurity and its associated precipitation patterns. Besides, the household’s coping strategies to withstand food insecurity and adaptation mechanisms to the varying precipitation play a vital role in dealing with food insecurity (Wolteji *et al.*, 2022). The government, humanitarian agencies, and vulnerable households are the major actors in addressing food insecurity. More importantly, the government and other relevant humanitarian agencies have a significant role in enhancing vulnerable household's capacity to effectively cope with food insecurity and adapt to erratic precipitation.

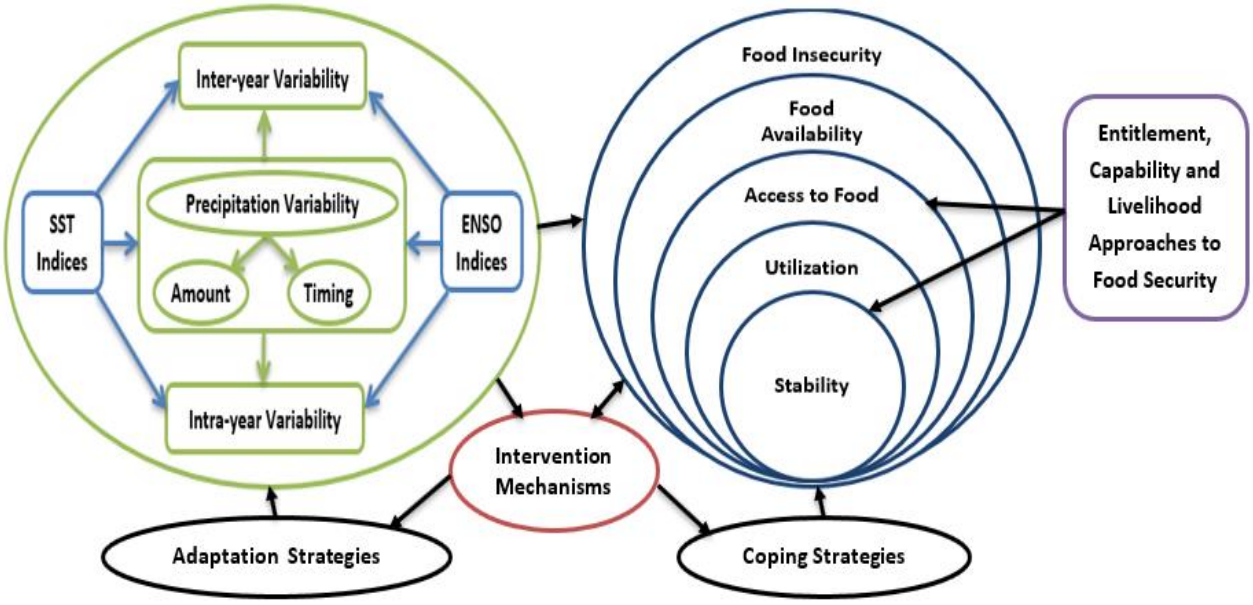


Figure 1.1. Conceptual framework of the study

1.6 Significance of the Study

Academic significance: the findings of the study will contribute to the food insecurity-related science with respect to precipitation variability and response mechanisms. It will also serve as a base for other researchers who are interested in investigating food insecurity and associated climate factors in rural areas by providing methodological guides to assess food insecurity in the vulnerable rural areas. Besides, the findings related to the coping, adaptation, and intervention mechanisms in this study will assist future researchers in critically reviewing the mechanisms and coming up with practical solutions to reduce the prevalence of severe and moderate food insecurity nationally, regionally, and at the household level.

Policy significance: this study has come up with the features of the prevailing food insecurity, its associated climate-related factors, and critiques of the food security intervention mechanisms. Hence, the main results of the study will serve as vital policy inputs to revise the existing national food security policy and/or formulate new food security policy, strategies, and programs at regional or lower levels.

Practical significance: the study will help state and non-state actors in ensuring food security in the vulnerable areas by providing relevant food insecurity information that could help them understand the main features of food insecurity in rural areas and its associated climate factors.

1.7 Scope of the Study

Geographical scope: This study was conducted in the selected drought-prone rural areas of Tigray region. Thus, other food-insecure rural, urban, or other areas like refugee and internally displaced (IDP) camps were not considered in this study.

Conceptual scope: This study has limited itself to assessing the chronic food insecurity in the drought-prone rural areas of the Tigray region. For this reason, the transitory food insecurity caused by the war and external shocks were not considered. In addition, the term drought is delimited to a meteorological drought. Furthermore, adaptation mechanism in this study is used to refer to the agricultural adaptation mechanisms practiced by the vulnerable rural households of the study areas.

Time scope: The time of data (recall period) for the study to analyze the food insecurity status in the study areas was spread over 12 months. Further, to analyze the climate factors associated with precipitation patterns in the selected study areas, the time frame covers 41 years, i.e. 1979-2019.

1.8 Organization of the Dissertation

This dissertation is organized into eight chapters. Chapter one deals with the introduction, which incorporates the background of the study, research problem, objectives, research questions, significance of the study, and scope of the study. Chapter two deals with a review of related literature. In the third chapter, research methodology that includes research design, population and sampling methods, data collection techniques, and data analysis methods are described in depth. The operational framework of the study is also depicted in table form in this chapter.

Chapter four describes the status of food insecurity in the drought-prone rural areas comprehensively. Further, chapter five addresses precipitation variability and its teleconnection with the global SST and ENSO indices in the food-insecure rural areas. Chapter six is all about coping strategies for food insecurity and further addresses the adaptation mechanisms to meteorological drought in the drought-prone areas. And, chapter seven captures food security intervention mechanisms of various levels relevant to the study areas. Chapter eight, the last chapter of the dissertation, summarizes the overall findings, lessons as well as policy recommendations. These are followed by references used in the study.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Review of Theoretical Literature

2.1.1 The evolution of the concept of food security and its developments

In 1943, the Food and Agriculture Organization (FAO) was established at the United Nations Conference on Food and Agriculture. Two years before, President Roosevelt identified 'freedom from want' meaning that the supply of secure, sufficient, and suitable food for everyone, as one of the 'four essential freedoms' that should be considered all over the world (Shaw, 2007). Further, in 1948, the right to food was stated in the Universal Declaration of Human Rights as one of the essential elements of an adequate standard of living (UDHR, 1948).

Since 1970, the concept of food security has undergone major developments. According to Maxwell and Smith (1992), in the 1970s, the concept of food security was attached to the national and global food supplies; a decade later it shifted to the household and individual's access to food. The same source revealed that during the period from 1970 to 1990, more than 180 issues were dealing with the concept of food security. This implies that a considerable reconstruction of thinking on food security has occurred over the last three decades. These concepts were also indications of the policy analyses, which have reshaped our thinking about food security.

The 1970s was the period when food security evolved as a concept. The world's food crises that occurred between 1972 and 1974 were believed to be the sources of concern for food security (Maxwell and Smith, 1992 and Clay, 2002). This led to discussions on the global food problems and the set-up of different institutions for information provision. Consequently, the World Food Conference was held in 1974 covering discussions on policy issues and resources to promote food security (Shaw and Clay, 1998).

During the World Food Conference of 1974, the United Nations (1975) defined food security as: *"availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices"*. This indicates that the focus was given to the volume and stability of food supplies. In 1983, the concept of food security was expanded to include secure access to food supplies by vulnerable people, basically because of the failure of the Green Revolution to meet the intended poverty and malnutrition reduction aims (Clay, 2002); implying that the problem was from lack of demand of food. It was

then redefined as *"ensuring that all people at all times have both physical and economic access to the basic food that they need"* (FAO, 1983).

Three years later, in 1986, the World Bank came up with a report on the temporal dynamism of food insecurity. According to the report, two concepts were distinguished in food insecurity: chronic food insecurity and transitory food insecurity, in which the former was associated with problems of continuing poverty and low incomes, and the latter was associated with periods of intensified pressure caused by natural disasters, economic collapse or conflict (World Bank, 1986).

By the mid-1990s, the concept of food security was broadened to incorporate food safety, preferences, and nutrition (Clay, 2002); reflecting concerns about food composition and nutrient requirements for an active and healthy life. These incorporations specifically imply that the concept had an interrelated set of actions contributing to the same agenda. In addition to this, food security was included as one major component of human security in the 1994 UNDP Human Development Report (UNDP, 1994). This inclusion has related the concept of food security with the human rights perspective.

In 1996, a World Food Summit took place which provided a framework for important changes in the policies to achieve food security. And, a widely accepted new definition of food security was adopted as: *"Food security, at the individual, household, national, regional and global levels is achieved when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life"* (FAO, 1996). This definition describes the accessibility, availability, utilization, and stability, which are known as the four pillars of food security.

Five years later, in 2001, this definition was again defined as: *"Food security is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"* (FAO, 2002). This was the generally accepted and most recent definition in the development of the concept of food security. The basic difference between these two definitions is that the ultimate focus in the 1996 definition was members of the individual household; whereas, the 2001 definition focuses on the access to food by vulnerable individual households.

According to the last definition, food insecurity exists when people do not have adequate physical, social, or economic access to food. This concept shall not be used interchangeably with famine and hunger, because famine and hunger are results of food insecurity.

2.1.2 Issues behind the current concept of food security

Three important changes have been observed in the development of the concept of food security since its origin in 1974. One of the significant transformations was the shift from the view of food security from the food supply approach to a sustainable livelihoods approach (Carr, 2006). The second shift was the change from standardized indicators to logical perception (Maxwell, 1996) and the third shift was the change from a global overview down to the household (Coates, 2013). No one would be certain how the concept of food security would be changed in the future, considering the dynamic nature of the issue.

In the 1970s, objective indicators were the ways used to measure food security. Thus, conditions of food security of people were given due emphasis. In the recent concept of food security, it is the subjective approach being used to measure the status of food security (Maxwell, 1996). As a result, there have been more than 200 separate definitions of food security in published materials (Napoli *et al.*, 2011 and Gibson, 2012). Here, anyone can add or remove any indicators assumed to measure food security. For this reason, a variety of indicators are used to measure food security (Carletto *et al.*, 2013), and there have been commendable advances in the measurement of food security (Coates, 2013).

If this subjectivism has to work for the future, questions would arise about how to make value judgments for the indicators. Besides, this could be a source of the question for "whose approach do we choose and why?", as a subjective degree of belief can bring a range of unfortunate consequences, such as disagreement in science (Chalmers, 2013). Problems of this kind may lead analysts to raise questions about the subjective approach to food security.

The contemporary concept of food security goes beyond the food supply approach and tries to link with other casual elements. This is because a lack of food in each place cannot be the only cause of food insecurity. Rather, it can be caused by the lack of access and production, which is related to social capacity and status (Carr, 2006). This emphasizes the roles of society, local knowledge, and perception in food systems.

Nowadays, the concept of food security is used in many ways, making it difficult to understand the true extent of the problem. Many scholars like Maxwell (1996); Clay (2002); Pinstrup-Andersen (2009); Gibson (2012) and Coates (2013) agree on the complexity of the concept of food security. The concept has also been exposed to a subjective interpretation by many writers (Gibson, 2012). This is partly because of the nature of the food problems experienced in different parts of the world (Maxwell, 1996). In this situation, it would be difficult to know enough about the problem and the mechanisms to respond.

It is very clear that there are four dimensions of food security known as "pillars of food security" (FAO, 2002): food availability, which refers to the supply side; food access, which refers to the demand side; food utilization, which refers to the nutrient and energy content of the food consumed and food stability, which refers to the uninterrupted food access periodically. All these pillars of food security must be fulfilled to say that a nation or a certain household is food-secured (FAO, 2008). This indicates that food security is measured by the simultaneous fulfillment of all the four dimensions. The question here is about how all these dimensions combine and interact with each other to measure food security (Gibson, 2012). Besides, achieving all pillars of food security simultaneously would be difficult for countries like Ethiopia.

Moreover, there has been a marked distinction between the internationally recognized definition and the way it is applied in measuring food security (Coates, 2013). This indicates a lack of clarity in the concept of food security about which indicator is measuring what aspect of food security. Thus, it is imperative to check the complementariness of the set of indicators and treat the dimensions of food security separately. Unless the international community reconstructs this complex concept into a single and clear concept, food security is likely to continue to suffer from misconceptions and recurring food insecurity (Gibson, 2012). Indeed, the collective actions would be misguided by the challenges of the practical interpretations.

2.1.3 Theoretical approaches to food security

i. The Entitlement Approach

The entitlement approach to food security is a framework developed by economist Amartya Sen in 1981. It fundamentally changed how food security is understood, moving beyond food availability to a more comprehensive view of how individuals or groups gain access to food. Entitlement approach to food security focuses on how a person's access to food is affected by their

economic, social, and legal circumstances. This approach challenges the idea that food security is determined by the food available in a country. It explains why famines occur even when there is enough food and focuses on how legal, economic, and political processes affect a community's access to food.

The entitlement approach shifts the focus from food availability to food access. The approach challenges the traditional "food availability decline" hypothesis, which attributed famines solely to a drop in food supply (Bowbrick, 2022). Instead, Sen (1982) argued that food insecurity often occurs even when food is available, because people lack the means to acquire it.

The entitlement approach shifts the paradigm of famines from a supply approach to the ability of people to access food. It highlights that food insecurity can result from economic collapse or job loss, natural disasters, and political and social systems, even when food is abundant. In a famine, there may be sufficient food available in the market, but people may not have the entitlement to access it if they have lost their jobs, assets, or income due to economic downturns or political disruptions. This is the difference between availability and entitlement (the ability to access it).

Sen’s approach centers on the concept of "entitlements," which are the resources and opportunities a person can legally command to obtain food. If someone’s entitlements fail due to unemployment, falling wages, rising food prices, or loss of assets, they may face starvation, regardless of how much food exists in the market or region.

According to Sen (1982), food security is not just about the availability of food, but also about an individual's entitlements, the set of resources they can command through various means, such as income, assets, or social rights. In simpler terms, entitlements refer to the means or rights through which people can access food, whether through purchasing power, direct production, or social networks. Sen argued that food security depends not only on food being available but also on an individual's ability to access it economically, physically, and socially.

Sen argued that famine and food insecurity often occur not due to a lack of food, but because of the failure of entitlements, people lose access to food even when the food is available. This could be because of economic shocks, loss of employment, displacement, or political conflict.

Sen identified four main sources of food entitlement: production-based, trade-based, own-labor, and inheritance and transfer entitlement. A failure in any of these is called an "entitlement failure"

which can lead to hunger. This approach revolutionized food security analysis by: highlighting economic and social factors; showing that famines can strike specific groups and emphasizing the role of policy and governance. The approach also linked this to broader ideas, like democracy's role in famine prevention. He noted that no major famine has occurred in a functioning democracy with a free press, as public accountability forces governments to act.

The entitlement approach remains relevant as food insecurity persists globally, often tied to economic access rather than shortages. It is a reminder that boosting production alone is not enough; policies must ensure people can actually get that food. This has important implications for addressing food insecurity, as it points to the need for policy interventions that address economic access, the redistribution of resources, and the strengthening of social safety nets.

Nevertheless, the entitlement approach is not perfect. The approach is too individualistic, overlooking community or structural factors. It does not also fully address food utilization (nutrition quality) or stability over time, which are now part of modern food security definitions. Further, it assumes markets function rationally, which may not hold in conflict zones or during extreme disruptions.

ii. The Capability Approach

The capability approach to food security, developed by economists Jean Dreze and Amartya Sen in 1989, focuses on the ability of individuals to achieve well-being through access to the means to live a healthy and fulfilling life, rather than simply focusing on the availability of resources like food (Dreze and Sen, 1990). This approach shifts the focus from simply ensuring food availability to enhancing individuals' abilities to achieve food security based on their own circumstances, preferences, and needs. It emphasizes human well-being and freedom, looking at what people are actually able to do and be, rather than just what resources they have access to.

In the context of food security, this approach goes beyond traditional metrics like food production or distribution and examines whether people have the real capabilities to access, utilize, and enjoy sufficient, safe, and nutritious food. It considers factors such as income, education, health, social norms, gender dynamics, and infrastructure, which all influence a person's ability to be food secure.

According to the approach, capability refers to the set of options or freedoms people have to achieve food-related functionings. For example, having money to buy food is useless if there's no market nearby or if illness prevents someone from eating. The approach asks whether individuals can convert available resources into food security, emphasizing agency and diversity in needs. Personal (e.g., age, disability), social (e.g., gender roles), and environmental (e.g., climate, infrastructure) factors are conversion factors that affect how resources translate into food security. A farmer might have land but lack irrigation, reducing their capability to grow food.

The capability approach considers food security within the broader context of poverty, where individuals may be deprived not only of food but also of other critical resources such as education, healthcare, and access to social networks. This highlights that food security cannot be addressed in isolation from broader socioeconomic issues. The approach goes further to ask whether individuals have the freedom and ability to use food to live a healthy life. For example, even if a person has enough calories, they might not be able to cook or properly use that food if they lack the capability to do so due to physical, economic, or social constraints.

The approach stresses agency, the ability of people to make choices and decisions about their lives, including how to use food to enhance their well-being. If individuals lack agency, they might be food insecure even if they have access to enough food. For example, a person living in a food desert may have physical access to food, but their ability to obtain nutritious and affordable food may be limited by other constraints such as transportation or information.

The approach recognizes that people have diverse needs and preferences (Robeyns, 2005). Food security should thus not be measured merely in terms of calorie intake, but in terms of the individual's ability to achieve adequate nutrition, health, and a satisfactory standard of living. For instance, a person's capability to prepare healthy meals may depend on their cooking skills, their time, and their access to clean water, energy sources, and appropriate food markets.

The capability approach also emphasizes social relationships and social capital as factors influencing food security. A person's ability to share food, access community resources, or gain support through social networks can significantly impact their food security. Cultural factors may also shape what is considered "adequate" food security, and these should be factored into assessments. The approach incorporates the idea that food security should not only meet present needs but should also consider long-term sustainability. This involves ensuring that people can

continue to access nutritious food over time without exhausting resources or harming the environment.

According to the capability approach, food security policies should focus not only on increasing food production or distribution but also on enhancing individuals' capabilities. In addition, food security assessments should go beyond simply measuring food availability or income, incorporating a broader set of indicators that capture people's ability to access, afford, and use food in a healthy way. Furthermore, addressing food security involves addressing other factors such as health, education, employment, and social support. For example, improving people's health or education increases their capabilities to use food to maintain a healthy life.

Generally, the capability approach to food security looks at food access not just as a matter of having enough food but as a question of whether people have the freedom and resources to make choices that allow them to live healthy and fulfilling lives. It emphasizes a broader view of poverty and well-being, beyond just the material access to food.

iii. The Livelihood Approach

The livelihood approach, also known as the Sustainable Livelihoods Approach (SLA), is a framework for improving development cooperation. It was developed in the mid-1980s by Robert Chambers in response to the limitations of conventional development concepts (Chambers, 1988). It is based on the idea that development should enhance people's ability to secure their own livelihoods. The SLA is a holistic approach that considers a household's assets, institutional structures, and transformations.

The SLA is based on the idea that food security is an outcome of a household's ability to access and utilize its assets, and food is just one of the range of factors that determine poor people's decisions. The SLA is based on the experiences of the past and builds on the methods that have been developed over the past 20 years (Young et al., 2001).

The livelihood approach to food security emphasizes the importance of people's means of living, including the resources and activities they use to secure food and other essentials. It focuses on sustaining livelihoods by addressing both the capacity to produce or earn income and the broader socio-economic and environmental context that shapes people's ability to access food. This approach integrates economic, social, and environmental factors to understand food security and

is particularly useful in rural areas or in situations where people depend on multiple sources of income or activities to meet their food needs.

According to the livelihood approach (Chambers, 1988), the key livelihood assets are: human capital (skills, knowledge, and health that people possess, which enable them to earn income and manage food resources); natural capital (natural resources such as land, water, forests, and fisheries, which provide food and materials); physical capital (physical infrastructure and assets such as tools, equipment, and transportation); financial capital (the availability of money or credit, which enables people to purchase food or other necessities when local production is insufficient) and social capital (the social networks and relationships that people have access to, such as family, friends, or community groups).

The livelihood approach emphasizes that food security is shaped by a variety of external factors such as economic policies, climate change, natural disasters, market fluctuations, and political instability. These factors influence people's ability to access food and sustain their livelihoods. Vulnerability to shocks (like droughts, floods, economic crises, or market failures) is central to this approach. Vulnerability varies based on factors such as wealth, location, and social status.

People use a range of strategies to secure their livelihoods, including farming, fishing, herding, wage labor, self-employment, or remittances from family members. The livelihood approach emphasizes the diversity of income-generating activities people use to cope with food insecurity, especially in households or communities where agriculture alone is not sufficient to meet food needs. For example, a farmer may rely on both crop production and livestock rearing, but also seek off-farm employment or send family members to work in urban areas to generate income.

Livelihood diversification is a core principle of this approach. People often engage in multiple activities (agriculture, business, remittances, etc.) to diversify income sources and reduce the risk of food insecurity. This helps them spread risk in the face of economic shocks, environmental stress, or other external challenges. For instance, a household might grow crops, run a small business, and have members working in urban areas to balance risks like poor harvests or fluctuating food prices.

Food security in the livelihood approach is not just about immediate access to food but also about sustainability. It includes improving long-term resilience to environmental or economic shocks and ensuring that livelihoods are sustainable in the face of changing circumstances. This may

include managing natural resources sustainably, ensuring long-term access to productive land, or addressing structural inequalities that limit people's access to resources.

The livelihood approach promotes integrated development strategies that address multiple dimensions of poverty, such as access to education, healthcare, clean water, and financial services, alongside direct interventions to improve food security. Programs might focus on improving agricultural productivity, supporting local markets, developing skills and education, or building community resilience to environmental shocks.

Policies should focus on supporting diverse livelihoods rather than focusing only on increasing food production. This might involve ensuring access to credit, improving market access, or investing in education and health to increase the human capital of households. Policies should also focus on reducing vulnerability, such as by providing safety nets (e.g., social protection, food aid, or disaster relief) for households at risk of food insecurity.

Targeting the most vulnerable households and communities is key to the livelihood approach. Vulnerable populations often rely on multiple, less productive livelihood strategies, and interventions need to strengthen these diverse activities (such as enhancing agricultural productivity, improving off-farm income opportunities, or securing rights to land and natural resources).

Strengthening the resilience of livelihoods is critical in this approach. This might involve providing people with resources and knowledge to manage risks, such as crop insurance, weather forecasts, or training in climate-resilient farming techniques.

Generally, the livelihood approach to food security goes beyond the simple availability of food and looks at the broader context of people's livelihoods, focusing on how individuals or households use a variety of assets and strategies to secure food and sustain their well-being. It takes into account diverse income sources, vulnerability to risks, and the need for long-term resilience in the face of economic, social, and environmental challenges.

iv. The Human-right approach

The human rights approach to food security frames the issue of food access and security as a fundamental human right, emphasizing the legal obligation of governments to ensure that all people can access sufficient, nutritious food. This approach links food security with the right to

food, a human right recognized under international law, and stresses that food insecurity is not simply a matter of individual or household failure but a result of structural inequalities, governmental policies, and social and political factors.

The right to food is enshrined in international human rights law, including Article 25 of the Universal Declaration of Human Rights (1948) and the International Covenant on Economic, Social, and Cultural Rights (ICESCR, 1966), which recognize that everyone has the right to an adequate standard of living, including food (McClain-Nhlapo, 2004). The right to food goes beyond merely having enough food; it involves ensuring that people can access, afford, and use food in ways that are culturally appropriate, nutritionally adequate, and sustainable.

Under this approach, states have an obligation to respect, protect, and fulfill the right to food: States should not take actions that directly or indirectly interfere with people's ability to access food (e.g., land grabbing, trade policies that harm local food production). Governments must prevent others (e.g., private corporations, individuals) from violating people’s right to food (e.g., by ensuring that companies do not monopolize food resources or violate labor rights). Further, States must take positive actions to facilitate access to food by improving food systems, providing social safety nets, promoting economic opportunities, and ensuring access to food for vulnerable populations.

The human rights approach emphasizes three key criteria to achieve food security: Availability (food must be available in sufficient quantities and quality); accessibility (food must be physically and economically accessible to all individuals, meaning that people must have both physical and economic access) and adequacy (the food available must be nutritious and culturally appropriate, ensuring that it meets dietary needs and supports health).

A fundamental principle of the human rights approach is that food security must be achieved for all people, without discrimination based on race, gender, age, disability, or any other status. This approach highlights the importance of addressing inequalities in society, as marginalized groups (e.g., women, children, indigenous peoples, and rural communities) often face higher risks of food insecurity. Gender equality is particularly emphasized, as women in many societies are disproportionately affected by food insecurity due to gender-based discrimination in access to resources, decision-making power, and social support networks (Agarwal, 2018).

The human rights approach calls for active participation of all affected communities in decisions that affect their food security. People should be empowered to claim their right to food, engage in policy-making processes, and hold governments accountable. Ensuring the right to participation involves public consultations, access to information, and the capacity for individuals and communities to demand their rights to food security from their governments.

A human rights approach requires that states be held accountable for failing to respect, protect, and fulfill the right to food. This means that individuals and groups must have access to legal remedies and complaint mechanisms if their right to food is violated. This could include the ability to seek judicial or administrative remedies, ensuring that food insecurity caused by government policies, land grabs, or other violations can be challenged through legal channels.

The human rights approach also emphasizes the sustainability of food systems, recognizing that the right to food must be realized in ways that do not compromise the ability of future generations to enjoy food security. The approach also links food security to other human rights, such as the right to health, the right to work, and the right to an adequate standard of living, recognizing that food security cannot be achieved in isolation from other socio-economic and environmental rights.

Food security policies must be human rights-based and include measures that respect, protect, and fulfill the right to food. This might involve enacting laws that protect land rights and prevent land grabbing or eviction of farmers; ensuring social protection programs like food assistance, unemployment benefits, or child nutrition programs that help vulnerable populations access food and promoting policies that ensure equal access to resources for marginalized groups, such as women, Indigenous communities, or low-income families.

International organizations, such as the United Nations, play a crucial role in promoting the right to food globally. They can monitor the fulfillment of food security commitments and provide guidance on best practices. States are encouraged to report on their progress in realizing the right to food and may be held accountable for violations through international human rights mechanisms, such as the UN Human Rights Council.

The monitoring of food security under the human rights approach involves both qualitative and quantitative measures, looking at not only the availability and accessibility of food but also whether people have the legal capacity and the economic means to exercise their right to food. It

also requires participatory assessments, involving affected communities in evaluating whether they are able to realize their right to food.

The human rights approach looks at the root causes of food insecurity, including poverty, inequality, political instability, climate change, and conflict. It encourages governments to address these underlying issues to prevent food insecurity from occurring in the first place.

Generally, the human rights approach to food security views food insecurity as a violation of human rights and stresses that the right to food must be legally guaranteed, with governments taking responsibility for ensuring that all people have access to adequate, nutritious, and culturally appropriate food. It highlights the importance of non-discrimination, participation, accountability, and sustainability, and calls for a broader understanding of food security that encompasses not just food availability but the social, economic, and political conditions that enable people to live with dignity and have reliable access to food.

2.2 Review of Empirical Literature

2.2.1 Food insecurity in urban areas

Food security is becoming an increasingly pressing issue in urban areas. This is mainly due to the rapid urban population growth that does not always practice agriculture to produce food. For this reason, urban areas are usually dependent on rural areas to meet their food demands (FAO, 2017). Considering the rapid population growth in urban areas of developing countries, food security would be a top policy agenda. Thus, investing in food security in rural areas could be one finest way of responding to urban food insecurity.

The urbanization process in Ethiopia is among the fastest in the world with an estimated urbanization growth rate of 5.4 percent per year (Schmidt *et al.*, 2020). Today, nearly one-fifth of the Ethiopian population lives in urban areas. According to CSA (2017), the average household size in Ethiopia was 4.6 members in 2016; of which, rural households had 4.9 persons per household and were slightly larger than urban households which was 4.2 persons.

Urban food insecurity in Ethiopia is attention-seeking because of high rates of urban poverty, high dependence on food supplied by the market, and fluctuating food prices. According to a study by Birhane *et al.* (2014), three-quarters of the households in Addis Ababa, the capital city of Ethiopia were food-insecure, of which 23 percent were in a state of hunger. A similar study done by Etana

and Tolossa (2017) revealed that 88.6 percent of households in the capital were food-insecure. The problem was higher among the unemployed and low-income households, daily wagers, and public servants' household heads (Birhane *et al.*, 2014 and Etana and Tolossa, 2017).

Scholars like Walsh and Van Rooyen (2015) and Guerrero *et al.* (2014) tried to compare the food security status in rural areas to urban areas. Accordingly, Walsh and Van Rooyen (2015) reported that there were significantly more food-insecure households in urban areas of South Africa than in rural households and Guerrero *et al.* (2014) reported that there were no significant differences in the prevalence of food insecurity across urban, suburban, and rural regions of Wisconsin, USA. Further, Nord (2000) stated that food insecurity in rural areas was overstated since the cost of living is less in rural areas.

Because urban food security is overwhelmingly dependent on rural food supply, findings related to Walsh and Van Rooyen (2015); Guerrero *et al.* (2014) and Nord (2000) can significantly lead decision-makers to understate rural food insecurity. From the beginning, two things can be compared if they have the same or similar features of the issue under study. Yet, urban and rural areas are two socio-economically, demographically, geographically, and culturally different spaces (Pateman, 2011 and Howard, 2013), and with different infrastructural provisions. These variations are widespread in developing countries. In many developing countries, rural people do not have access to social infrastructure as compared to their urban counterparts (Braun, 2007). This implies that although rural and urban areas are two inseparable domains (Gebre and Gebremedhin, 2019), they have significant differences in their socioeconomic sphere that one should consider during a comparative study. Therefore, food security in urban and rural areas should be studied and reported separately instead of comparing it using the same measuring standards.

2.2.2 Food insecurity in rural areas

The transformation of rural areas initiated by agricultural development can bring positive changes in terms of food security and can contribute to better access to food in urban areas. Addressing the root causes of food insecurity starts in rural areas. When rural areas are excluded and marginalized, the most adverse impacts of food insecurity will continue to occur in rural and urban areas. Thus, there is a need to better understand the nature of food insecurity in rural areas.

The nature and features of food insecurity in rural areas significantly vary from urban areas. According to the FAO (2018) report, rural food-insecure people differ from their urban

counterparts in many aspects. The status of food security in rural areas is attributed to agricultural activities, which is highly susceptible to climate variability. Food security in urban areas, on the other hand, is attributed to the ability to access food (Cohen and Garrett, 2010). For that reason, rural and urban households use different strategies to address food insecurity (Tomayko *et al.*, 2017). Thus, comparing rural and urban areas in terms of food security would be less important in the effort to address food insecurity in rural areas.

Considering the many disadvantages that rural areas have, people living in rural areas are more vulnerable to food insecurity than people living in urban areas. When looking at the occurrence of food insecurity across rural and urban spaces, 80 percent of the global underfed people reside in rural areas (FAO, 2018). Rural people are more than three times as likely to be food-insecure as compared to urban dwellers; it is more than four times higher in people engaged in agriculture than those engaged in other sectors (World Bank, 2016).

Although this comparative figure does not still show how poor the rural poor are, it implies that the rural people are at a higher risk of hunger and undernutrition. These variations between rural and urban areas are also manifested across different countries. This point of view would be clear when the number of food-insecure people living in rural areas of developed and developing countries is analyzed. According to the findings of a research conducted across 105 countries by Alkire *et al.* (2014), 86 percent of food-insecure people in Sub-Saharan Africa and South Asia live in rural areas, while the figure was 28.6 percent for developed countries. This clearly indicates that the global average of the food-insecure people living in rural areas does not specifically represent the developed countries.

As indicated in Table 2.1, the geographical prevalence of undernourishment in the world and Africa was uneven. The number of food-insecure people in the world has been increasing since 2017 and was estimated to be more than 783 million in 2022 (FAO, 2023).

Table 2.1. Prevalence rate of food insecurity in the World and Africa (2015-2022)

Region	Prevalence rate of food insecurity (%)							
	2015	2016	2017	2018	2019	2020	2021	2022
World	7.9	7.8	7.5	7.6	7.9	8.9	9.3	9.2
Africa	15.8	16.6	16.5	16.6	17.0	18.7	19.4	19.7
Sub-Saharan Africa	18.2	19.1	18.9	19.1	19.5	21.6	22.2	22.5
Eastern Africa	24.6	26.2	26.2	26.0	26.7	28.1	28.4	28.5

Middle Africa	23.3	24.7	23.7	24.4	24.8	27.6	28.5	29.1
Southern Africa	9.3	8.3	7.8	7.7	8.3	9.5	10.0	11.1
Northern Africa	5.4	5.7	6.0	6.0	5.8	6.0	6.9	7.5
Western Africa	10.6	10.7	10.6	11.1	11.0	13.7	14.5	14.6

Source: FAO (2023)

In Africa, the number of food-insecure people in 2022 was 341.8 million (FAO, 2023), accounting for one-third of the global food-insecure people. Eastern Africa, where Ethiopia is found, is the most food-insecure region in Africa and the world. On the contrary, the prevalence rate of undernourishment in North America and Europe was below 2.5 percent in 2022, as reported by FAO (2023).

There are also great disparities among the food-insecure people in rural areas itself. Rural people living in the high mountains, pastoral areas, drylands, rainforest jungles, and small islands with lower population densities, poor agroecological resources, limited access to markets, and few job opportunities are more vulnerable to food insecurity (FAO, 2018). Therefore, it is imperative to describe the food insecurity status of any area not by comparing it to other areas; but rather by describing it in terms of the degree of severity and persistence of the problem. In this way, decision-makers can make informed and effective decisions.

Generally, the nature of food security in rural and urban areas, although might have some similarities, they vary in different aspects of food security. While food security in rural areas is linked to agricultural production (availability and stability), the steadiness in food prices (economic access) is usually linked with urban food security. Therefore, the description of the food security status in both spaces would be informative if it is explained in terms of the four pillars of food security, rather than by using aggregate measurements.

According to Table 2.2, a comparison of food insecurity in rural, peri-urban, and urban populations at the global, regional, and subregional levels shows that food insecurity affected 27.6 percent of people living in rural areas in 2022 when compared to 26.3 percent in peri-urban areas and 23 percent in urban areas of Sub-Saharan Africa.

Table 2.2 Prevalence of food insecurity in the World and Africa by level of urbanization in 2022

Region	Spatial prevalence rate of food insecurity (%)		
	Rural	Peri-urban	Urban
World	12.8	11.6	9.4

Africa	25.9	23.1	20.2
Sub-Saharan Africa	27.6	26.3	23.0
Eastern Africa	25.7	26.7	20.5
Middle Africa	44.1	44.0	35.4
Southern Africa	15.9	13.1	10.2
Northern Africa	10.1	8.2	11.9

Source: FAO (2023)

Food security in rural areas can directly affect the food security status of urban areas. This is because nearly 70 percent of all food consumed worldwide is produced in rural areas (Locke, 2017). In Africa, more than half of the urban food consumption is met by rural food supply (Vorley and Lançon, 2016). This shows that enhanced food production in rural areas can serve dual purposes: ensuring food availability in rural areas and food access in urban areas. This can also play a pivotal role in steadying the urban food price and overall rural economic transformation.

2.2.3 Food insecurity in rural areas of Ethiopia

Ethiopia is predominantly an agrarian nation, in which the agricultural practices are mostly rainfed. Hence, any variation in the climate conditions can have adverse impacts on agricultural production. An overwhelming dependence on rainfed agriculture is one of the reasons for the pervasiveness of food insecurity in rural Ethiopia (Mekonnen and Gerber, 2017). Notwithstanding the importance of agriculture in the country, the sector needs a transformation to contribute to food security and serve the economy better.

Ethiopia is one of the developing countries with a higher number of food-insecure people. The country's GDP per capita in 2020 was US$ 1066, which is much lower than Sub-Saharan Africa's GDP per capita, i.e. US$ 4319 (Plecher, 2020). Despite some improvements gained in building the national economy in the last two decades, achieving food security is still a challenge in Ethiopia. According to WFP (2020), the prevalence rate of undernourishment in Ethiopia was 31 percent in 2017; about 5.9 million people were with acute food needs in 2020.

Food insecurity in Ethiopia is more pronounced in rural areas as compared to urban areas (World Finance, 2017). A study done by Moroda *et al.* (2018) revealed that 41.3 percent of households in rural areas of Boset district of Oromia region were highly food-insecure. Similarly, it was found that 79.1 percent of rural households in southern Wello of Amhara region were food-insecure (Agidew and Singh, 2018). Unlike the urban areas, shortage of farmland, recurring drought,

climate change, and shortage of precipitation were the main factors associated with food insecurity in these rural areas (Agidew and Singh, 2018).

Drought, which is a major cause of food insecurity, is a recurring phenomenon in Ethiopia. From 1983 through 1985, Ethiopia experienced the severest food insecurity in Africa which caused the death of an estimated one million people (Reid, 2018). This problem was site-specific to northern Ethiopia. In 2015-2016, an El Niño induced drought took place in the lowlands of the country (Singh *et al.*, 2016). During that time, nearly one-fourth of the Ethiopian population was food-insecure and more than 18 million people were requesting urgent food aid (Mohamed, 2017).

According to FAO (2000), although natural hazards, conflict, and population growth are the underlying causes of food insecurity, the natural resource systems, crop-based systems, pastoralism, knowledge and information systems, household economy, marketing and credit systems, access to infrastructure and social services are always linked with food insecurity in rural areas. In Ethiopia, recurrent drought, reliance on precipitation, backward agricultural technologies, and inappropriate agricultural policies were the major factors for food insecurity in rural areas (Devereux, 2000). Further, Endalew *et al.* (2015) reported that population pressure, shortage of farmland, poor soil fertility, and outbreaks of animal and plant diseases were the causes of the worsening situation of food insecurity in rural Ethiopia.

2.2.4 Precipitation variability as a cause of food insecurity

Climate change is associated with many global phenomena including food systems. A significant number of scholars like Darwin (2001), Schmidhuber and Tubiello (2007), Wheeler and Braun (2013), and Muluneh (2021) agree on the impact of climate change on food production. Precipitation, the main source of water in rainfed agriculture, is one of the elements of climate that highly determines agricultural production and productivity in rural areas.

Precipitation variability is the variation in the amount, season, and distribution of precipitation over a given period in each place. Precipitation can increase or decrease in higher or smaller levels from time to time, but the extreme variability would have an adverse impact on food production. Although precipitation shortage is the main problem in many dry-land areas of the world, there are also areas where excess precipitation is a threat to their agricultural activity and their life too. Further, the timing in the precipitation pattern is the other form of variability. According to Torres *et al.* (2019), variations in the timing and intensity of precipitations are higher in an intra-year than

inter-yearly. Thus, understanding the nature, seasonality, and degree of precipitation variability is important to suggest adaptation strategies.

Food security depends on food availability, access, utilization, and stability; thus, it is better to study the impact of precipitation variability in each of these pillars. The impact of precipitation variability is direct, and higher on agricultural production, which in turn determines the food availability. According to Von Braun (1991), a 10 percent decline in the average amount of precipitation leads to a 4.4 percent reduction in food production. Besides, precipitation variability has a prominent impact on food stability as households are uncertain about the precipitation pattern. Precipitation variability has increased fluctuation in food production, and it was a source of high uncertainty regarding food production in 71 developing countries (Kinda and Badolo, 2019). Apart from this, the impact of precipitation variability on food access and utilization is likely to be less in relation to food availability and stability.

In Ethiopia, considering the higher dependence of the economy on rainfed agriculture, it is not arguable to say that precipitation variability has a significant impact on food security. The recurrent droughts that have been seen in Ethiopia were mainly caused by precipitation variations. Among others, the amount and variability of precipitation were important determinants of food security in Ethiopia (Demeke, 2011; Alemayehu and Bewket, 2016 and Agidew and Singh, 2018). However, the underlying causes of precipitation variability in Ethiopia like the ENSO and SST are not well researched.

According to the World Bank (2010), Ethiopia is among the countries listed as the most vulnerable to adverse impacts of climate variability. Yet, not all parts of the country are equally vulnerable to the impacts of precipitation variability. Subsistence farmers and pastoralists were relatively the most susceptible to precipitation variability in Ethiopia (Asfaw *et al.*, 2018). Geographically, the most severe drought was reported during 1984 - 1985 in *Wollo*, and the longest duration of drought, which lasted for 63 months was recorded in the *Borena* zone (Suryabhagavan, 2017). Seasonally, the *Kiremt* season is less variable in many parts of Ethiopia than the *Belg* season (Alemayehu and Bewket, 2016).

2.2.5 Household's coping mechanisms for food insecurity and meteorological drought

Households are the most important agents in the struggle to achieve food security. An individual farmer's role in responding to food insecurity and the varying precipitation is very significant.

Farmers are the ones who face the immediate impacts of food insecurity (Berry *et al.*, 2006) and react to the problem at the first stage. They also prevent the occurrence of the problem by adjusting their farming system to make them more resilient to the problem (Arbuckle *et al.*, 2015). In rural areas, where the impact of climate variability on food production is more noticeable, the household's choice of coping mechanisms plays a vital role in reducing and averting the risks of food insecurity.

Household's choice to adopt coping mechanisms depends on different factors. However, it is the climate pattern that mostly affects farmers' decision to choose peculiar coping mechanisms. Teklewold *et al.* (2019) indicated that climate was the major determinant of households' decisions to adopt alternative combinations of practices in the Nile basin of Ethiopia. Because climate variability is the major cause of food insecurity, particularly in the Tigray region (Weldearegay and Tedla, 2018), adapting to climate variability can significantly contribute to addressing the problems of food insecurity in rural areas. Thus, the adoption of multiple climate variability adaptation strategies is essential for improving the household's food security.

The household's decision to adopt a particular adaptation measure is also affected by several policy-related factors. A policy that affects one practice can have spillover effects on other practices (Teklewold *et al.*, 2019). Although the use of fertilizer and improved seeds was less probable under small farm-level and low precipitation conditions, conservation tillage, crop diversification, and other agricultural water management practices were effective adaptation mechanisms to the climate variability in the Nile basin of Ethiopia (Teklewold *et al.*, 2019).

Generally, there are different mechanisms for adapting to climate variability that are being used by rural households; of which, climate-smart agricultural practice is the one essential mechanism for addressing food insecurity. Teklewold *et al.* (2019) found that the adoption of climate-smart agricultural practices has increased dietary diversity and improved the food security of households in the Nile basin of Ethiopia. More importantly, the adoption of combinations of these practices has increased the per capita nutrition consumption and dietary diversity as compared with the adoption of a single climate-smart agricultural practice (Teklewold *et al.*, 2019).

Deressa *et al.* (2009) also found that the use of different crop varieties, tree planting, soil conservation, early and late planting, and irrigation were among the mechanisms farmers used to adapt to climate variability in the Nile Basin of Ethiopia. Similarly, a research conducted in the

central Rift Valley of Ethiopia shows that practices like crop diversification, planting date adjustment, soil and water conservation, and management, increasing the intensity of input use, integrating crop with livestock, and tree planting were the practices adopted by most of the rural households to adapt to the varying climate (Belay *et al.*, 2017).

Although adapting to climate variability is very important as a preventive measure against food insecurity, reaction mechanisms are also equally important in reducing the risks of food insecurity. In Ethiopia, the coping mechanisms used by rural households include minimizing the number and quantity of meals in a day, diversifying livelihood income sources, migration, and wage labor (Sewnet, 2015). Besides, reducing meal size, reducing the frequency of meals served, working as a daily laborer, and selling livestock were major coping mechanisms to address food insecurity in western Ethiopia (Sani and Kemaw, 2019).

In the Tigray region, food-insecure households use different coping mechanisms like working as daily laborer, reducing meals, borrowing, selling productive assets, and switching meals (Weldearegay and Tedla, 2018). Similarly, strategies like selling household assets, leaving the entire day without eating, and sending household members for begging were among the coping mechanisms used by the food-insecure households in rural Adwa (Negash and Alemu, 2013).

2.2.6 Intervention mechanisms to food insecurity

Government is one of the most important actors in responding to food insecurity. The role of the government and other stakeholders in enabling farmers to adapt to the varying precipitation is prominent. In some places like the central Rift Valley of Ethiopia, reacting to the varying climate and its associated precipitation variability has been beyond the capacity of the farmers (Belay *et al.*, 2017). Hence, the hand of the government and other humanitarian organizations is highly crucial in enabling farmers to cope with the problem effectively. Li *et al.* (2018) indicated that the combined efforts of the government and farmers are significant in addressing drought and boosting agricultural output.

In many cases, the government, including many humanitarian organizations reacts to food shortages by providing food aid. This could not be a long-lasting solution to food insecurity as it heavily relies on fund-raisings and the commitment of different organizations to allocate aid (Haile, 2005). Since the causes of food insecurity are multifaceted, early and integrated prevention measures are required. Besides, short and long-term policies and programs should be set based on

the available resources to improve food security and reduce the dependence on food aid. According to Von Braun and Olofinbiyi (2007), governments should consider micro-level interventions in tandem with macroeconomic policies, and market integration and price stabilization must be in place for programs to function effectively.

The establishment of a food security policy framework should be the first task in combating food insecurity. And, the policy should have clear objectives and be aligned with the national development policies. According to FAO (2009), there are two approaches in formulating food security policies: mainstreaming food security issues into the overall national development policies, and/or preparing a specific food security policy that can address all aspects relevant to achieving food security. More importantly, food security should address the four pillars of food security that are not fulfilled: insufficient food supplies, insufficient access to food, ineffective utilization (malnutrition), and instability in the other three pillars over time. Thus, it is important to review which pillars of food security need to be fulfilled and to what extent these pillars are primary concerns in formulating a food security policy, which have to be implemented effectively.

Irrigation is a key element in many food security programs supposed to bring a long-lasting solution to food insecurity in rural areas. The irrigation goal is achieved if water resources are prudently harvested with the active engagement of the farmers (Brelle, 2016). The performance of irrigation practices relies on a secured water resource like sufficient and reliable precipitation and its utilization. More importantly, water resource management which determines the generation, distribution, conservation, and utilization of water appears as a key factor in improving farmers' agricultural production.

During times of food insecurity, food aid is the most common reaction mechanism used by many governmental and non-governmental organizations in places where food deficit occurs. This mechanism has been criticized for its lack of timeliness, high cost of delivery and administration, and problems in its distribution (Del Ninno *et al.,* 2005). Further, dependence on food aid could not be a long-lasting solution to food insecurity as it only addresses the symptoms, not the root causes. Thus, although food aid is a mere strategy to address short-term food insecurity, long-lasting strategies that could address the causes of recurring food insecurity should be the prime agenda.

Crop insurance is the other coping strategy designed to manage risks related to agriculture. This has a positive impact on the food security of farmers. In eastern India, the participation of farmers in crop insurance increased rice yields of large farms by 49 percent, and rice yields of small farms by 16 percent (Ranganathan *et al.*, 2018). Geographically, crop insurance is mainly practiced in developed countries. Although there are no recent data on the distribution, the FAO (2005) report shows that Africa has only a two percent global share of crop insurance, while the figure was 55 percent and 29 percent in North America and western Europe, respectively.

Nowadays, Information and Communication Technology (ICT) is becoming an important tool to fight against food insecurity. Lack of access to information related to new agricultural technology, skill, and knowledge are few of the challenges that rural people are facing today (Nakasone and Torero, 2016). This limits the opportunities for agricultural growth and improvements. Today, ICTs are expanding around the developing world.

In Ethiopia, the Productive Safety Net Program (PSNP) is one of the most common programs used to address food insecurity. The program was introduced in 2005 to help the chronically food-insecure households. According to Welteji *et al.* (2017), PSNP in the Bale zone, Oromia region of Ethiopia, was found to be helpful in fulfilling consumption needs, asset accumulation, and the overall food security status of the beneficiary households. Yet, the program needs due care in reaching the needy households, and it would be better if a focus is given to equipping the farmers with effective skills of managing food shocks rather than exploiting their labor for cash.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Overview of the Study Areas

Atsbi-wenberta, Irob and *Hintalo-wejerat* were the most food-insecure rural districts in Ethiopia's Tigray region, according to the 2019 report by the Tigray region PSNP office. Conferring to the latest administrative boundary restructuring, *Atsbi-wenberta* was divided into two rural districts: *Atsbi* and *Tsirae-wenberta*; *Hintalo-wejerat* was also divided into two rural districts: *Hintalo* and *Wejerat*.

Atsbi-wenberta and *Irob* are found in the astern zone of Tigray, whereas *Hintalo-wejerat* is located in the southeastern zone of the region. The three districts are located in the eastern part of Tigray adjacent to the Afar region. While all the study areas share a regional boundary with the Afar regional state, *Irob* shares an international boundary with Eritrea in the north.

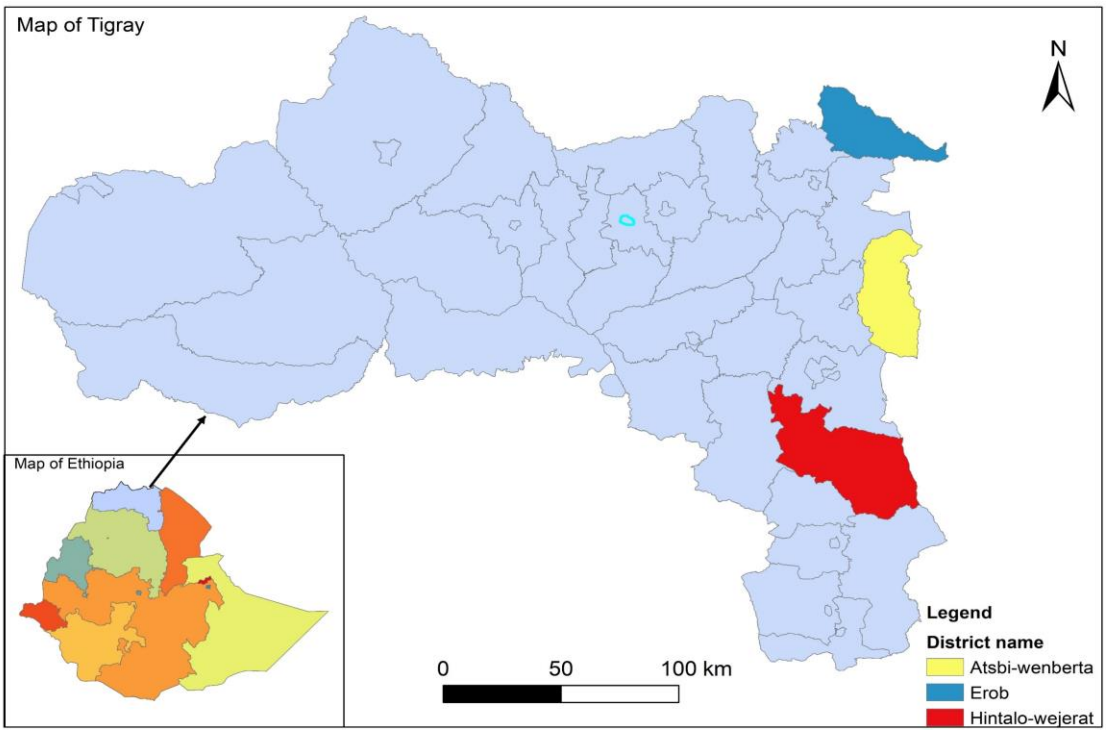


Figure 3.1. Administrative map of the study areas (2019)

Atsbi, Dowhan, and *Adigudem* towns are the market centers for the three rural districts, i.e. *Atsbi-wenberta, Irob* and *Hintalo-wejerat*, respectively. The road distance from the capital Mekelle to *Atsbi* town is 70 km (through *Wukro*); 195 km to *Dowhan* (through *Endamosa*); 35 km to

Adigudem and about 70 km to *Bahre-tseba* (the market center of *Wejerat* district). Before the administrative boundary restructuring in Tigray, *Atsbi-wenberta*, *Irob* and *Hintalo-wejerat* had a total rural population of 140,204; 31,331 and 188,062, respectively. In December 2023, a report by the offices of the three rural districts revealed that the newly restructured rural districts of *Atsbi, Irob,* and *Wejerat,* in which the samples for the study were taken, had a total rural population of 94,210; 33,280 and 88,800, respectively.

Table 3.1 shows the study areas are found in similar longitudinal locations. Referring to the Koppen climate classification map for Ethiopia (1980-2016), *Irob* and *Hintalo-wejerat* have an arid, steppe and hot (BSh) climates; whereas, *Atsbi-wenberta* has an arid, steppe, and cold (BSk) climates (Beck *et al.,* 2020). Like the other parts of Tigray, the study areas have three distinct climatic seasons based on precipitation. The first is the main rainy season, which lasts from June to mid-September, the second is the dry winter season from October to February, and the third is the pre-monsoon hot season from March to May (Gebrehiwot and Van der Veen, 2013).

Table 3.1. Geographical location of study areas

Name of study areas	Elevation (m)	Latitude (North)		Longitude (East)	
Atsbi-wenberta	2511	13.8465	13.9132	39.6763	39.7903
Irob	1931	14.4291	14.5528	39.3695	39.5974
Hintalo-wejerat	2107	13.2677	13.3572	39.5013	39.6908

Agriculture is the dominant economic sector in the study areas, in which crop production, livestock, and forestry are the leading agricultural activities. In addition, the agricultural systems in these areas depend on rain-fed agriculture dominated by small-scale farmers with average land holdings of less than a hectare per household.

3.2 Research Design

3.2.1 Research types

This study is based on an integration of descriptive, explanatory, and exploratory research types. To describe the existing food insecurity status and the adopted coping and adaptation strategies, a descriptive research was used; to explain the cause-effect relationship between the precipitation pattern of the study areas and the global SST and ENSO indices, an explanatory research was used. In addition, an exploratory research was adopted to explore the food security intervention mechanisms of various levels used in reference to drought-prone rural areas.

3.2.2 Research approach

A mixed research approach was applied in which quantitative and qualitative studies were integrated to describe the results of the study numerically and in a meaningful way. Specifically, to describe the food security coping and adaptation strategies, a concurrent triangulation mixed research approach was adopted to compare the qualitative and quantitative databases for convergence. In addition, a concurrent nested mixed research approach was used to describe the food insecurity status and explain the nature of precipitation variability and its associated factors, in which the quantitative research approach was predominantly applied; it is also used to describe the food security intervention mechanisms, in which the phenomenological qualitative research approach was predominantly used.

3.2.3 Research strategy

Survey research was employed to effectively and efficiently collect factual data from the sampled population using a questionnaire. Secondary data from relevant regional and district-level offices were also gathered using survey research.

3.2.4 Research time dimension

In this study, an approximation of a longitudinal study using cross-sectional research was used for the time dimension of the study to solicit data about the past.

3.3 Data Type and Sources

3.3.1 Primary data

The collected primary data for the study include food insecurity status, coping strategies, and food security intervention mechanisms at the community level. Hence, household heads were the primary data sources. Further, primary data regarding food security intervention mechanisms at the regional level was gathered from the regional PSNP office. Moreover, data with respect to household's choice of coping and adaptation strategies to food insecurity and drought was gathered from elders, selected model farmers, local administrators, and religious leaders of the respective sub-districts.

3.3.2 Secondary data

The secondary data collected for the study is related to the precipitation data of the selected study areas for the period of 1979-2019. The monthly precipitation data for the study areas were obtained from the Ethiopian National Meteorological Agency (NMA).

Additionally, the global sea-surface temperature (SST) and El-Nino southern oscillation (ENSO) data for the specified period were obtained from the IRI/LDEO Climate Data Library and the US National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center, respectively. Of the ENSO indices, a three-month Oceanic Nino Index (ONI) was used to track the ENSO pattern. According to Lindsey (2009), the ONI is a primary indicator for monitoring the seasonal climate pattern of ENSO.

Further, secondary data regarding children's and Pregnant and Lactating Women's (PLW) malnutrition status was gathered from the respective health offices of the three districts. Moreover, data regarding food security intervention mechanisms at the national level was gathered from relevant documents of the Ethiopian Food Security Policy, Food Security Strategy, Food Security Program, and PSNP implementation manual.

3.4 Sampling Techniques and Study Population

In this study, both probability and non-probability sampling techniques were used. The base for this study is the prevalence of chronic food insecurity. For this, drought-prone rural areas with a higher proportion of food-insecure populations were selected in the study. Hence, of the non-probability sampling techniques, a judgmental sampling method was used to select the rural districts and target population.

During 2021, data obtained from the Tigray region office of food security shows that *Irob, Atsbi-wenberta*, and *Hintalo-wejerat* rural districts (see Figure 3.1), were the most affected drought-prone rural areas of Tigray region with a higher proportion of food-insecure population. In addition, two sub-districts (*tabias*, the last administrative units in Tigray) from each district with a higher number of food-insecure population (based on the district's PSNP data), a total of six sub-districts were selected to conduct the survey. Hence, *Alitena* and *Haraze-sebeata* from *Irob* district; *Haresaw* and *Hadinet* from *Atsbi-wenberta* district and *Gonka* and *Seneale* from *Hintalo-wejerat* district were selected for this study.

Rural Productive Safety Net Program (PSNP) beneficiaries were the target population purposively selected for this study, as their major inclusion criterion to the program was their being the most food-insecure. As such, the main purpose of this study was to capture food insecurity status, coping strategies, and adaptation mechanisms in the most food-insecure households living in the drought-prone rural areas. In these stated sub-districts, a total of 6,528 food-insecure households were rural PSNP beneficiaries. This number was then used to determine the final sample size. The following formula was then adopted from Survey Monkey (2019), which is the easiest and fastest online sample size calculator for survey research. The formula is based on the margin of error and confidence level, which is convenient for representing a limited and relatively homogeneous population with similar socioeconomic characteristics (Survey Monkey, 2019).

$$Sample\ size = \frac{\frac{z^2 * p(1-p)}{e^2}}{1 + (\frac{z^2 * p(1-p)}{e^2 N})}$$

where, N= population size, e = margin of error, z = confidence level and p = population variability

Assuming a 95 percent confidence level, 5 percent margin of error, and 50 percent of population variability, the final sample size was calculated to be 363. This was distributed to each sub-district proportionally as shown in Table 3.2. By the end of the survey, all the filled-in questionnaires were collected.

Furthermore, a probability sampling technique, simple random sampling, was employed in selecting respondent households from the six sub-districts selected from the three districts for administering the questionnaire. A complete list of households registered under the PSNP was available to make the random selection.

Table 3.2. Distribution of the sample size to sampled study areas

No	Name of the sub-district	Number of food-insecure households under PSNP	Final sample size
1	*Alitena*	1,029	57
2	*Haraze-sebeata*	1,174	65
3	*Gonka*	1,022	56
4	*Seneale*	1,235	69
5	*Haresaw*	1,080	61
6	*Hadinet*	988	55
	Total	6,528	363

3.5 Methods of Data Collection

Survey questionnaire:

Data about the food insecurity status, coping mechanisms, adaptation strategies, and food security intervention mechanisms at the community level were collected using an interview-based questionnaire. Both open and closed-ended questionnaires were administered to the randomly selected respondents. This was done to obtain structured responses and self-expressed opinions from the household heads. The questionnaires were translated into the local language (Tigrigna and Saho) and administered through face-to-face interaction with household heads by trained enumerators (food security experts in the respective study areas).

Assessment of the food security situation in agriculture-based rural communities should be done during the period of higher food shortages (Kennedy *et al.*, 2011). The pre-harvest or agricultural lean season normally spreads between April and September. Thus, the data were gathered during May-June (2023), which falls under the most food-insecure period. Besides, based on the degree to which household food insecurity is likely to fluctuate over time, the time frame (recall period) for this study was 12 months. According to Coates (2004), applications of food insecurity scales have generally used either 12 months, 6 months, or 30 days.

Key Informant Interview:

Key informant interview (KII) was used to gather additional data about the status of children's and PLW malnutrition levels in the study areas and food security intervention mechanisms at regional and community levels. Hence, the head of the Tigray region PSNP office, three heads of district health offices, and three PSNP officers of the selected districts were interviewed. A semi-structured interview was employed to make the interview guided by flexible schedules for elaboration and to make the interviews smooth. Key informants were asked about the prevalence of malnutrition in their respective districts and the ongoing food security intervention mechanisms.

Focus Group Discussion:

Focus group discussion (FGD) was used to obtain data concerning households' choice of coping strategies for food insecurity and adaptation mechanisms to the recurring meteorological droughts. A total of six FGDs (one FGD for each sub-district) composed of nine to ten individuals from elders, model farmers, women, local administrators, and religious leaders was organized. The FGDs were tasked with discussion about their preferred food insecurity coping strategies and

adaptation mechanisms to meteorological drought. Questions were made clear before the discussions, and each FGD was completed in no more than 90 minutes.

Observation:

This tool was used to capture data about the malnutrition status of children aged 6-59 months. For this purpose, the children's feet and eyes were observed and tested against the occurrence of oedema and Bitot's spot, which are critical indicators of children's malnutritional status. The presence of Bitot's spots on children's eyes was observed with the support of a magnifier and flashlight.

Documentary Sources:

Precipitation data of the study areas were generated from the NMA archives; SST and ENSO data were generated from reports and archives of the CFSR, IRI/LDEO Climate data library, and NOAA. In addition, relevant documents including Ethiopia's Food Security Policy, Food Security Strategy, Food Security Program, and PSNP implementation manual were analyzed to describe the existing food security intervention mechanisms at various levels.

3.6 Data Quality Control Procedures

To ensure data validity, the questionnaires were tested prior to the field survey through a pilot survey in randomly selected 20 households. Lastly, the tool was administered after possible improvements in the questionnaire were successfully conducted. To ensure the reliability of data about child malnourishment, selected children were tested in addition to the nutritional survey report by the health offices of the districts.

Since the questionnaires were filled in by trained enumerators, all the administered questionnaires were returned with minimum acceptable errors. Besides, the errors were corrected in the field. Finally, the data were carefully coded, followed by data entry using SPSS V. 27.

Precipitation data obtained from the Ethiopia National Meteorological Agency (NMA) were double-checked for consistency using a station data obtained from the Tigray Region Meteorology Service Center. In addition, a gridded Climate Forecast System Reanalysis (CFSR) data was used to fill in the missing data during the study period. CFSR data are provided at an hourly time resolution on the horizontal grid with a spatial resolution of ~38 km (0.5 degree x 0.5 degree latitudinal and longitudinal resolution) since 1979. According to Dile and Srinivasan (2014) and

Fuka *et al.* (2014), CFSR is the most reliable meteorological data source for Ethiopia where there is data scarcity.

3.7 Data Analysis Techniques

3.7.1 Data analysis methods of food insecurity

To analyze the food availability, access to food, and food stability, a combination of Household Food Insecurity Access Scale (HFIAS) and Food Insecurity Experience Scale (FIES) were adapted. Additionally, Household Food Expenditure (HFE) was used to assess the economic access of the households to food. Further, the Household Dietary Diversity Score (HDDS), Food Consumption Score (FCS), anthropometry measure of mid-upper arm circumference (MUAC), nutritional oedema test, and Bitot's spot were used for measuring the utilization component of food security as discussed below.

Generally, a descriptive analysis technique (mean values, frequencies, percentiles and crosstabulation) was used to analyze the quantitative data about food insecurity status of the rural households using analysis tools in the SPSS V. 27.

Household Dietary Diversity Score (HDDS)

HDDS is a description of the number of food groups consumed by household members in the previous 24 hours. The HDDS was first developed by the Food and Nutrition Technical Assistance (FANTA) Project; as also indicated by Swindale and Bilinsky (2006), it is a 12-scale level and a proxy measure of access to food by households. It was standardized by FAO a few years later, developed into a guideline to address diet diversity measurement, and became a standard tool. Counting of food groups consumed over a period of the past 24 hours, and gives the dietary diversity score of households in the drought-prone rural areas of Tigray. Then, mean scores are derived to analyze consumption patterns of sample rural households and the differences in diet diversity between them. The measure of diet diversity captures the food groups consumed, showing the importance of HDDS in measuring food security.

$$HDDS = Sum\ (A + B + C + D + E + F + G + H + I + J + K + L) \quad (1)$$

Where, A to L are the 12 individual food groups representing cereals, root and tubers, vegetables, fruit, meat, egg, fish, legumes, milk, oil and fats, sweets, and spices.

The average household dietary diversity score for the population of study can be calculated as follows:

Sum (HDDS) / Total number of households surveyed (2)

Food Consumption Score (FCS)

FCS is an index developed by WFP that aggregates household-level data on the diet diversity and frequency of food groups consumed for seven days prior to the interview/survey conducted on selected representative households (Wiesmann *et al*., 2006; Maxwell *et al.*, 2013 and IDEP, 2023). FCS is stronger than HDDS in the sense that it combines food frequency, dietary diversity and relative nutritional importance of the various food groups (a maximum of 12 groups) consumed by the rural households over the indicated period. FCS is calculated as:

- grouping food items in the specified food groups;
- summing all the consumption frequencies of food items within the same group;
- multiplying the value of each food group by its weight and then
- summing the weighted food group scores.

Based on WFP's recommended cut-offs, FCS results of 0-21 are labeled as poor; 21.5-35 as borderline, and FCS above 35 as acceptable (IDEP, 2023).

Analyzing malnutrition

Moderate Acute Malnutrition (MAM) is identified for children 6-59 months, using the standard interval measure of MUAC <125 mm and >115 mm).

Severe Acute Malnutrition (SAM) is identified for children 6-59 months, using the standard interval measure of MUAC <115 mm or the presence of bilateral pitting oedema.

Global Acute Malnutrition (GAM) is the presence of both MAM and SAM in a population. A GAM value of more than 15 percent indicates an emergency. According to WHO (2000), the thresholds for GAM are:

- <5 percent, acceptable
- 5-9.9 percent, poor
- 10-14.9 percent, serious, and

- >15 percent, critical

Nutritional oedema is an independent indicator of SAM in children 6-59 months of age (Roberfroid *et al.*, 2013). Nutritional oedema for children 6-59 months is identified by thumb pressure on the top side of both feet gently for three seconds. The child has oedema if the indent stays after lifting the thumb for some time and it is then considered as SAM (Roberfroid *et al.*, 2013).

Bitot's spot is a vitamin A deficiency and is identified when a slightly elevated, white foamy lesion can usually be seen as the temporal part of the bulbar conjunctiva near the limbus at the left or right positions (Mayo-Wilson *et al.*, 2011). The presence of Bitot's spots on children's eyes was observed with the support of a flashlight.

3.7.2 Data analysis methods of precipitation, global SST and ENSO data

Mann-Kendall test (Mann, 1945 and Kendall, 1975) was used to statistically assess if there was a monotonic upward or downward trend in the precipitation pattern. Besides, the Sen's Slope estimator was used to analyze the magnitude of the trend in the precipitation pattern. The XLSTAT analysis tool was used during the Mann-Kendall and Sen's Slope estimator test. And, Stata software Version 14 was used to draw the fitting values. On the other hand, the coefficient of variation (CV) was used to describe the degree of precipitation variation in the three districts.

A Canonical Correlation Analysis (CCA) method was applied using the Climate Predictability Tool (CPT) to analyze the correlation between the precipitation pattern and global SST. Because of the quantitative nature of the data with normal distribution, the Pearson correlation method was used to test the relationship between the precipitation pattern and the global SST and ENSO indices with three months of lag time.

The Mann-Kendall test is calculated using equation 1:

$$S = \sum_{i=1}^{n-1} . \sum_{j=i+1}^{n} \operatorname{sgn}(X_j - X_i) \qquad (1)$$

where S is the Mann-Kendal's test statistics, n is the number of data points, X_j and X_i are the data values in the time series j and i $(j > i)$ respectively. The $\operatorname{sgn}(X_j - X_i)$ is the sign function as indicated in equation (2):

$$\mathrm{sgn}(\mathrm{X_j}-\mathrm{X_i})=\begin{cases}+1 \text{ if } (\mathrm{X_j}-\mathrm{X_i})>0\\ 0 \text{ if } (\mathrm{X_j}-\mathrm{X_i})=0\\ -1 \text{ if } (\mathrm{X_j}-\mathrm{X_i})<0\end{cases} \quad (2)$$

The variance is calculated by employing equation (3):

$$Var\ (s)=\frac{n(n-1)(2n+5)-\sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18} \quad (3)$$

where n is the number of data points, m is the number of tied groups (a set of sample data that have the same value), the summation sign (Σ) indicates the summation over all tied groups, and t_i is the number of data points for the i^{th} tie. If there are no tied groups, this summation process can be ignored. In the case where the sample size $n > 10$, $\mathrm{Z_{MK}}$ approximates the standard normal distribution with the mean $(S) = 0$ and it is computed using equation (4):

$$\mathrm{Z_{MK}}=\begin{cases}\frac{\mathrm{S}-1}{\sqrt{Var\ (S)}} \text{ if } (S)>0\\ 0 \qquad\quad \text{if } (S)=0\\ \frac{\mathrm{S}+1}{\sqrt{Var\ (S)}} \text{ if } (S)<0\end{cases} \quad (4)$$

The presence of a statistically significant trend is evaluated using the $\mathrm{Z_{MK}}$value. Positive values of $\mathrm{Z_{MK}}$ indicate increasing trends, while negative $\mathrm{Z_{MK}}$ values show decreasing trends. Testing trends are performed at the specific α (0.05) significance level. When $|\mathrm{Z_{MK}}| > \mathrm{Z_{1-\alpha/2}}$, the null hypothesis is rejected, indicating that a significant trend exists in the time series. $\mathrm{Z_{1-\alpha/2}}$ is the critical value of $\mathrm{Z_{MK}}$ and it is obtained from the standard normal distribution table which is 1.96.

The Mann–Kendall test only indicates the direction. Hence, the magnitude of the trend is usually determined by Sen's test which is defined by calculating the slope. The slope (change per unit time) was estimated based on the procedure in equations (5) and (6).

$$\mathrm{Q_i}=\frac{(\mathrm{X_i}-X_j)}{\mathrm{i}-\mathrm{j}} \quad (5)$$

Where $\mathrm{X_i}$ and X_j are considered as data values at time i and j ($i > j$) correspondingly and Q is the slope. The Sen's estimator is computed as $\mathrm{Q_{med}} = \mathrm{Q}_{\frac{\mathrm{N}+1}{2}}$ if N appears odd, and it is considered as $\mathrm{Q_{med}} = \frac{1}{2}(\mathrm{Q}_{\frac{\mathrm{N}}{2}} + \mathrm{Q}_{\frac{\mathrm{N}+2}{2}})$ if N appears even which is given as:

$$Q_{med} = \begin{cases} Q_{\frac{N+1}{2}} & if\ N\ is\ odd \\ \frac{1}{2}\left(Q_{\frac{N}{2}} + Q_{\frac{N+2}{2}}\right) & if\ N\ is\ even \end{cases} \quad (6)$$

Q_{med} is computed by a two-sided test at 100 (1-α) % confidence interval and then a true slope can be obtained by the non-parametric test. Positive value of Q_{med} indicates an upward or increasing trend and a negative value of Q_{med} gives a downward or decreasing trend in the time series.

Coefficient of variation of the annual precipitation variation is calculated as equation 7:

$$CV = \frac{SD}{\bar{X}} * 100 \quad (7)$$

where SD is the standard deviation which is computed by square root of the variance, and $\bar{X}$ is the sample mean of the annual average precipitation.

In this study, Pearson's correlation coefficient was used to measure the significance of a correlation analysis among the precipitation patterns of the three districts and the likelihood of global SST and ENSO variations. The Pearson correlation coefficient in this study is defined as follows: Suppose that there are two variables *X* and *Y*, each having *n* values *X1, X2, ... Xn*, and *Y1, Y2, ... Yn*, respectively. Let the mean of *X* be $\bar{x}$ and the mean of Y be $\bar{y}$. Then, Pearson's *r* is given by:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2]\,[n\sum y^2 - (\sum y)^2]}} \quad (8)$$

where the summation proceeds across all "*n"* possible values in this sample.

3.7.3 Data analysis methods of coping strategies and adaptation mechanisms

Data analysis techniques consisting of descriptive statistics (mean values, frequencies, and percentiles) and the Coping Strategies Index (CSI) were used to analyze the household's coping strategies for food insecurity.

CSI was developed by CARE/WFP in 2003 to measure households' coping strategies to food insecurity and it is used to describe food security situations (Maxwell *et al.*, 2003; Drysdale *et al.*, 2019 and Melese *et al.*, 2021). CSI combines both the frequency and severity of coping strategies. The frequency of coping strategies measures how many days per week a household had to rely on the various coping strategies. The severity of coping strategies is measured using data collected from the FGDs by asking the participants to classify their coping strategies based on: 1=less severe, 2=moderate, 3=severe, and 4=very severe). Thus, the CSI score was calculated by combining both

the frequency and severity of coping strategies. A higher CSI indicates a more food-insecure household and the vice versa.

The average CSI in this study was calculated based on the ranks given in the FGDs for coping strategies adopted using Weighted Mean Score. A four-point scale with a scoring order of 3, 2, 1, and 0 for frequently, sometimes, rarely, and never was used to calculate the frequency of households' reliance on various coping strategies, as indicated by Adebo and Falowo (2015) and Drysdale *et al.* (2019).

$$CSI = N_3X_3 + N_2X_2 + N_1X_1 + N_0X_0 \quad (1)$$

where N is the number of households using a particular coping strategy and X is the scoring order for frequency. CSI was used in rank order to reflect the comparative position of each of the coping strategies in terms of use. The Weighted Mean Score (WMS) is calculated as follows:

$$WMS_i = CSI/Z \quad (2)$$

WMS = weighted mean score Z = total number of household heads and i = individual coping strategies.

Further, data obtained from the FGDs were used to analyze the coping strategies and adaptation mechanism choices of rural households. Households' choices of coping and adaptation strategies were analyzed using the Paired Comparison Analysis (PCA).

The PCA method was used to rank households' choice of coping strategies and adaptation mechanisms. PCA is a tool for evaluating a small range of options by comparing them against each other. This method is applied to rate and rank the different options for food insecurity coping strategies and adaptation mechanisms for the recurring meteorological droughts, where the choices are subjective by nature.

PCA was performed using a matrix. This matrix is made in a way that avoids comparing an option with itself or duplicating any comparison. Two extra rows were added at the end of the table representing the frequency of each option that has been selected and the ranking of all options based on their count.

3.7.4 Data analysis methods of food security intervention mechanisms

Qualitative data were mostly obtained from documents regarding food security intervention mechanisms. Hence, a qualitative method of data analysis, i.e. documentary and content analysis were mainly used for analyzing the data that were obtained from the relevant documents. And, a quantitative method of data analysis (descriptive analysis) was used for analyzing the data obtained from the questionnaire regarding intervention mechanisms at the community level. Further, a narrative analysis method was applied to the data obtained through the interview.

3.8 Data Presentation Methods

Tables, charts, and graphs were used to present the analyzed quantitative data pertaining to food insecurity status, precipitation patterns, coping strategies and adaptation mechanisms, and food security intervention mechanisms at the community level. Besides, maps are used to present correlational values between precipitation patterns and the global SSTs.

The analyzed qualitative data about food security intervention mechanisms, on the other hand, are presented in a descriptive text and self-explanatory statements.

3.9 Ethical Considerations

This study adhered to the principles of the Declaration of Helsinki, a statement of ethical principles for research involving human participants, including research using identifiable human material or data. The anonymity of respondents and the identity of the researcher were considered as ethical issues in this study. Hence, the researcher/data enumerators took an official letter from Mekelle University to handle any uncertainties during the field survey. The letter was used to make clear to the data providers that the data was only to be used for research purposes.

Besides, the researcher and data enumerators asked the respondents for their verbal consent to participate before the data gathering, and the anonymity of the respondents was ensured. Moreover, politeness and courtesy in gathering the required data were the ethical guides performed.

Table 3.3. Operational (logical) Framework

Research objectives	Variables	Indicators	Methods of data collection	Data sources	Methods of data analysis	Analysis tools
To describe the food insecurity status in the selected drought-prone rural areas of Tigray	Food insecurity	Food availability	Questionnaire	HH heads	HFIAS & FIES	SPSS MS-Excel
		Access to food	Questionnaire	HH heads	HFE	
		Food utilization (nutrition)	Questionnaire, KII and observation	HH heads and children	HDDS, FCS, and MUAC	
		Food stability	Questionnaire	HH heads	Descriptive	
To analyze the nature and associated climate factors of precipitation variability in the selected drought-prone rural areas of Tigray	Precipitation variability	Trends in the precipitation pattern	Archives	NMA CFSR	Mann-Kendall, Sen's Slope, & CV	XLSTAT STATA
		Degree of correlation among precipitation and SST	Archives	IRI/LDEO	CCA	CPT
		Degree of correlation among precipitation and ENSO	Archives	NOAA	Pearson correlation	SPSS
To explain the rural household's coping and adaptation mechanisms to food insecurity in the drought-prone rural areas	Coping strategies to food insecurity	Lists of coping strategies	Questionnaire	HH heads	CSI	MS-Excel
		Choice of coping strategies	FGD	Community members	PCA	MS-Excel
	Adaptation mechanisms to meteorological drought	Lists of adaptation mechanisms	Questionnaire	HH heads	Descriptive	SPSS
		Choice of adaptation mechanisms	FGD	Community members	PCA	MS-Excel
To explore the food security intervention mechanisms used by various actors of different levels in the selected drought-prone rural areas	Food security intervention mechanisms	At international level	Archives	Websites	Content, narrative, and framework analysis	-
		At national level	Archives	Websites		
		At regional level	KII and archives	PSNP office		
		At community level	KII & Questionnaire	HH heads	Descriptive	SPSS

CHAPTER FOUR

A Comprehensive Analysis of Food Insecurity in the Drought-prone Rural Areas of Tigray

4.1 Introduction

Global hunger is on the rise, with a significant increase in the proportion of people facing severe food insecurity. According to the FAO (2023) report, the number of severely food-insecure individuals surged from 623.8 million in 2017 to 783.1 million in 2022. This growing crisis disproportionately affects rural communities, with 33.3 percent of rural people experiencing food insecurity in 2022, compared to 26 percent in urban areas (FAO *et al*., 2023).

Sub-Saharan Africa (SSA) has the highest proportion of severely food-insecure people in the world with a total of 310.6 million people facing chronic hunger in 2022 (FAO, 2023). Ethiopia is one of the SSA countries with a significant number of food-insecure people. In the last twenty years, Ethiopia has gained important achievements in food security. Nevertheless, hunger has been a major concern in Ethiopia. In 2023, an estimated 20.1 million people were facing chronic hunger across the country with 7.4 million severely undernourished children and women (WFP, 2023).

Tigray is one of the food-insecure regions in Ethiopia, which, over the past many decades has been affected by recurrent food insecurities (Endalew *et al.*, 2015). During 1984/1985, Tigray experienced severe food insecurity which caused the death of an estimated one million people (Reid, 2018). Food insecurity is still the main stressful issue in the region. In June 2022, a staggering 47 percent of Tigray's population was severely food insecure (WFP, 2022a), which is the worst period of food insecurity compared to the earlier times. According to a research cited in the Associated Press news (2023), nearly 1,400 people have died because of hunger in Tigray from November 2022 to July 2023 alone; hunger was associated with more than 68 percent of deaths in Tigray making hunger the main cause of death in the region.

In times of food insecurity, it is the rural population who suffers the most. In Tigray, most rural households rely on agriculture, which mostly is dependent on erratic precipitation, to pursue their livelihoods. Because of their limited livelihood strategies, rural communities in Tigray region are more vulnerable to acute undernutrition (Weldemariam *et al.*, 2023).

According to the Tigray Region PSNP Office (2019), western Tigray was classified as the only food-secure zone of the region; nearly ten rural districts from eastern, southeastern, and southern parts of the region were classified as severely food-insecure rural districts. In 2003, there were

only 16 food-insecure rural districts out of the then 34 rural districts (at present, after administrative boundary restructuring, there are 57 rural districts) in Tigray (WFP, 2009). This number increased to 31 (91%) rural districts in 2019, as reported by the Tigray region PSNP Office (2019).

The limited and variable precipitation patterns in the drought-prone rural areas of Tigray (Gebre *et al.*, 2024) caused *Irob*, *Atsbi-wenberta*, and *Hintalo-wejerat* to be labeled as the most food-insecure districts. Yet, there is no clear data regarding the food availability, access to food, utilization (nutrition), and stability in the food-insecure rural districts of Tigray region. Clear information on food insecurity situations is vital for addressing the problem sustainably (Mock *et al.*, 2013). However, decision-makers and various stakeholders have been usually challenged with incomplete and contradicting information regarding food insecurity situations (FAO, 2015).

Food security, as indicated by FAO (2008), is achieved when all the four pillars of food security: food availability, access to food, utilization, and stability are concurrently fulfilled by all people at all times. Thus, food security assessment reports are expected to reflect those food security components and their levels. In this regard, a significant number of food security assessment methods have been applied by different practitioners. However, it was difficult to understand which food security component those mechanisms were measuring and why.

Proper intervention mechanisms demand proper analysis of food insecurity. Yet, most researches have analyzed food security by considering only the food availability and access components (Manikas *et al.*, 2023); the utilization and stability aspects were seldom addressed when analyzing food security. Similarly, many food insecurity studies in Ethiopia used one or combined indicators of food security where the key components of food security were not fully addressed (Tora, 2023).

In addition, previous food security researches by Asrat and Anteneh (2020); Eshetu and Guye (2021) and Getaneh *et al.* (2022) used to identify the food-insecure people in a given geographical region. For this reason, there is no sufficient understanding about the severity and general food insecurity situation within the food-insecure rural community living in drought-prone rural areas.

Therefore, this study has come up with an explicit food insecurity status measure in the drought-prone rural areas of the Tigray region by capturing the important components of food security. This chapter is published as a research article in a peer-reviewed journal. The findings of this study will contribute to the intervention mechanisms to achieve food security in the drought-prone rural areas of the Tigray region, Ethiopia.

4.2 Research Methods

The study aims to provide a comprehensive understanding of food insecurity in the study areas. For this purpose, a mixed research approach was followed to describe food insecurity in the study areas. Primary data was collected from household heads, while secondary data were gathered from health offices in three districts. Data were collected through an interview-based questionnaire, translated into local languages, and administered face-to-face. The study was conducted during May-June 2023, the most food-insecure period, and a 12-month recall period was used to augment this. Key informant interviews were conducted to gather additional information about children's and PLW malnutrition levels and food security intervention mechanisms. Nutritional data on children aged 6-59 months were collected through MUAC, oedema, and Bitot's spot tests.

Food availability, access to food, and stability in rural households were analyzed using various tools. The Household Food Insecurity Access Scale (HFIAS) and Food Insecurity Experience Scale (FIES) were used to assess household's food availability and economic access to food. The Household Dietary Diversity Score (HDDS) was used to measure the utilization component of food security.

Further, the Household Dietary Diversity Score (HDDS) and the Food Consumption Score (FCS) were used to analyze the nutritional (food utilization) aspect of food security. The study also identified Moderate Acute Malnutrition (MAM) and Severe Acute Malnutrition (SAM) in children aged 6 to 59 months. Global Acute Malnutrition (GAM) was identified as an emergency if a GAM value of more than 15 percent was found. Nutritional oedema was identified as an independent indicator of SAM in children aged 6 to 59 months. Bitot's spot was identified as a vitamin A deficiency.

4.3 Results and Discussion

4.3.1 Demographic and socio-economic characteristics of the households

Analysis of demographic and socio-economic characteristics of household heads has a pivotal importance in food security research. A 2022 food security research in the Gondar area shows that age and sex of household head, income, family size, asset ownership, on-farm and off-farm activities, and farmland size were significant determinants of food security at the household level (Awoke *et al.*, 2022).

In Figure 4.1, it is shown that 71.6 percent of the interviewed households were male-headed. According to Negesse *et al.* (2020) female-headed households (FHH) had a possibility of double increase to be food-insecure when compared to male-headed households (MHH) in Ethiopia.

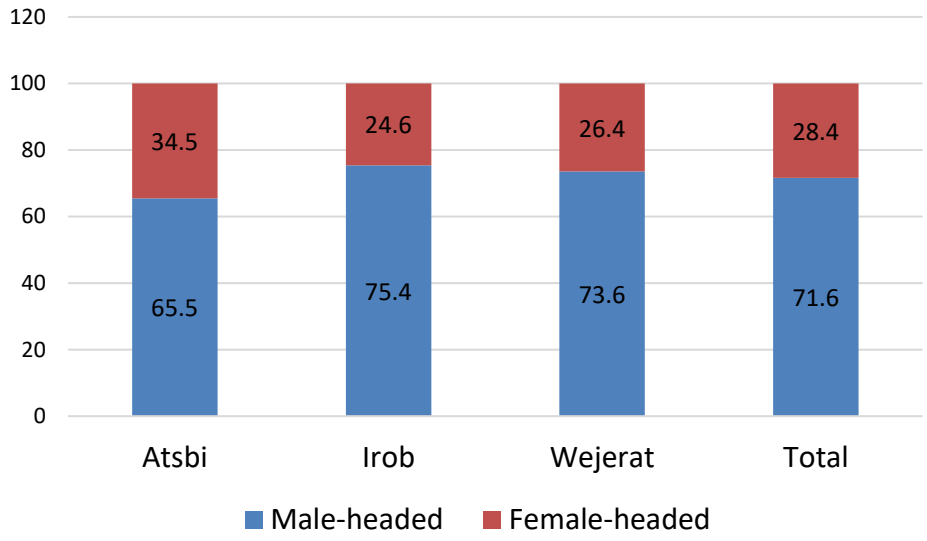


Figure 4.1. Sex of the household head

The average age of the household head was 46.6 years, as shown in Table 4.1. Nearly 47 percent of the household heads were illiterate, and only 7 percent of the household heads had reached or completed grade 10.

The average family size in the study areas was 5.4. This is higher when compared to the national average of 4.6 as per the 2016 demographic and health survey of Ethiopia (CSA, 2017). Food insecurity among large family households in Jimma was 3.74 times higher than that of less family households (Asesefa *et al.*, 2018).

The average number of economically active members of each household in the study areas was 1.67. For that reason, the dependency ratio in the study areas was found to be 1.85 (not reported in Table 4.1), meaning that 100 economically independent persons supported nearly 185 persons in addition to themselves. This is much higher than the Ethiopian dependency ratio of 0.74 percent in 2022, as reported by Trading Economics (2023).

Table 4.1. Demographic and socio-economic characteristics of households

No	Households' characteristics	Min.	Max.	Mean	Std. D.
1	Age of the household head	20	80	46.60	12.48
2	Formal schooling year of the household head	0	15	3.17	3.68
3	Total number of household members (Family size)	2	11	5.40	2.12
4	Total number of female household members	1	7	2.70	1.23
5	Total number of male household members	0	9	2.75	1.75
6	Total number of under five years age children	0	3	0.92	0.81
7	Number of economically active household members	0	4	1.67	0.79
8	Average amount of annual income in ETB	1,500	16,000	5,830.6	3777.41

In the study areas, about 23.1 percent (not reported in Table 4.2) of the households had no own farmland. In line with this, the average livestock ownership was found below one for cattle, donkeys/horses, and camels, as shown in Table 4.2. And, the average household ownership rate for sheep/goat and chicken was 1.6 and 2.78, respectively.

Table 4.2. Livestock and land ownership

No.	Asset ownership	Minimum	Maximum	Mean	Std. D.
1	Total number of cattle	0	3	0.91	0.95
2	Total number of donkeys or horses	0	2	0.32	0.49
3	Total number of camels	0	1	0.02	0.15
4	Total number of sheep and/or goats	0	10	1.6	2.06
5	Total number of chickens	0	10	2.78	2.73
6	Farmland size in hectares	0	1	0.21	0.73

Rural people rely mainly on agricultural activities to earn income. As indicated in Figure 4.2, on-farm activities were the main source of income for the households followed by humanitarian aid. Yet, almost all (98.8%) of the interviewed smallholder households were dependent on rainfed agriculture (data not shown). Besides, as revealed in Table 4.2, the average farmland size of the households was 0.21 hectares.

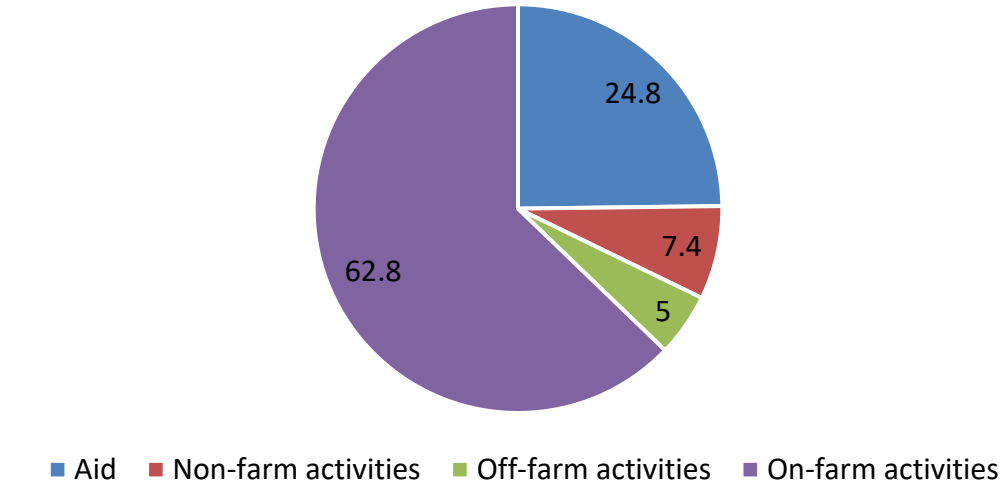


Figure 4.2. Main income source of households

The average annual income of the households under the study was ETB 5,830 (USD 104.13, as of December 28, 2023)[1]. This is far below the global low-income threshold of USD 1,045 and less (WHO, 2023). Concerning the source of food, agriculture was the main source of food for a majority (41.6%) of the households and nearly 28 percent of the households get their food from the market, as shown in Figure 4.3.

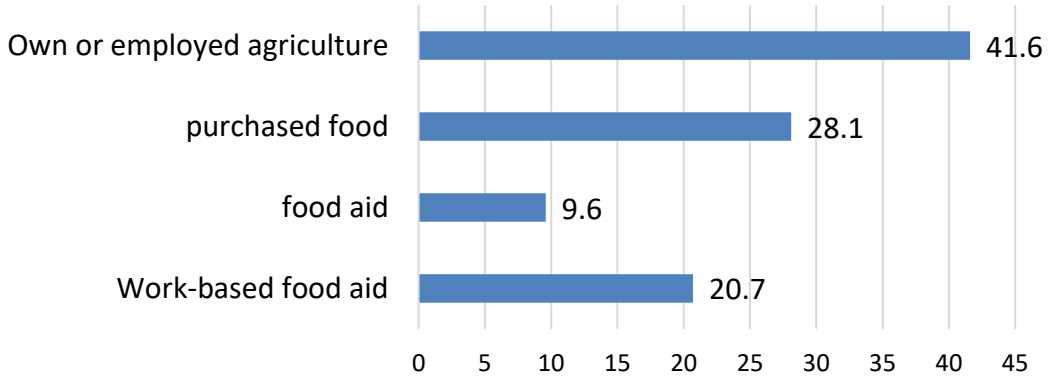


Figure 4.3. Main food source of households

As reported by 29.5 percent of the studied households, September was a month of chronic hunger followed by June, May, and August, as depicted in Figure 4.4.

[1] One USD = ETB 56.148

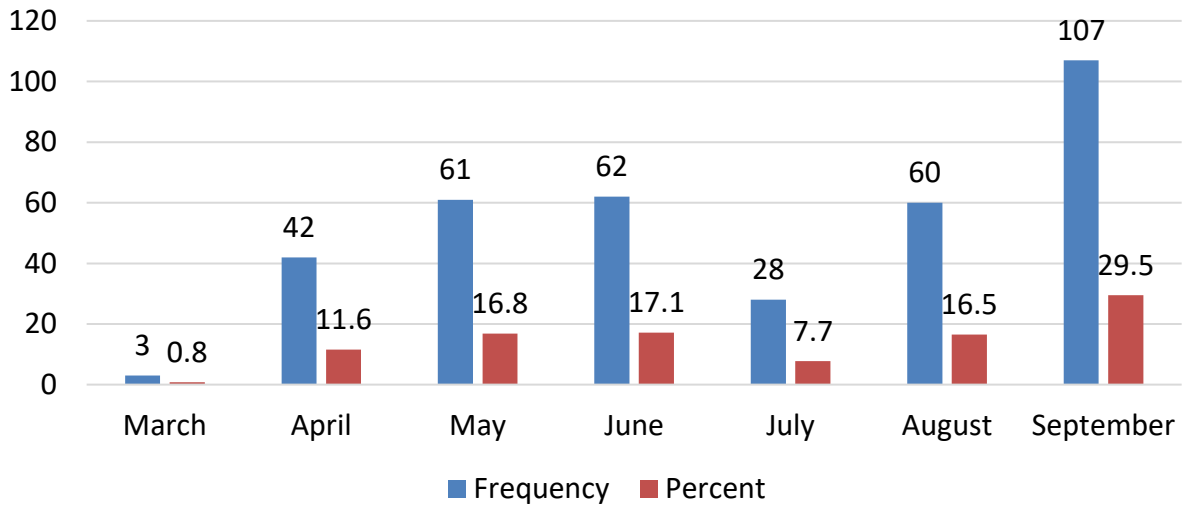


Figure 4.4. Month of chronic hunger

4.3.2 Analysis of food insecurity

Based on the 1996 World Food Summit, the four dimensions of food security, i.e. food availability, access to food, food utilization (nutrition), and food stability must be fulfilled simultaneously by all people, at all times for the realization of food security objectives (FAO, 2008). To meet these requisites for food security, food insecurity in the drought-prone rural areas of Tigray is analyzed by considering the four pillars of food security, as discussed below.

4.3.3 Food availability

Rural people are chief food producers; In many societies, rural people are the primary vendors at food markets. By selling their food products, they contribute to local economies and ensure food accessibility to urban areas. Paradoxically, rural people who produce most of the food supply are more food-insecure in many developing nations when compared to urban people. According to Ahmadi *et al.* (2021), 80 percent of the rural people in Iran suffered from food insecurity in 2020.

In Ethiopia, people living in drought-prone rural areas are at greater risk of food insecurity. According to Asrat and Anteneh (2020), about 13 percent of Ethiopian people live in drought-prone rural areas and many of these households suffer from chronic undernourishment and food insecurity. Food security research in the arid and semi-arid areas of Southern Ethiopia by Eshetu and Guye (2021) indicated that the prevalence of food insecurity in these areas was 68 percent, and the average vulnerability to food insecurity was 73 percent. Similarly, about 64 percent of the

sampled households living in the northeastern rift valley of Ethiopia, which is another drought-prone area of Ethiopia, were found to be food insecure (Getaneh *et al.*, 2022).

In the drought-prone rural areas of Tigray, many rural villagers have been suffering from chronic food shortages. As indicated in Table 4.3, 66.7 percent of the households mostly cut the size of their meal and/or have been eating less than they felt they should. In addition, more than 90 percent of the households reported that there were times when there was no food at all to eat in their house and more than 80 percent of the households had felt hunger because there was no food at the household.

A similar food security study in Tigray by Weldegiargis *et al.* (2023) confirmed that nearly 75 percent of interviewed households were eating smaller meals or went a whole day without eating any food.

Table 4.3. Household food availability status

No.	Questions	Yes	No	How often did this happen? (%)		
				Everyday	Sometimes	Rarely
1	Did you or any household member ever eat less than you felt you should?	100.0	0.0	68.0	7.7	24.3
2	Did you or any household member ever cut the size of the household meals?	100.0	0.0	66.7	15.1	18.2
3	Was there ever no food to eat of any kind in your household because of lack of resources to get food?	92.3	7.7	8.1	20.3	71.6
4	Were you or any household member ever hungry?	82.1	17.9	6.3	14.9	78.8
5	Were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	98.9	1.1	92.0	5.8	2.2
6	Did you or any household member have to eat a limited variety of foods due to a lack of resources?	100.0	0.0	81.0	12.6	5.4

4.3.4 Access to food

In rural areas, having physical, economic, and social access to food is crucial for livelihoods and is among the basic requirements for achieving food security. Elderly and vulnerable populations in rural communities often require physical access to the nearest urban and peri-urban areas for

market purposes. According to Nakamura *et al.* (2020), rural road development in Ethiopia was associated with a significant increase in household welfare. Yet, gaining physical access to the food market is the main challenge for rural communities.

Despite the promising progress in road infrastructure, a greater proportion (about 40%) of the populations living in Bangladesh, Nepal, Kenya, Uganda, Ethiopia, Mozambique, Tanzania, and Zambia are suffering from remoteness (Purdie *et al.*, 2016). According to Nagesso *et al.* (2019), only 10 percent of the rural population in Ethiopia lives within two kilometers of an all-weather road. In rural Ethiopia, the average distance of rural communities to the nearest market was estimated to be 7.82 km (Regasa *et al.*, 2020). This negatively affects rural communities physical access to food.

Similar research in the Dedo district of Oromia region shows that more than 65.9 percent of the villagers had to travel about 4 to 5 km distance from their home to the next main road and 21.6 percent of respondents revealed that the distance from the nearest main road to market was 6 to 7 km (Wudad *et al.*, 2021). In 2022, more than 75 percent of the households in Tigray reported that they do not have physical access to markets (WFP, 2022a).

All the market centers of the study areas, i.e., *Atsbi*, *Dowhan,* and *Bahre-tseba* were accessible from the main road through solely a low-quality earthen road of 25, 80, and 34 km long, respectively. Nevertheless, all the interviewed households were unconnected to any road transport; they had to walk for an average of one hour and forty-three minutes to get to the nearest food market. In some remote rural areas of *Irob* district, the villagers had to walk for nearly four hours. For this reason, only 12.1 percent of the elderly rural population of the study areas can access the food market. And, a significant (20.4%) number of households in the study areas, in which women and girls take on such tasks, had no access to the food market, as shown in Table 4.4.

Table 4.4. Household's response regarding their access to food

No.	**Questions**	**Yes**	**No**
1	Do the elders have access to food market?	44 (12.1%)	319 (87.9%)
2	Do the women and girls have access to food market?	289 (79.6%)	74 (20.4%)
3	Was the money you spent enough to purchase your required food?	0 (0%)	363 (100%)
4	Were you or any household member hungry because there was no money to buy food?	359 (98.9%)	4 (1.1%)

The other key determinant of food security is economic or financial access to food. Globally, nearly 3.1 billion people cannot afford a healthy diet (IDEP, 2023). According to the Global Food Security Index (2022), Ethiopia was ranked 108th out of 113 countries with the least food affordability of 32.9 percent. In 2022, about 85 percent of the rural households in Tigray were unable to afford food prices because of lack of money to purchase food (WFP, 2022a). According to the same source, prices of cereals and pulses in Tigray have been remarkably high when compared to prices in Dessie; the prices of teff (*Eragrostis tef*), maize, sorghum, wheat, rice, and fava beans have risen steeply in Tigray markets.

In this study, 28.1 percent of households relied on purchased food, and an average of ETB 586.7 was incurred monthly by the households to purchase food. In this regard, all the interviewed households replied that the money they spent on food was not enough to buy the required food. In line with this, almost all (98.9%) of the households claimed that they have experienced hunger because there was no money to purchase food, as shown in Table 4.4.

4.3.5 Food utilization

Food utilization (nutrition), the other key pillar of food security, is essential to lead a healthy life. According to WHO (2018), better nutrition is related to improved infant, child, and maternal health, stronger immune systems, safer pregnancy and childbirth, and lower risk of non-communicable diseases. This time, food utilization in general and nutrition and food safety in particular are becoming the main issues in food research discourses.

One way of assessing food utilization at the household level is by looking at dietary diversity. Nearly all (94.2%) of the households reported that they have been eating two or fewer food varieties in a day. Besides, 92 percent of the households claimed that they were unable to eat the kinds of food they preferred and 81 percent of the households had to eat a limited variety of foods because of lack of resources. In 2016, 23 percent of rural households in Tigray had low food diversity (Schwei *et al.*, 2017).

As shown in Figure 4.5, dry-bread made of wheat flour, *Injera*[2] with *Shiro*[3], porridge made of various cereals, and roasted cereals are the food staples of the study areas. This shows that almost all the households in the study areas consume two food groups: cereals and legumes, which indicates that their dietary diversity is below the minimum dietary diversity of four to five food groups (WHO, 2008).

Injera is a traditional staple food in Ethiopia and Tigray where the study districts are located. According to Neela and Fanta (2020), different studies were conducted on the composite flour development of *Injera* for its better nutritional and sensory quality; few studies reported the fermentation process had contributed to a reduction of nutritional quality and mineral availability in injera.

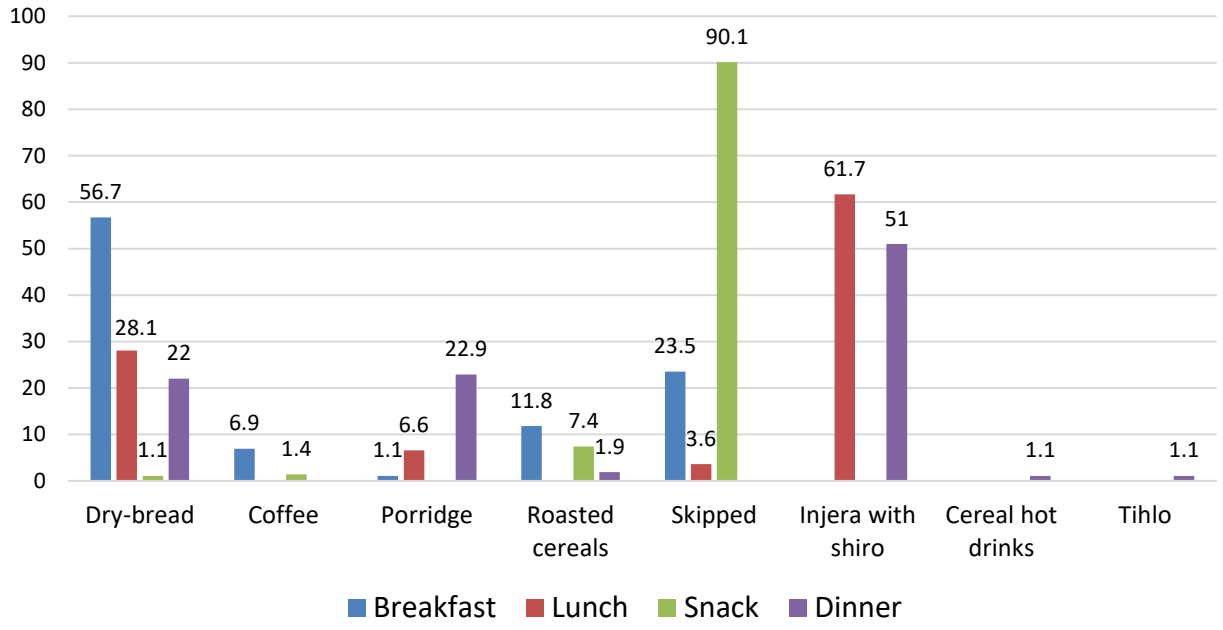


Figure 4.5. Consumption pattern of staple foods in the study areas

In this study, the average Food Consumption Score (FCS) was found to be 18.9 at the time of the survey. According to IDEP (2023), household's FCS below 21 is categorized as poor. Figure 4.6

[2] a fermented flatbread traditionally made of unique or mixed cereals of teff, wheat, barley, sorghum, maize, etc. flours

[3] ground chickpeas or broad bean stew

shows that 296 (81.5%) of the households had a poor FCS of 21 and below, and the rest had a borderline FCS of 21.5 – 25. According to food insecurity research findings based on FCS, more than half of the sampled households in Ethiopia were food-insecure (Ambaw *et al.*, 2021; Fite *et al.*, 2022 and Sileshi *et al.*, 2023).

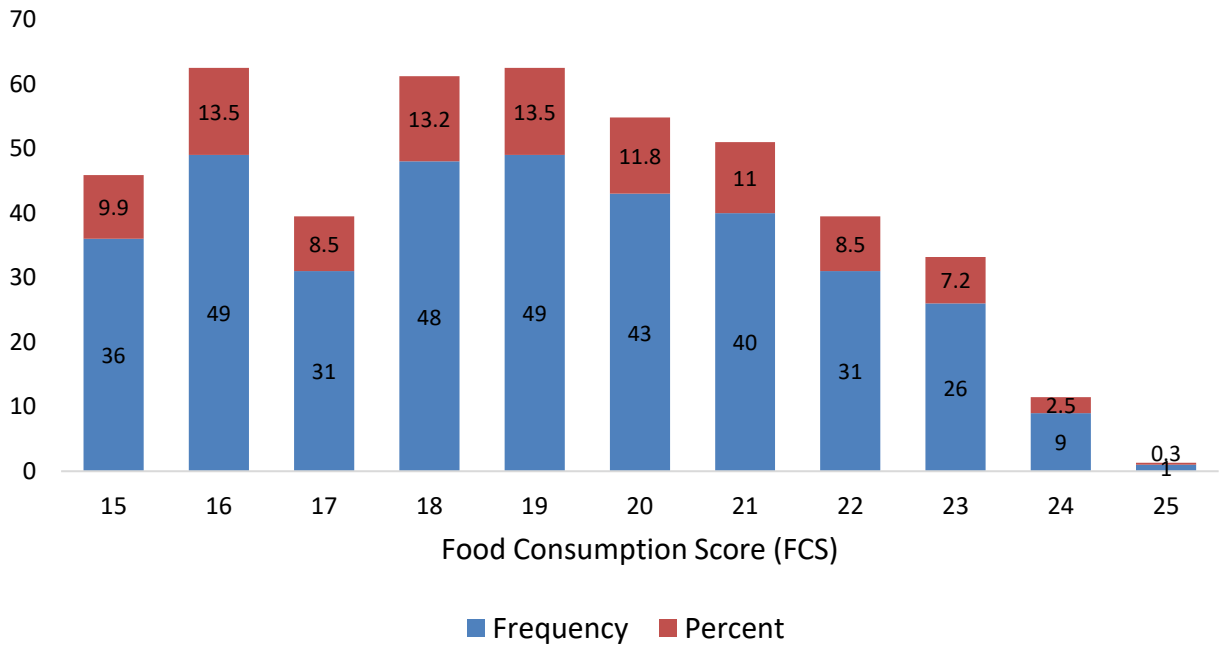


Figure 4.6. Food Consumption Score of studied households

The Ethiopian socio-economic survey data reported by Jateno *et al.* (2023) revealed that cereals and pulses were the most dominant food groups consumed by 96.4 and 82 percent of the households in Ethiopia, respectively. The same source reported that food commodities like meat and fruits were the least consumed food groups by households in Ethiopia.

Figure 4.7 indicates that more than 90 percent of the households did not consume important diets like meat, egg, dairy products, and honey for seven days before the survey. As a result, the average Household Dietary Diversity Score (HDDS) for this study was found to be 2.47. According to Kennedy *et al.* (2011), HDDS values less than five are labeled as low or poor food diversity. In rural Ethiopia, the average HDDS value for the year 2022 was 5.52 (Kabeta *et al.*, 2023). Similarly, the mean dietary diversity of pregnant and lactating women in Ethiopia in 2020 was 3.99 and 65.7 percent of the pregnant women were found to have poor food diversity (Bitew *et al.*, 2021).

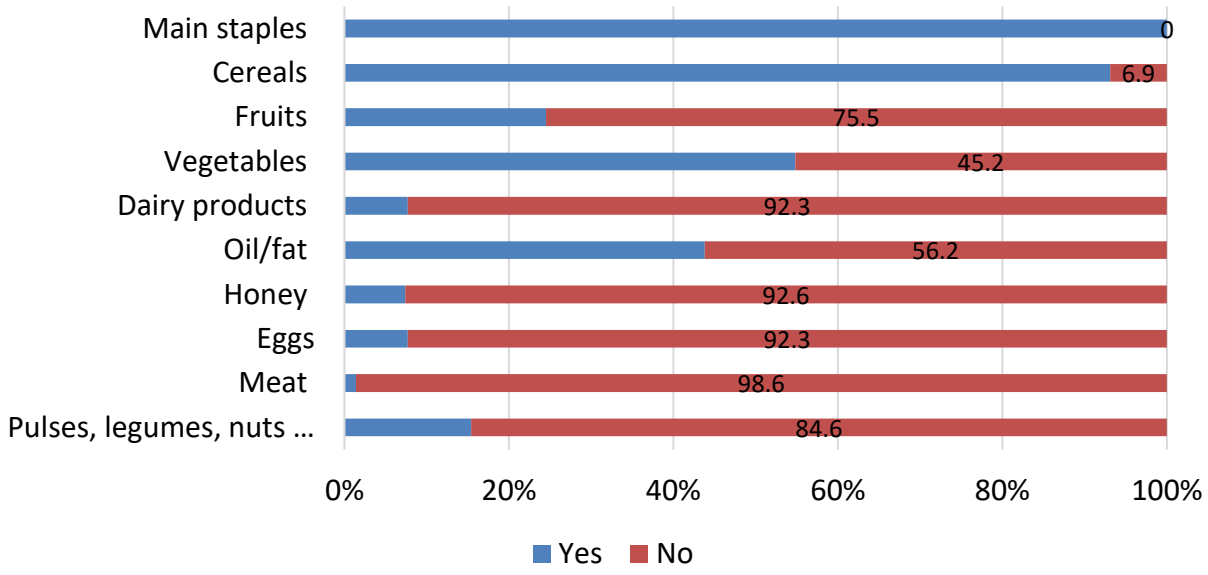


Figure 4.7. Weekly food diversity consumption

Balanced nutrition is particularly vital during childhood. The physical and mental development of infants and children is dependent on adequate nutrition (Roberts *et al.*, 2022). Nevertheless, based on the UNICEF, WHO, and World Bank (2021) joint child malnutrition 2021 estimate, 149.2 million children in the world under the age of 5 were stunted and 45.4 million were wasted (low weight-for-height). The same report shows that the number of stunting children is declining in all parts of the world except in Africa.

Acute malnutrition is a persistent public health issue affecting the world population disproportionately. In 2016, there were 32.8 million children worldwide affected by Moderately Affected Malnutrition (MAM), of which about 97 percent of them were living in underdeveloped countries; there were 18.7 million children worldwide affected by Severe Acute Malnutrition (SAM), of which about 99 percent of them were living in underdeveloped countries (Black *et al.*, 2016). Similarly, there were nearly 17 million under-five children worldwide affected by SAM in 2018; of which 75 percent of them were living in low-income countries (UNICEF, WHO and World Bank, 2021).

In Ethiopia, the prevalence of MAM and SAM in under-five children in 2021 was 18 and 8 percent, respectively (Anato, 2022). A similar research finding by Ghimire *et al.* (2020) shows that the prevalence of SAM in under-five children in Ethiopia in 2019 was 5.8 percent. According to WHO

(2000), a Global Acute Malnutrition (GAM) value of more than 15 percent is categorized as a critical severity of malnutrition and indicates an emergency.

In Tigray, an acute malnutrition assessment based on MUAC and oedema by WFP (2022a) reported that the prevalence GAM, MAM, and SAM in 2021 among under-five children was 29.4, 23.6 and 5.8 percent, respectively and 53.6 percent of lactating women and 59.6 percent of pregnant women were affected by acute malnutrition. Similarly, a rapid nutritional assessment by Mulugeta and Gebregziabher (2022) showed that 28 percent of children aged 6–59 months had GAM, and 6 percent had SAM.

In the selected study areas, data obtained from the health offices of the respective districts revealed that, out of the screened 11,321 children aged 6-59 months, more than half of them (5,698 children) were affected by acute malnutrition during December 2023; of which 4.2 percent and 46.1 percent of them were affected by SAM and MAM, respectively. On the other hand, of the screened 10,446 pregnant and lactating women (PLW), 6,213 (59.5%) were affected by acute malnutrition during December 2023, as illustrated in Figure 4.8.

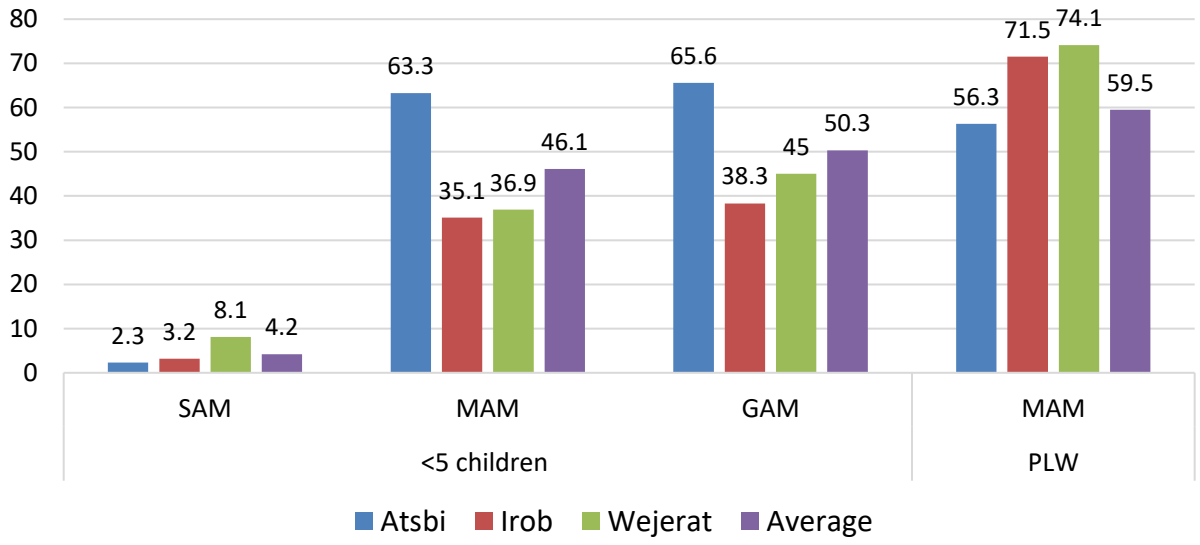


Figure 4.8. Prevalence of acute malnutrition among 6-59 months of age children and PLW based on MUAC

In this study, 265 children aged 6-59 months from the food-insecure rural households were surveyed to test the level of malnutrition based on MUAC and oedema, of which 159 (60%) of them were found with acute malnutrition and 56 (21.2%) of the children were affected by SAM.

In line with this, Ghimire *et al.* (2020) reported that Children from severely food-insecure households in Ethiopia were four times more likely to be affected by SAM.

Vitamin A Deficiency (VAD) is among the health problems in developing countries. In Ethiopia, VAD was recognized as a public health problem in the 1970s; studies showed a higher prevalence of VAD in Ethiopia, which is higher than WHO standards (Yisak *et al.*, 2020). Bitot's spot was used in this study to assess VAD and its prevalence was 1.9 percent. According to Yisak *et al.* (2020), the prevalence rate of Bitot's spot in Ethiopia in 2019 was 0.8 percent. The value of prevalence of Bitot's Spot more than 0.5 percent is used as the WHO standard point to declare that VAD is a public health issue in a given area (WHO, 2004).

4.3.6 Food stability

Food stability is the other significant component of food security. According to the food security concept of FAO (2008), food stability occurs when the other three components of food security, i.e. food availability, access to food, and utilization are secured by all households or individuals in all times even in times of bad events. Similarly, Helland and Sørbø (2014) explained food stability as the sustainability in availability of food, access to food or ability to purchase food, and sufficient nutrition. In the Sustainable Development Goals of 2030, the significance of food stability is highlighted: "SDG 1: No poverty" and "SDG 2: Zero hunger" describe the food stability component of food security.

Apart from achieving food security at all levels, achievement of food security also requires a time dimension. According to Maxwell and Smith (1992), food insecurity can be categorized as "chronic": a continuous failure to get food; or "transitory": a temporary failure to get food. Consistent handling of food security thus requires integrating time and spatial dimensions.

In light of limited food availability, securing stable food access is unthinkable in food-insecure rural households. As shown in Table 4.5, a majority (94.8%) of the rural households in the study areas reported during the survey that they had stored food. However, 76.7 percent of these households had stored food that could last only for days; the rest of them had stored food that could last for a few weeks. Thus, all the households were uncertain about the availability of food for consumption after a month. As a result, all the households had anxiety about having sufficient future food to feed themselves and their children, mothers, and elders. Besides, almost all (97.8%) of the households were worried about getting a variety of foods for the future. Similar to this, a

food insecurity study by Weldegiargis *et al.* (2023) reported that 75 percent of the households in Tigray had experienced anxiety and uncertainty about food supply in 2021.

Table 4.5. Household's response regarding food stability

No.	Questions	Yes	No
1	Do you have any stored food for future use?	344 (94.8%)	19 (5.2%)
2	Did you worry that your household would not have enough food?	363 (100%)	0 (0%)
3	Did you worry that your household would not have enough money to purchase food?	363 (100%)	0 (0%)
4	Did you worry that any of the children, women, or the elders would not have enough food?	363 (100%)	0 (0%)
5	Did you worry that your household would not have a variety of foods (like meat, egg, milk and milk products …)?	355 (97.8%)	8 (2.2%)

For the reason that food stability is related to the other three food security pillars, any activity in rural areas oriented to achieve sustainable food availability, access to food and utilization will contribute to the attainment of food stability in particular and food security in general.

4.4 Conclusion

The food security situation in the drought-prone rural areas of Tigray region is life-threatening and needs an instant action. In all measurements, the households living in the studied areas were critically food-insecure. Many of the food-insecure households rely on their farm activities to meet their food requirement where the farmland size is too small to support their larger family size. This signals that the high food insecurity problem encountered in the area shall not be left unattended and requires diligent actions.

The food availability and hunger levels of the food-insecure households were unacceptably worrisome. Because of limited food supplies, almost all the study rural communities had to eat a lesser amount of food which might be the cause of famine and starvation. It is even more challenging for these rural communities to get access to food because of their limited physical, social, and economic capacities. In times of food shortages, the study communities had to walk for longer and more challenging distances to purchase food with inadequate money at hand.

Both the Food Consumption Score (FCS) and Household Dietary Diversity Score (HDDS) results show a limited variety of food consumption below the standards. For this reason, 6-59 months of age children living in the food-insecure rural areas are at higher risk than any other age group. The

SAM, MAM, and GAM results were very high, which are greater than the WHO cut-off points for an emergency. Besides, because of the higher prevalence of Bitot's spot above the WHO standard, VAD in the food-insecure study areas is a public health concern. This calls for immediate attention and implies that much more has to be improved to curb the serious food insecurity prevailing in the study areas.

More importantly, the study communities had very limited or no food supplies for their future use. In this situation, the food insecurity status of the communities living in these drought-prone rural areas will get worse and might cost lives. Thus, an integrated life-saving task is required and diversifying livelihood sources of the food-insecure rural communities is a "must-to-do" activity to sustainably achieve food security. In due course, priority should be given to attaining the food availability and access components of food security.

This study implies that long-term food security attainment plans are much required to guide the intervention mechanisms to be undertaken by the government of all levels, international communities, and humanitarian agencies. In the meantime, elaborated short-term strategies are needed to address the children's malnutrition and households' food shortage in the drought-prone rural areas of Tigray.

This study did not measure child malnutrition by taking all anthropometric measurements and did not measure the calorie intake of food-insecure households. Hence, analyzing the stunting (low height-for-age) and wasting (reduced height-for-weight) for under five-years age children and measuring the calorie intake of these food-insecure rural households is left for future researchers interested in conducting similar food security studies.

CHAPTER FIVE

Precipitation Variability and its Teleconnection with the Global SST and ENSO Indices in the Food-insecure Rural Areas of Tigray

5.1 Introduction

Climate change, the catchy phrase, is the major threat to food security in rural areas. Because of the limited capacities to cope with the changing climate, food insecurity is higher in rural areas of developing countries, where much of their population depends on rain to produce food. World Bank (2016) reported that rural farmers are more than four times as likely to be food-insecure when compared to urban dwellers engaged in non-agricultural sectors.

Food insecurity, in many parts of the developing world, is associated with shortages and variability of precipitation (Darwin, 2001; Schmidhuber and Tubiello, 2007; Wheeler and Braun, 2013; Afifi *et al.*, 2014 and Muluneh, 2021). In 2024, it is projected that nearly 100 million people will need food assistance globally, partly because of the ongoing strong El Niño event (World Bank, 2023a). A similar study by Kinda and Badolo (2019) showed that precipitation variability has reduced food availability per capita and increased fluctuation in food production for 71 developing countries. According to Von Braun (1991), a 10 percent decline in the average amount of precipitation led to a 4.4 percent reduction in food production.

Ethiopia is predominantly an agrarian nation, in which more than 80 percent of the population relies on agriculture. More importantly, nearly 90 percent of smallholder farmers mainly depend on rain-fed agriculture (Alhamshry *et al.*, 2020). For this reason, Ethiopia is listed as the most vulnerable country to adverse impacts of climate variability (World Bank, 2010). However, not all parts of the country are equally vulnerable to the impacts of climate variability. Subsistence farmers were relatively the most susceptible to climate variability in Ethiopia (Asfaw *et al.*, 2018). Subsequently, the problem of food insecurity in Ethiopia is more pronounced in rural areas (World Finance, 2017). Further, an overdependence on rain-fed agriculture was one of the reasons for the pervasiveness of food insecurity in rural Ethiopia (Mekonnen and Gerber, 2017).

In Ethiopia, the intensity and variability of precipitation have been the important determinants of food security in rural areas (Demeke, 2011; Alemayehu and Bewket, 2016; Lewis, 2017 and Agidew and Singh, 2018). Between 2015 and 2016, an El Niño induced drought took place mainly in the lowlands of the country (Singh *et al.*, 2016).

Tigray is one of the regions in Ethiopia that has been affected by recurrent droughts over the past many decades (Endalew *et al.*, 2015). In the region, the average precipitation is very short and variable as compared to the southern and western parts of Ethiopia (Seleshi and Demaree, 1995; Woldehanna, 2000 and Weldearegay and Tedla, 2018). According to Demeke *et al.* (2011) and Weldearegay and Tedla (2018), precipitation variability was the major cause of food shortage in Tigray region. Nevertheless, rural farmers in Tigray still depend on the unreliable precipitation to produce food.

Although precipitation variability has many forms, the intensity and timing in the precipitation pattern are the main form of variability. According to Torres *et al.* (2019), variations in timing and intensity of precipitation are higher in an intra-year than inter-yearly. Intra-year precipitation variability matters most as many rural farmers keep months and seasons to do farming activities. In the Tekeze-Atbara river basin, Abebe *et al.* (2022) found that precipitation variability was higher in the other seasons than the summer; most of the precipitation was occurring in less than 3 months.

Precipitation variability is highly determined by global sea-surface temperature (SST) and El Niño/La Niña Southern Oscillation (ENSO). The SST is among the major drivers of precipitation variability (Dittus *et al.*, 2018), particularly for the Ethiopian precipitation (Alhamshry *et al.*, 2020). Besides, the ENSO is the other most important determinant of precipitation variability, particularly in the precipitation pattern of Ethiopia (Kasie *et al.*, 2019 and Tefera *et al.*, 2020). These two factors highly determine the intra-year and inter-year precipitation variability.

However, different areas have varying sensitivities to the SST and ENSO indices; the impacts of those indices greatly vary spatially. Hence, studies on precipitation variability and its associated climate factors have to be conducted at the lowest possible geographical spaces. Furthermore, there is a lack of knowledge on how significant the influence of SST and ENSO is on the local level precipitation variability of the food-insecure rural areas of the Tigray region.

Therefore, this study has investigated the precipitation time-series trend on monthly, seasonal, and annual scales, its degree of variability, and detected the significance of the global SST and ENSO indices on the precipitation pattern of the food-insecure rural areas of Tigray region, Ethiopia. This chapter is published as a research article in a peer-reviewed journal. The findings would be crucial for guiding local-level food production-related decisions and indicating feasible adaptation strategies to reduce risks in food production.

5.2 Research Methods

The study focuses on drought-prone rural areas with a higher proportion of food-insecure populations. To explain the cause-effect relationship between the precipitation pattern of Tigray's *Irob*, *Atsbi-wenberta*, and *Hintalo-wejerat* rural districts and the global SST and ENSO indices, an explanatory research was used based on a predominantly quantitative research approach. The study has used secondary data in which monthly precipitation data were obtained from the Ethiopian National Meteorological Agency (NMA), global SST data from the IRI/LDEO Climate Data Library, and ENSO data from the US National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center.

Mann-Kendall test and Sen's Slope estimator using the XLSTAT analysis tool, and a coefficient of variation (CV) were used to assess the trend in precipitation patterns. In addition, a Canonical Correlation Analysis (CCA) method was applied to analyze the correlation between precipitation patterns and global SST. Furthermore, the Pearson correlation method was used to test the significance of correlation analysis among the precipitation patterns of the three districts and the likelihood of global ENSO variations with three months of lag time.

5.3 Results and Discussion

5.3.1 Precipitation pattern of the study areas

In areas where precipitation is relatively low, its efficient utilization matters most. *Atsbi-wenberta*, *Irob*, and *Hintalo-wejerat* are the most food-insecure rural areas of the Tigray region. As shown in Table 3.1, these three districts are found in a similar geographical location. Table 5.1 also shows that these areas can get precipitations in any month of the year. This demands an enhanced utilization of the rainwater precipitated in these areas.

Regardless of the variation in the amount of precipitation, Figure 5.1 shows that the three districts have a bimodal nature of precipitation pattern with a higher and lower amount of precipitation during the JJAS (June-September) and MAM (March-May) seasons, respectively. This corresponds with the findings of Kahsay *et al.* (2019) and Gebru (2020) who reported a bimodal nature of precipitation patterns in eastern and southern Tigray.

In the three districts, August has a comparatively maximum average amount of precipitation, and the precipitation during July has never been zero for the last 41 years. The monthly average amount of precipitation was relatively low during October to February, and it was high during June to

September. However, the range between the maximum and minimum amount of monthly precipitations was extremely higher in the rainy months than in the drier months.

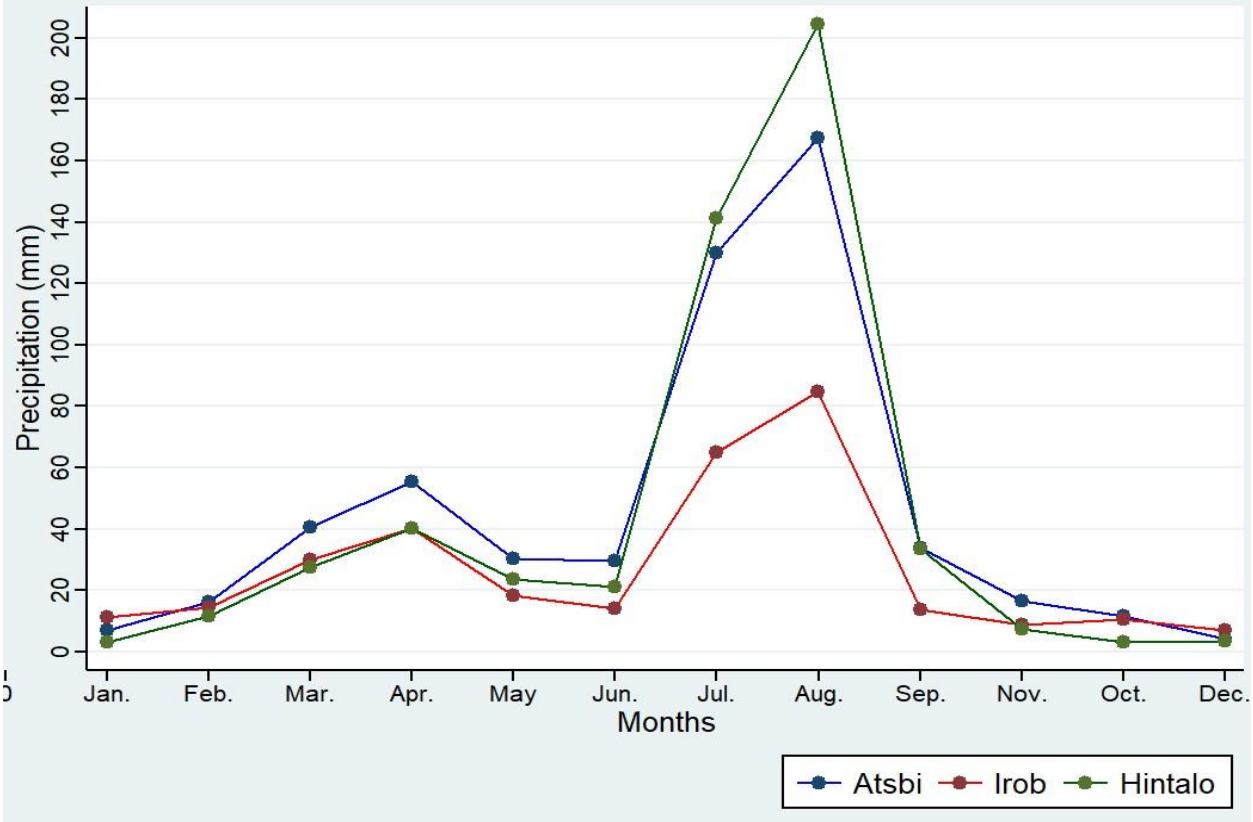


Figure 5.1. Monthly average precipitation of the study areas (1979-2019)

The average annual precipitation in the three districts, namely: *Atsbi*, *Irob*, and *Hintalo* was found to be 542.5, 318, and 520.7mm, respectively (Table 5.1). The average annual precipitation in Ethiopia between 2001 and 2020 was 1,073mm (World Data Atlas, 2023). And, the average annual precipitation in the Tigray region for the same period was 725mm (Weldearegay and Tedla, 2018). This indicates that the average annual precipitation in the study areas ranging between 318mm for *Irob* and 542.5mm for *Atsbi* (Table 5.1) is lower than the national (1,073mm) and regional (725mm) average annual precipitation.

The average annual precipitation in the study areas shows that these areas are affected by meteorological drought. As defined by the National Drought Mitigation Center of the United States (2024), meteorological drought is a prolonged period of precipitation deficiency when compared to the normal (average) amount of annual precipitation of the region. According to the meteorological drought classification in Ethiopia by Fentaw *et al*. (2023), *Atsbi* and *Hintalo* areas

are characterized by moderate meteorological drought, and *Irob* is characterized by severe meteorological drought when compared to the national average annual precipitation.

Although crop production with these amounts of precipitation may be possible, it is not sufficient and reliable. In line with this, FAO (1986) suggests irrigation-based crop production in areas where average annual precipitation is less than 1200mm. FAO (1986) also suggests that irrigation is a must in areas with less than 400mm of average annual precipitation. In all the study districts, even the maximum annual precipitation recorded in the last 41 years was less than 1200mm. More extremely, the maximum annual precipitation for *Irob* district was only 643.9mm. In this condition, achieving food security would be a challenge with a conventional farming system.

Table 5.1. Maximum, minimum, and average precipitation of the study areas (1979 – 2019)

Time	Average precipitation (mm)			Maximum precipitation (mm)			Minimum precipitation (mm)		
	Atsbi	Irob	Hintalo	Atsbi	Irob	Hintalo	Atsbi	Irob	Hintalo
January	7.1	11.3	3.1	38.5	66.4	30.6	0.0	0.0	0.0
February	16.3	14.6	11.7	88.3	78.5	81.3	0.0	0.0	0.0
March	40.5	29.9	27.6	184.0	153.9	202.0	0.0	0.0	0.0
April	55.4	40.2	40.3	141.8	116.0	173.9	0.0	0.0	0.0
May	30.2	18.5	23.7	115.3	84.1	145.8	0.0	0.0	0.0
June	29.5	14.0	21.2	158.2	116.5	131.2	0.0	0.0	0.0
July	129.9	64.9	141.1	333.9	180.0	346.6	14.0	6.8	19.4
August	167.4	84.6	204.4	366.0	318.5	674.6	55.0	0.0	53.3
September	33.9	13.7	33.7	155.5	58.0	260.4	0.0	0.0	0.0
October	16.6	8.7	7.3	206.0	126.9	50.1	0.0	0.0	0.0
November	11.5	10.6	3.3	67.0	88.4	30.9	0.0	0.0	0.0
December	4.3	6.9	3.5	50.4	51.8	44.6	0.0	0.0	0.0
MAM	126.1	88.6	91.5	327.6	238.0	392.4	11.1	0.0	0.0
JJAS	360.7	177.2	400.3	800.5	443.9	965.0	84.8	29.6	152.8
Annual	542.5	318.0	520.7	972.8	643.9	1103.5	166.7	99.4	241.2

There was a similar trend in the annual precipitation for all the study areas up to 2008 as depicted in Figure 5.2. Nevertheless, it was observed that there was a steady increment in the average annual precipitation in *Atsbi*; whereas, there was a decrement in the other two sites. The decrease in the average annual precipitation of *Hintalo* was found to be statistically significant ($P<0.05$), as shown in Table 5.2.

When we see the trend in the annual precipitation on a larger scale, Onyutha *et al.* (2016) indicated the long-term trends in the annual precipitation in Sudan, Ethiopia, and Egypt were mostly negative. On the other hand, the annual precipitation projected by Ongoma *et al.* (2018) and Cook *et al.* (2020) indicates a significant increase in annual precipitation over East Africa. This implies that the models that have been projecting the possible trends in precipitation, unless cascaded to the local level, would affect the decisions of relevant actors in handling food insecurity.

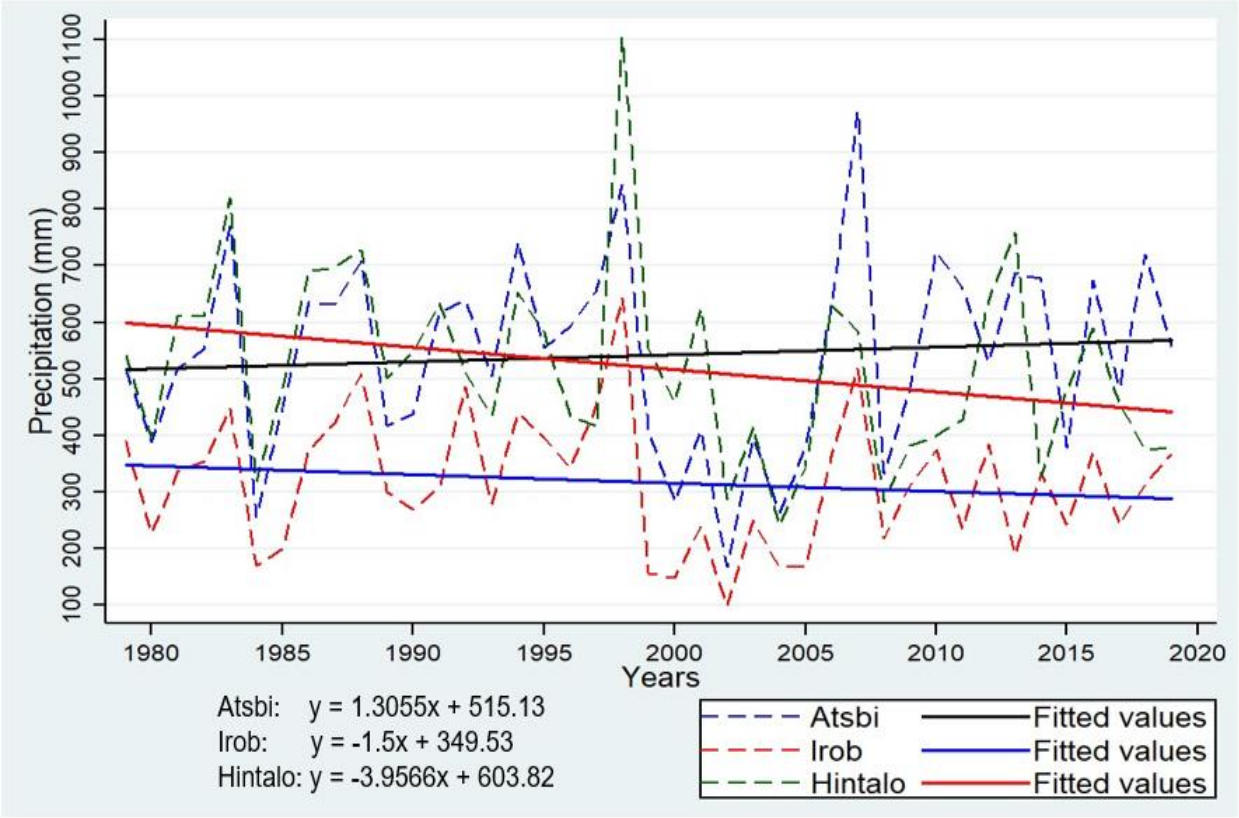


Figure 5.2. Trend in the annual total precipitation (1979-2019)

The three districts have shown a slight increase in their average precipitation of JJAS season, as shown in Figure 5.3. This season is the most important time for agricultural production in Ethiopia and in the study areas particularly. In line with this, Yibrah *et al.* (2018) indicated that the performance of wheat and barley production in the *Enderta* district of the Tigray region was significantly associated with the JJAS precipitation pattern.

Although there was no significant precipitation trend during JJAS in the study areas, the CV of the season has shown a higher degree of variability (Table 5.2). Similarly, Kahsay *et al.* (2019)

revealed that variability in the onset and cessation time of precipitation in East Tigray during the JJAS season was higher in the last 15 years.

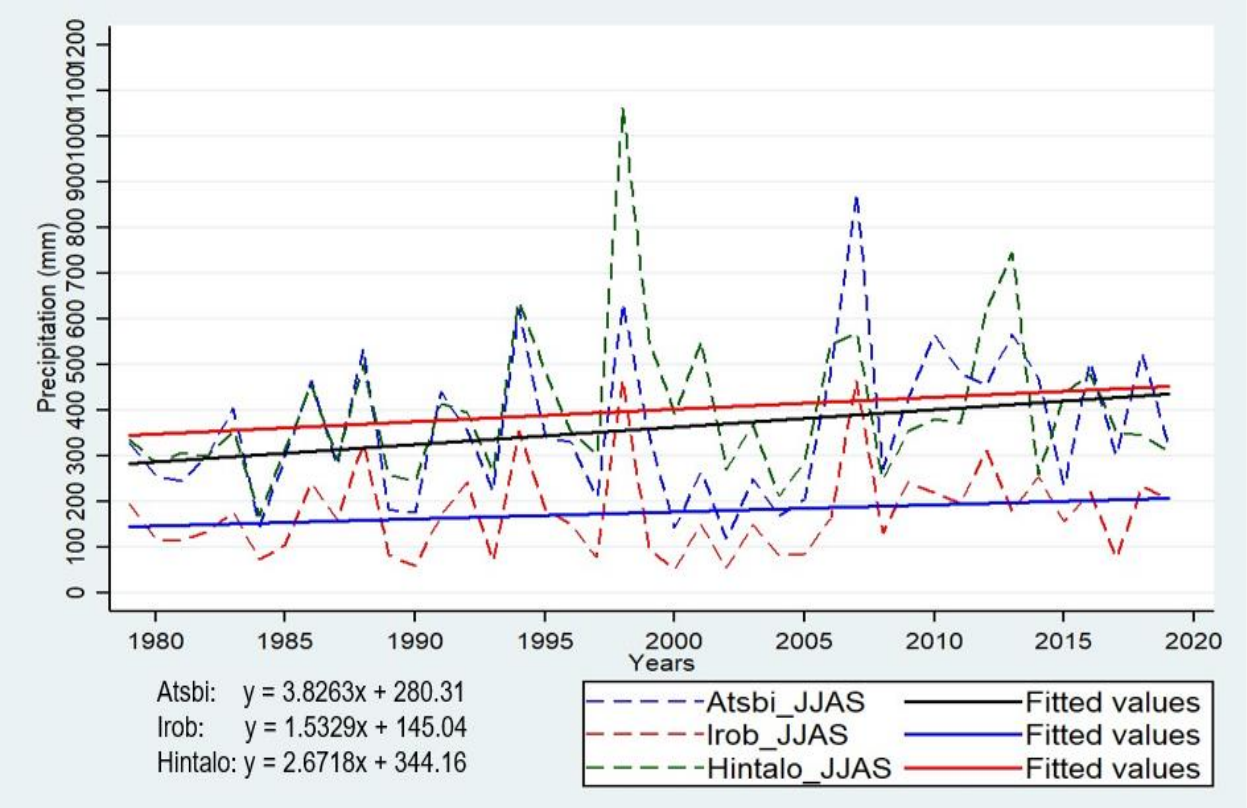


Figure 5.3. Trend in the June – September (JJAS) total precipitation (1979-2019)

The MAM season is the other important rainy season for all over the region next to JJAS season. During this season, unlike the JJAS, the three districts have experienced a decrease in their average precipitation, as shown in Figure 5.4. The decrement was again statistically very significant ($P<0.01$) for *Hintalo* district, as shown in Table 5.2. This trend variability needs to be considered in any future agricultural or rainwater harvesting activities of the MAM season.

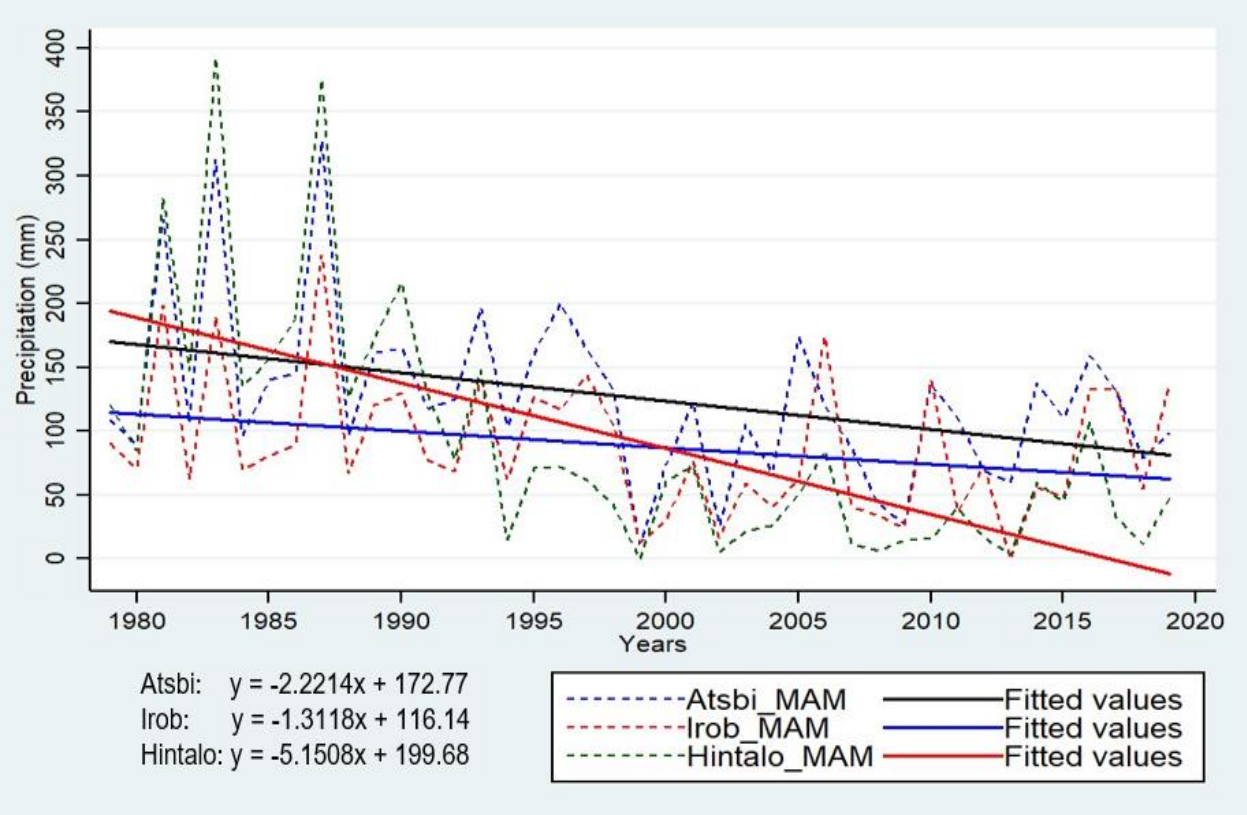


Figure 5.4. Trend in the March – May (MAM) total precipitation (1979-2019)

5.3.2 Monthly, seasonal, and annual precipitation variability of the study areas

Considering the variability in the average amount of monthly precipitation, the Mann-Kendall test presented in Table 5.2 illustrates the three districts to have shown a statistically insignificant decreasing trend during December to May. On the contrary, the average monthly precipitation from June to November has shown an increment but not statistically significant.

Seasonally, these areas have experienced a decreased trend during MAM, in which the trend was statistically significant for *Hintalo* ($P < 0.01$). The decreased amount in *Hintalo* during the MAM season was 16.343mm per annum. A similar Mann-Kendall trend study by Berhe *et al.* (2023) on the eastern zone of the Tigray region revealed a non-significant increase and decrease for the JJAS and FMAM seasons, respectively. During the JJAS season, the trend was increasing and statistically insignificant for the three districts.

Annually, the test showed that only *Atsbi* had experienced a positive shift in the average amount of annual precipitation; but, *Irob* and *Hintalo* have experienced a decreasing trend with a

statistically significant trend for *Hintalo* (P < 0.05). The Sen's Slope here shows that the average annual precipitation has been decreasing by 4.098 mm per annum in *Hintalo*.

Table 5.2. Mann-Kendall test, Sen's Slope and coefficient of variation of the trend in precipitation

Time	Mann-Kendall Test			Sen's slope			Coefficient of Variation (%)		
	Atsbi	*Irob*	*Hintalo*	*Atsbi*	*Irob*	*Hintalo*	*Atsbi*	*Irob*	*Hintalo*
January	-0.150	-0.237	-0.225	-1.202	-1.847	-2.195	129.14	130.30	202.51
February	-0.437	-0.536	-0.653	-8.261	-10.323	-12.864	127.66	122.65	180.65
March	-0.111	-0.111	-0.480	-11.408	-11.724	-23.650	98.55	110.94	159.32
April	-0.333	-0.197	-0.444	-13.670	-10.105	-44.807	67.33	80.52	114.76
May	-0.254	-0.229	-0.401	-3.034	-3.217	-10.521	94.18	106.62	128.49
June	0.028	0.111	0.111	4.093	2.046	2.315	130.03	165.74	104.54
July	0.167	0.333	0.000	7.599	9.056	12.444	60.24	68.94	51.68
August	0.000	0.111	0.222	14.746	1.255	24.360	44.43	69.12	51.07
September	0.287	0.237	0.222	16.651	1.867	16.416	108.76	116.84	131.09
October	0.061	0.028	0.111	1.025	0.025	0.100	208.7	240.10	171.00
November	0.222	0.310	0.028	1.225	0.211	0.100	167.97	203.62	208.90
December	-0.237	-0.197	-0.237	-0.125	-3.505	-1.345	211.7	160.71	245.11
MAM	-0.222	-0.267	-0.556**	-5.386	-6.085	-16.343	52.36	60.30	100.88
JJAS	0.167	0.111	0.278	62.960	16.349	29.887	44.98	56.69	41.31
Annual	0.073	-0.078	-0.220*	1.462	-1.181	-4.098	31.25	36.61	31.92

**. Trend is significant at the 0.01 level; *. Trend is significant at the 0.05 level

In line with this, the variability of the monthly average precipitation depicted in Table 5.2 shows extremely very high variability during all months except for July and August, which was relatively much lower than the other months. Seasonally, the coefficient of variation was nearly similar for both the MAM and JJAS seasons of *Atsbi* and *Irob* districts. However, the variation during MAM was much higher than JJAS for *Hintalo*.

Based on Addisu *et al.* (2015), precipitation variability is categorized into low when CV value is below 20%, moderate (20% < CV < 30%), and high when CV value is higher than 30 percent. The coefficient of variation for the annual precipitation was almost similar for the districts but higher than the regional average, which was 16 percent during 1997–2017 (Weldearegay and Tedla, 2018). In southern Tigray, the coefficient of variation for the annual precipitation during 1981-2010 ranged from 33 – 233 percent (Hayelom *et al.*, 2017). On the other hand, annual precipitation data for 40 years from 109 meteorological stations in Ethiopia showed a coefficient of variation ranging from 20 to 89 percent (Addisu *et al.*, 2015).

5.3.3 Correlation between precipitation variability of the study areas and the global SST

To monitor the precipitation variability, it is crucial to specify the causal factors and study their correlations. The global SST is among the key factors that plays a significant role in influencing the variability of the monthly, annual, and decadal precipitation patterns. Alhamshry *et al.* (2020) suggested the use of SST of the southern Pacific and northern Atlantic oceans as effective inputs for prediction models of Ethiopian summer and spring rainfalls, respectively. Previous studies confirm that the spatial and temporal precipitation variability in Ethiopia is attributed to the variations in SSTs over the Atlantic, Indian, and Pacific Oceanic indices (Degefu *et al.*, 2017; Zeleke *et al.*, 2017; Dubache *et al.*, 2019; Alhamshry *et al.*, 2020; Molla, 2020; Tefera *et al.*, 2020 and Bayable *et al.*, 2021).

The strength of the statistical association between Ethiopian precipitation and global SST greatly varies with time and space. The JJAS precipitation of the central and western Ethiopia was found to be correlated with the equatorial east Pacific and Indian Ocean SSTs (Degefu *et al.*, 2017). In addition, the drying trend in southern and northern Ethiopia was associated with Atlantic Ocean warming and SST of the western Pacific Ocean (Zeleke *et al.*, 2017).

The annual precipitation of eastern Ethiopia was negatively correlated with the SST of Pacific Ocean for JJA while positively correlated with MAM seasons (Bayable *et al.*, 2021). Further, the SST of central, western, and southeastern of the Indian Ocean was found to affect the precipitation pattern of western, eastern, northwestern, and southeastern parts of Ethiopia (Dubache *et al.*, 2019). More importantly, Tefera *et al.* (2020) identified the tropical Indian Ocean as a statistically significant drought-influencing factor in Ethiopia (Tefera *et al.*, 2020). There was a strong and positive correlation between the precipitation in northeastern Ethiopia and the southern Indian Ocean, Atlantic Ocean, and most of the western Pacific Ocean (Gobie and Miheretu, 2021).

In the Tigray region, the tropical Indian Ocean was identified as a statistically significant drought-influencing factor (Tefera *et al.*, 2020). The tropical Indian Ocean, tropical Atlantic Ocean, tropical Pacific Ocean, the Red Sea, and Nino 3.4 regions were the other drought-influencing factors on an annual scale (Tefera *et al.*, 2020); other events like Pacific Decadal Oscillation, Southern Oscillation Index and Indian Ocean Dipole were the important factors for causing meteorological and agricultural droughts in Tigray region (Molla, 2020).

Many of the correlation analyses made so far were larger in spatial and time scope. Thus, a monthly average precipitation of the three districts was used to test for its correlation with the global SST. This is vital in understanding the correlations in-depth.

As shown in Figure 5.5, the canonical correlation analysis shows that the MAM precipitation of the three districts was correlated to the global SST showing different correlational values. But, most of these correlations were not strong enough to determine the average monthly precipitation of the three districts. The central equatorial Pacific Ocean was strongly and positively correlated with April's average precipitation of *Atsbi* and *Irob*. Besides, April's average precipitation of *Atsbi* and *Hintalo* was strongly and negatively correlated with the SST of the eastern equatorial Pacific Ocean. Further, April's average precipitation of *Hintalo* has shown a strong negative correlation with the SST of the northeast and northwest equatorial Atlantic Ocean.

This implies that the declined average precipitation in April over *Atsbi* and *Hintalo* districts is associated with the warming in the central and eastern equatorial Pacific Ocean. In contrast, the eastern equatorial Pacific Ocean was the source of the limited amount of April's precipitation for *Atsbi* and *Hintalo* districts. Thus, the projected SST in these regions can be used to predict the precipitation to guide food production strategies during the month.

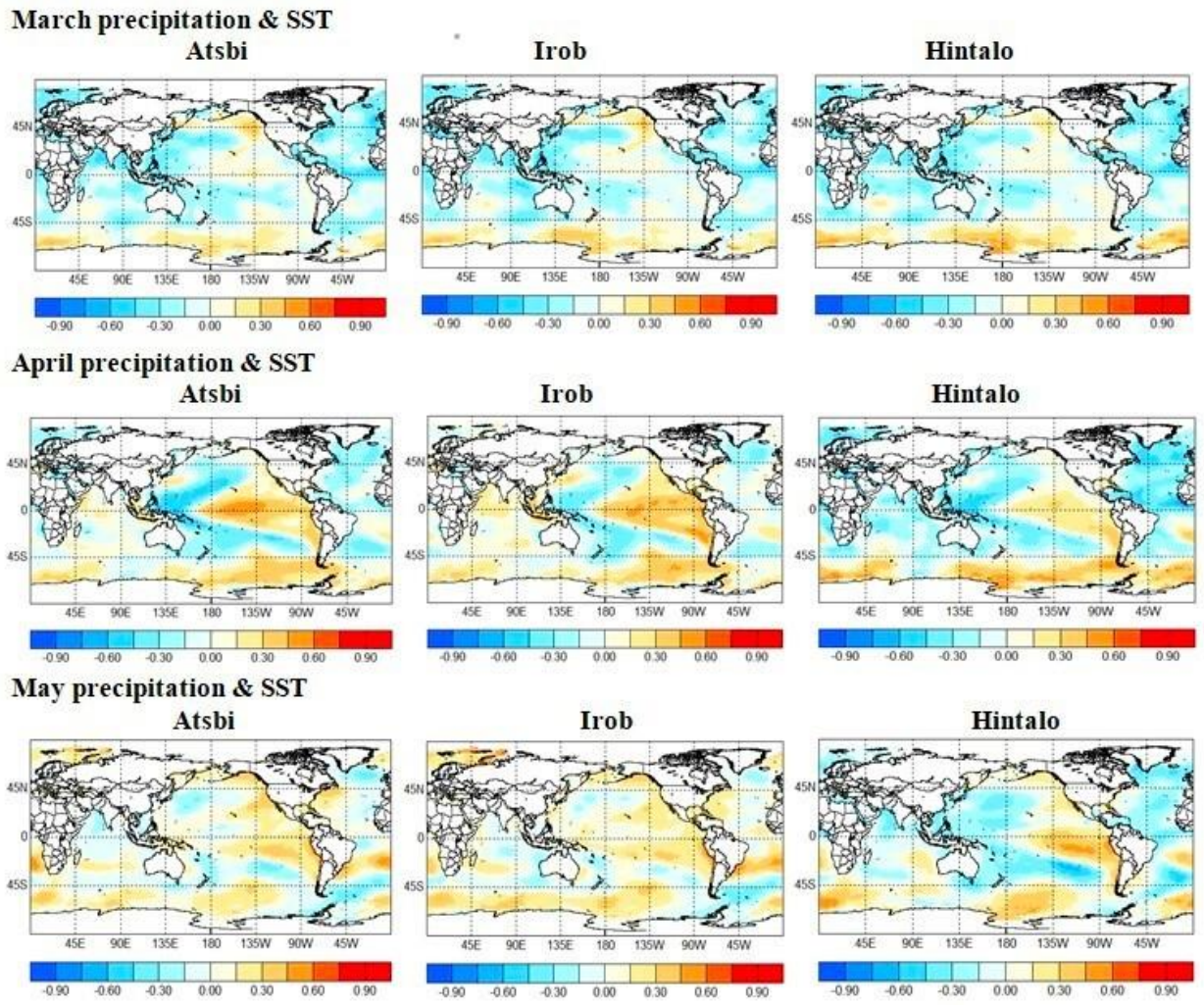


Figure 5.5. March-May precipitation and its correlation with the global SST

Similar to MAM, the JJAS precipitation of the three districts showed a weaker correlation with most of the global SST. Yet, a significant positive correlation was found between August's precipitation of the three districts and the SST of the western equatorial Pacific Ocean. The correlation was very strong with *Irob*'s August precipitation, as shown in Figure 5.6. Thus, the warming in the western equatorial Pacific Ocean had a strong correlation with reduced average August precipitation in the three districts; implying for making informed decisions about food production practices during the month.

Besides, *Irob*'s August precipitation has shown a strong positive correlation with the SST of the south equatorial Indian Ocean. On the other hand, *Atsbi*'s July precipitation was strongly and positively correlated with the western equatorial Indian Ocean. Moreover, September's

precipitation of *Irob* was found to be strongly and positively correlated with the SST of southwest equatorial Indian Ocean, West equatorial Pacific Ocean, Philippine Sea, and South China Sea.

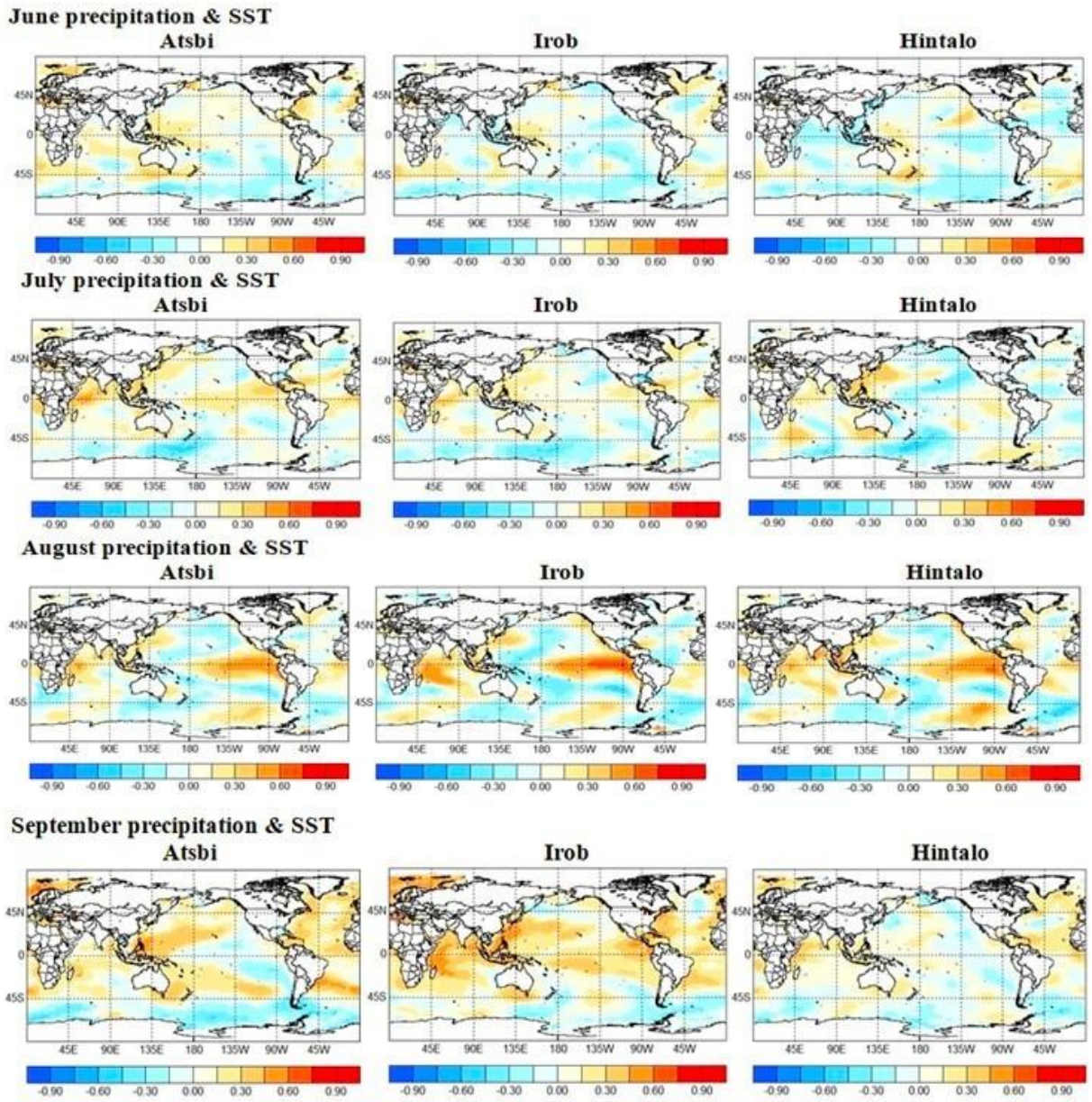


Figure 5.6. June-September precipitation and its correlation with the global SST

5.3.4 Correlation between precipitation variability of the study areas and ENSO

ENSO is a climate phenomenon caused by ocean-atmospheric interaction that occurs mainly in the tropical and sub-tropical Pacific Oceans. This naturally occurring phenomenon is the most

predictable climate system at the time scales from months to seasons and years (Tang *et al.*, 2018), providing the basis for regional and local level precipitation predictions.

ENSO has a significant climate influence on the climate patterns of various parts of the world including Ethiopia. Although the different parts of Ethiopia have different climate sensitivities, the 2015 drought that occurred in most parts of the country and East Africa was associated with ENSO-induced rain shortages (Philip *et al.*, 2018 and Bayable *et al.*, 2021).

In northern Ethiopia, periodicity in dryness and wetness was largely determined by ENSO variability in both the spring and summer rainy seasons (Zeleke *et al.*, 2017). Similarly, La Nina was associated with increased rainfall in most parts of the northeast Ethiopia, and El Niño was associated with decreased rainfall in limited parts of the region (Gobie and Miheretu, 2021).

As shown in Table 5.3, the effect of ENSO in most of the rainy months of the three districts was negligible. Nevertheless, the ENSO indices of JFM and FMA were associated with decreased April precipitation in *Atsbi* and *Irob* very significantly ($P<0.01$). Besides, the ENSO indices of FMA and MAM were associated with decreased May's precipitation in *Hintalo* significantly ($P<0.05$). On the other hand, the ENSO indices of MJJ were significantly associated with increased July precipitation in the three districts ($P<0.05$). Thus, relevant bodies are supposed to project ENSO data of JFM, FMA, MJJ, and MAM in advance for guiding food production activities in the three districts.

Table 5.3. The correlation between the study areas precipitation and the global ENSO

Precipitation in the study areas		Oceanic Nino Index (ONI)							
		DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS
March	Atsbi	0.118	0.109						
	Irob	0.082	0.080						
	Hintalo	0.068	0.055						
April	Atsbi		0.461**	0.449**					
	Irob		0.447**	0.440**					
	Hintalo		0.267	0.271					
May	Atsbi			0.202	0.255				
	Irob			0.203	0.250				
	Hintalo			0.313*	0.331*				
June	Atsbi				-0.042	-0.032			
	Irob				-0.175	-0.148			
	Hintalo				-0.099	-0.018			
July	Atsbi					-0.198	-0.345*		
	Irob					-0.295	-0.391*		

	Hintalo					-0.286	-0.341*		
August	Atsbi						-0.076	-0.212	
	Irob						0.120	-0.029	
	Hintalo						-0.015	-0.156	
September	Atsbi							-0.190	-0.197
	Irob							-0.196	-0.256
	Hintalo							-0.296	-0.270

**. Correlation is significant at the 0.01 level; *. Correlation is significant at the 0.05 level.

In Tigray region, in addition to the global SST indices, ENSO was identified as drought influencing factor (Molla, 2020 and Tefera *et al.*, 2020). Similarly, Looby (2019) stated that El Niño has intensified the severe and prolonged drought that has occurred in Tigray in the last 4 to 5 decades, as shown during the 2015-2016 El Niño. In line with this, Shiferaw *et al.* (2023) revealed that nearly 40 percent of precipitation variability in the Geba catchment of the Tigray region was caused by the combined effects of El Niño Southern Oscillation and Indian Ocean Dipole signals.

5.4 Conclusion

In Ethiopia, particularly in the Tigray region, smallholder farming is a common agricultural practice where farmers usually depend on precipitation. As precipitation is a natural phenomenon that varies with time and space, understanding the nature of precipitation variability can minimize the possible risks to rural households. It can also significantly improve the food security status of the vulnerable rural community.

Food production is mostly dependent on precipitation, particularly in areas where the farming system is dominantly rain-fed. The study areas have experienced a very short and variant precipitation pattern associated with global teleconnections. This calls for an urgent agricultural transformation from a conventional one to a climate-smart farming system.

The three districts have shown a similarity in the magnitude and seasonality of precipitation. March-May (*Belg*) and June–September (*Kiremt*) are the rainy seasons in the three districts. While the March-May average precipitation of the three districts has shown a decreasing trend, an insignificant increment was observed in the precipitation pattern of June-September. This entails careful decisions to be made for some agricultural practices during these seasons.

On the other hand, a marked variation was observed in the trend of the precipitation pattern among the three districts. Although no significant trend was detected in *Atsbi* and *Irob* precipitation patterns, a very significant decline in the trend during March-May average precipitation and a

significant decline trend in the annual average precipitation of *Hintalo* area is observed. Therefore, an immediate action ought to be initiated to get alternative sources of water for the rural areas where precipitation is the only source of food production.

More importantly, April's average precipitation of the three districts is found to be correlated with the SST of central and eastern equatorial Pacific Ocean and the northeast and northwest equatorial Atlantic Ocean. Further, the SST of South, West, and southwest of the equatorial Indian Ocean, and West equatorial Pacific Ocean was associated with July-September average precipitation with greater variation in strength among the three districts. The ENSO indices, on the other hand, were significantly associated with the July average precipitation of the three districts, April's average precipitation of *Atsbi* and *Irob*, and May precipitation of *Hintalo*.

Therefore, data about SSTs of the central and eastern equatorial Pacific Ocean, northeast and northwest equatorial Atlantic Ocean, southwest equatorial Indian Ocean, and west equatorial Pacific Ocean as well as data about the ENSO indices of JFM, FMA, MJJ, and MAM can be used to develop a skillful precipitation forecast for the areas under the study.

Generally, the limited amount of precipitation, given its higher degree of variability, will be the major challenge in the task of achieving food security in the food-insecure rural areas. Therefore, unless coping strategies are arranged that meet the varying monthly, seasonal, and annual precipitation, or alternative water sources are used and the rainwater is harvested prudently, these areas will continue to face the severe consequences of food insecurity.

Furthermore, the precipitation pattern and its teleconnection with the global SST and ENSO indices vary greatly in strength among the three districts. Thus, future researchers have to analyze precipitation patterns and any associations with their trend in clusters rather than as a whole. In this way, food security programs and actions can be effectively downscaled to the local level based on their respective precipitation pattern information.

CHAPTER SIX

Coping Strategies to Food Insecurity and Adaptation Mechanisms to Meteorological Drought in the Drought-prone Rural Areas of Tigray

6.1 Introduction

Food insecurity, a situation in which households lack access to adequate and nutritious food because of a lack of resources or money to purchase food, is associated with negative health consequences, such as increased chronic disease risk, child malnutrition, and mortality rate (Sun *et al.*, 2020). Food insecurity is still a major global issue, but developing countries, such as Ethiopia, are disproportionally affected. For example, in 2023, an estimated 20.1 million (about 17.5% of the total population) people were facing chronic hunger across the country with 7.4 million severely undernourished children and women (WFP, 2023).

Owing to the recent civil war and notable drought occurrences, the high prevalence of food insecurity in Tigray may have worsened. Findings from the WFP (2022a) show that, in June 2022, 47 percent of Tigray's population was severely food insecure. The same survey reported by Weldegiargis *et al.* (2023) confirmed that nearly 75 percent of the interviewed households in Tigray were eating cheap and small size meals or went a whole day without eating any food. As such, the drought-prone rural areas of Tigray are food insecurity hotspot areas with a higher number of vulnerable households.

In chapter three of this dissertation, it is stated that three drought-prone rural districts, namely: *Atsbi, Irob*, and *Wejerat* were categorized as the most food-insecure rural districts of Tigray region, as reported by the Tigray Region PSNP office (2019). In addition, in comparison to the national average annual precipitation, chapter five of this dissertation demonstrated that *Irob* is characterized by severe meteorological drought, whereas *Atsbi* and *Hintalo* areas are characterized by moderate meteorological drought. Meteorological drought is a long-term lack of precipitation in a specific area when compared to the average annual precipitation of the region (National Drought Mitigation Center, 2024).

Food-insecure rural households facing food insecurity usually adopt diverse coping strategies to reduce and mitigate the risks associated with food insecurity. However, the employed coping strategies can be either severe or less severe strategies based on the long-term impacts they would have on the nutritional health and physiology of the adopters (Negash and Alemu, 2013).

In food-insecure areas, households often use a variety of coping strategies to cope with the prevailing food insecurity. The widely used coping strategies include: eating less expensive food, borrowing money to purchase food, relying on relatives or friends for food, limiting portion sizes or the number of meals per day, begging for food, and sending household member(s) to relatives in other areas (Dlamini *et al.*, 2023). Similarly, rural households in Ethiopia have used different strategies to cope with food insecurity (Asesefa *et al.*, 2018; Gebre *et al.*, 2021; Yohannes *et al.*, 2023 and Bahiru *et al.*, 2023). In Tigray, the consumption of less preferred, same variety or less expensive foods, remittance, reduction of food portion size, selling of assets, daily labor, and borrowing money or grain were the adopted coping strategies in times of food insecurity (Weldemariam *et al.*, 2023).

In addition, food-insecure farming households use different adaptation strategies to avert the risks of meteorological drought. Of these, soil and water conservation, use of improved crop variety, tree planting, crop diversification, adjusting planting season, irrigation, agronomic practices, and integrating livestock with crop production were the agricultural adaptation strategies adopted by small-holder farmers in Ethiopia (Demem, 2023). In Tigray, practices such as crop diversification, planting date adjustment, soil and water conservation, intensified use of agricultural input, integration of crop production with livestock, and tree planting were the agricultural adaptation strategies adopted by rural farming communities (Belay *et al.*, 2017 and Gebru *et al.*, 2020).

However, coping and adaptation strategies adopted by food-insecure households living in drought-prone rural areas and their choice of strategies have been less researched. In addition, coping strategies for food insecurity have rarely been reported in line with adaptation strategies to meteorological drought, which is highly associated with food insecurity (Schmidhuber and Tubiello, 2007; Wheeler and Braun, 2013; Afifi *et al.*, 2014 and Muluneh, 2021).

Considering the significant number of people living in drought-prone rural areas, representative studies are needed to improve local and national food security intervention mechanisms. Therefore, this study has the dual objective of identifying vulnerable households' coping strategies for food insecurity and adaptation mechanisms to meteorological drought in the drought-prone rural areas of Tigray. In addition, households' choice of coping and adaptation strategies was adequately considered by the study to inform policy-makers and to add to the existing knowledge on the same.

6.2 Research Methods

A combination of quantitative survey and qualitative FGD data were used to describe the comprehensive understanding of how households respond to food insecurity and associated drought in the study areas. This study has used a mixed-methods approach to assess the coping and adaptation strategies to food insecurity and drought.

A pre-tested structured questionnaire was administered to randomly selected household heads in the study area. The questionnaire was translated into local languages and collected through face-to-face interviews by trained enumerators. In addition, six FGDs were conducted, one in each sub-district. The FGDs included knowledgeable elders, model farmers, local administrators, and religious leaders. Discussions focused on coping mechanisms for food insecurity and adaptation strategies for drought.

This paper analyzed households' coping strategies for food insecurity using descriptive statistics and the Coping Strategies Index (CSI). The CSI has measured food insecurity by combining the frequency and severity of coping strategies. Frequency was assessed by how often households relied on strategies, while severity was determined through FGDs where participants classified coping strategies on a four-point scale.

The data from FGDs were used in an analysis of coping strategies and adaptation mechanisms through Paired Comparison Analysis (PCA). PCA ranked the choices of strategies and mechanisms by comparing them against each other. This has provided insights into the subjective preferences of households facing food insecurity and recurring droughts.

6.3 Results and Discussion

6.3.1 Coping strategies to food insecurity

Food-insecure rural households use various strategies to cope with food insecurity (Dlamini *et al.*, 2023). Likewise, rural households in Ethiopia have used different strategies to cope with food insecurity (Asesefa *et al.*, 2018; Gebre *et al.*, 2021; Yohannes *et al.*, 2023 and Bahiru *et al.*, 2023). The sale of firewood and charcoal, labor work, selling livestock, renting land, migrating, and reducing the size of meals were the coping strategies used by food-insecure households in the Humbo district of Ethiopia (Bahiru *et al.*, 2023).

Food-insecure households in Jimma, Ethiopia also used different coping strategies such as changing consumption patterns, eating cheap foods, reducing meal frequency, and selling

household assets (Asesefa *et al.*, 2018). Similarly, food-insecure rural households in Southeast Ethiopia consumed less preferred and less-expensive food, borrowing food from relatives and friends, consuming seed stock, and feeding children first in response to food deficits (Gebre *et al.*, 2021). In southern Ethiopia, households were coping with food insecurity by utilizing less preferred and less expensive food, borrowing food, and participating in off-farm activities (Melese *et al.*, 2021).

In the Tigray region, coping strategies such as consumption of less preferred, same variety or less expensive foods, remittance, reduction of food portion size, selling of assets, daily labor, and borrowing money or grain were used in times of food shortage (Weldemariam *et al.,* 2023). According to the food security assessment by WFP (2022a) in Tigray, in response to food insecurity, 90 percent of households have limited portion sizes of meals; 85 percent relied on less preferred and cheap food; 74 percent restricted food consumption by adults to feed their children.

In the study areas, limiting household meal size, depending on aid, and consuming less quality and cheap food were the most frequently used coping strategies reported by 74.4, 74.1, and 73.8 percent of the food-insecure rural households, respectively (Table 6.1). In southern Ethiopia, consuming smaller amounts of food was the most widely used coping strategy for more than half of the households, and no household members went a whole day and night without food (Yohannes *et al.,* 2023).

On the other hand, Table 6.1 shows that sending children or household members to eat elsewhere or to work for food and reducing the meals of adults to feed the children were less frequently used coping strategies by the food-insecure rural households. In the Gambela region of Ethiopia, 21.9 percent of food-insecure households were sending household members to eat elsewhere to cope with food insecurity (Ayal *et al.*, 2023).

Table 6.1. Food insecurity coping strategies adopted by the food-insecure rural households

No.	Coping strategies	Always (6-7 days/week)		Sometimes (3-5 days/week)		Rarely (1-2 days/week)		Not at all (0 days/week)	
		Freq.	%age	Freq.	%age	Freq.	%age	Freq.	%age
1	Consume less quality and less expensive food	268	73.8	57	15.7	38	10.5	0	0.0
2	Reduce the meals of adults in favor of children	79	21.8	175	48.2	53	14.6	56	15.4

3	Limit the portion of meals for all household members	270	74.4	76	20.9	17	4.7	0	0.0
4	Consume food held for next season	192	52.9	59	16.3	98	27.0	14	3.8
5	Reduce the number of meals per day	167	46.0	140	38.6	56	15.4	0	0.0
6	Purchase food on credit	121	33.3	111	30.6	98	27.0	33	9.1
7	Send children or household members to eat elsewhere	7	1.9	62	17.1	101	27.8	193	53.2
8	Send children or household members to work for food	51	14.1	76	20.9	101	27.8	135	37.2
9	Depend on aid from family, friends, or external bodies	269	74.1	40	11.0	50	13.8	4	1.1
10	Use all or part of your savings to purchase food	210	57.9	78	21.4	69	19.0	6	1.7
11	Sell any assets to purchase basic food items	203	55.9	52	14.3	100	27.6	8	2.2
12	Reduce other expenses to meet food needs	161	44.4	121	33.3	70	19.3	11	3.0
13	Take a loan to purchase food	112	30.9	91	25.1	121	33.3	39	10.7
14	Skip part or entire days without eating	55	15.2	200	55.1	108	29.7	0	0.0
15	Feed working members of the household at the expense of non-working members	34	9.4	119	32.8	106	29.2	104	28.7

6.3.2 Households' choice of food insecurity coping strategies

The Paired Comparative Analysis (PCA) results showed a marked distinction in the choice of strategies to cope with food insecurity. As revealed in Table 6.2, consuming less quality and cheap food, reducing the meals of adults in favor of children, consuming food held for the next season, using savings to purchase food, and selling assets to purchase basic food items were the first choices of coping strategies in the six sub-districts of the study areas.

Moreover, the second most preferred coping strategies chosen by most of the households were limiting the portion of meals for all household members, reducing the number of meals per day, and sending children or household members to work for food. On the other hand, feeding working members at the expense of non-working members, skipping part or entire days without eating,

taking loans to purchase food, and sending children or household members to eat elsewhere were relatively the least preferred coping strategies by food-insecure rural households.

Table 6.2. Paired Comparative Analysis (PCA) of food insecurity coping strategies

No.	Coping Strategies	Rank						Overall rank
		Atsbi		Wejerat		Irob		
		FG1	FG2	FG3	FG4	FG5	FG6	
1	Consume less quality and less expensive food	1	5	2	4	5	4	2
2	Reduce the meals of adults in favor of children	4	7	8	11	1	1	6
3	Limit the portion of meals for all household members	2	3	3	3	4	2	1
4	Consume food held for next season	5	4	1	5	6	5	4
5	Reduce the number of meals per day	2	5	4	5	4	5	3
6	Purchase food on credit	3	9	7	6	10	9	10
7	Send children/household members to eat elsewhere	7	11	11	10	7	6	12
8	Send children/household members to work for food	9	10	6	2	2	3	6
9	Depend on aid from relatives or external bodies	3	11	4	7	3	4	6
10	Use all or part of your savings to purchase food	6	1	3	8	8	7	9
11	Sell any assets to purchase basic food items	8	2	4	1	9	7	5
12	Reduce other expenses to meet food needs	4	6	9	8	9	8	10
13	Take a loan to purchase food	10	8	5	9	11	11	13
14	Skip part or entire days without eating	11	12	9	11	13	10	15
15	Feed working members of the household at the expense of non-working members	10	11	10	10	12	9	14

There was no complete consensus regarding the severity of most coping strategies; however, based on the most frequent responses, taking a loan to purchase food, skipping parts or entire days without eating, sending children or household members to eat elsewhere, and feeding working members of the household at the expense of non-working members were the most severe coping strategies ranked by the rural households. Accordingly, about 70 percent of the food-insecure rural households relied on the most severe coping strategies, that is, frequently skipping part or entire day without eating (see Table 6.1). According to WFP (2022a), the percentage of households in

Tigray who used severe coping strategies increased from 52 percent in October 2020 to 60 percent in June 2022.

On the other hand, consuming less quality and less expensive food and limiting the portion of meals for all household members were the least severe coping strategies as shown in Figure 6.1. Accordingly, nearly 88 percent of the food-insecure rural households used the least severe coping strategy, frequently limiting the portion of meals for all household members.

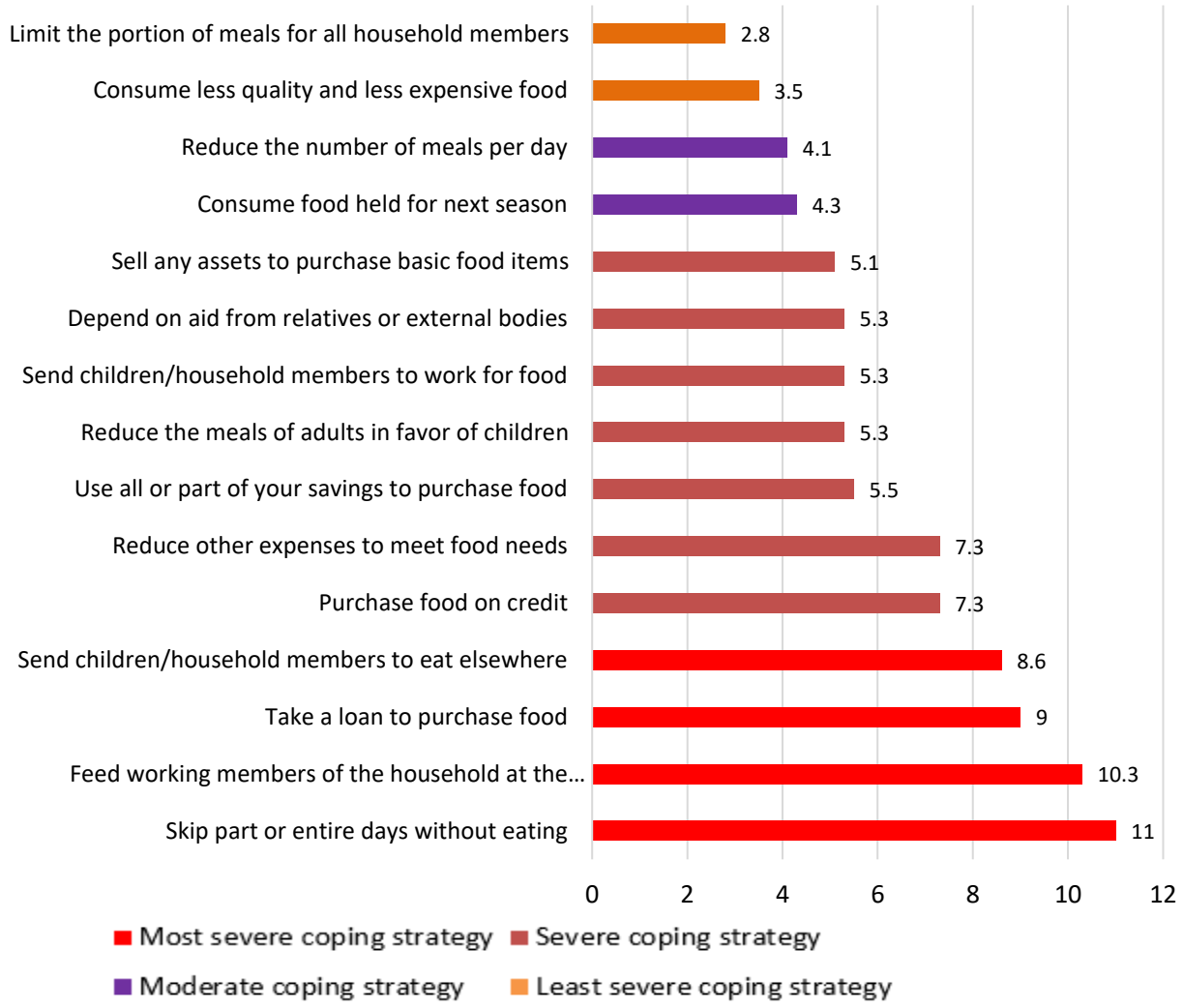


Figure 6.1. Consensus severity ranking of food insecurity coping strategies

Based on Table 6.3, the average CSI score in the study areas was found to be 148.5 out of 301, with the highest result of 268, implying for severe food insecurity status of households under the study. A reduced coping strategy index (rCSI) score based on the five standard food insecurity

related strategies study by WFP (2022a) in Tigray revealed an average rCSI of 31.48, with results ranging from 26.00 to 38.91.

Table 6.3. Coping Strategy Index (CSI) score

No.	Coping strategies	Average frequency	Average ranking	Severity weight	Weighted score
1	Consume less quality and less expensive food	6.0	3.5	1	6.0
2	Reduce the meals of adults in favor of children	3.0	5.3	3	9.0
3	Limit the portion of meals for all household members	6.2	2.8	1	6.2
4	Consume food held for next season	5.4	4.3	2	10.8
5	Reduce the number of meals per day	4.6	4.1	2	9.2
6	Purchase food on credit	3.3	7.3	3	9.9
7	Send children/household members to eat elsewhere	1.2	8.6	4	4.8
8	Send children/household members to work for food	1.5	5.3	3	4.5
9	Depend on aid from relatives or external bodies	6.1	5.3	3	18.3
10	Use all or part of your savings to purchase food	5.7	5.5	3	17.1
11	Sell any assets to purchase basic food items	5.3	5.1	3	15.9
12	Reduce other expenses to meet food needs	4.0	7.3	3	12.0
13	Take a loan to purchase food	3.2	9.0	4	12.8
14	Skip part or entire days without eating	2.2	11.0	4	8.8
15	Feed working members of the household at the expense of non-working members	0.8	10.3	4	3.2
Average coping strategy score					148.5

6.3.3 Agricultural adaptation mechanisms to meteorological drought

Adaptation options to meteorological drought in rural communities of Ethiopia can minimize the potential impact of meteorological drought on food insecurity (Wolteji *et al.*, 2022). However, it is important to note that adaptation strategies depend on household, local, or country level social, technological, and economic capacities. According to a review of adaptation strategies by Grigorieva *et al.* (2023), crop diversification, innovative breeding techniques; water and soil conservation, farmer training, and knowledge transfer are the adaptation strategies that can be applied at a local level. Similarly, a review of adaptation strategies adopted by smallholder farmers by Ogundeji and Okolie (2022) shows that rainwater harvesting, diversification of income sources, cultivation of short-season crops, and use of drought-tolerant crops were the agricultural adaptation strategies.

In Ethiopia, soil and water conservation, use of improved crop variety, tree planting, crop diversification, adjusting planting season, irrigation, agronomic practices, and integrating livestock with crop production were the agricultural adaptation practices adopted by small-holder farmers (Demem, 2023). In the Tigray region of Ethiopia, practices such as crop diversification, planting date adjustment, soil and water conservation, intensified use of agricultural input, integration of crop production with livestock, and tree planting were the agricultural adaptation strategies adopted by rural communities (Belay *et al.*, 2017 and Gebru *et al.*, 2020).

In this study, agricultural adaptation mechanisms such as livestock production and cultivation of short-duration crops were reported as regular agricultural adaptation mechanisms by 27.2 percent and 22.8 percent of the food-insecure rural households, respectively. Besides, Table 6.4 shows the use of fertilizer and cultivating drought-tolerant crops were reported to be the other frequent agricultural adaptation mechanisms by 18.3 percent and 14.9 percent of the food-insecure rural households, respectively. In contrast, the use of soil and water conservation practices, planting trees, use of improved crop seeds, irrigation and were the most utilized agricultural adaptation mechanisms in Eastern Tigray (Gebru *et al.*, 2020).

The agricultural adaptation mechanisms employed by rural households in the Ambassel district of Ethiopia were changing planting season, use of fertilizer, crop diversification, and livestock diversification as reported by 18.4, 14.3, 12.2, and 4.8 percent of the households, respectively (Destaw and Fenta, 2021). In northern Uganda, crop diversification and cultivation of drought-resistant varieties were the most widely practiced adaptation strategies (Atube *et al.*, 2021). In South Africa, only 5 percent of vulnerable rural communities maintain drought-tolerant breeds as an adaptation strategy for meteorological drought (Bahta and Myeki, 2021).

On the other hand, cultivating cash crops, preparing alternative wetting, harvesting rainwater, and crop diversification were comparatively the least adopted agricultural adaptation mechanisms by the food-insecure rural households in the study areas. According to Labeyrie *et al.*, (2021), the cultivation of cash crops when combined with crop diversification enhances rural households' dietary diversity and their food security in general. However, 93.1 percent of the rural households in the study areas have never adopted cash crop production as an agricultural adaptation strategy for meteorological drought (Table 6.4).

During the 2018 severe and wide-ranging drought, the most common adaptation option reported by farmers was adjusting planting and harvesting seasons (Holman *et al.*, 2021). In the study areas, only 7.2 percent of the households were adjusting the planting season regularly, and 28.6 percent of the households had never applied adjusting the planting season as an agricultural adaptation strategy.

Owing to rainwater scarcity in the study areas (Gebre *et al.*, 2024), adopting a rainwater harvesting strategy and preparing alternative wetting mechanisms is highly expected to cope with the meteorological droughts. However, Table 6.4 shows that 77.1 and 69.5 percent of the food-insecure rural households have never adopted the agricultural adaptation strategies of preparing alternative wetting and harvesting rainwater, respectively. Similarly, more than half of the rural households in the Karnataka region of India have not adopted an alternative wetting adaptation strategy (Bommaiah and Dechamma, 2020).

Table 6.4. Agricultural adaptation mechanisms to meteorological drought

No.	Adaptation mechanisms	Regularly		Sometimes		Occasionally		Never	
		Freq.	%age	Freq.	%age	Freq.	%age	Freq.	%age
1	Cultivating drought-tolerant crops	54	14.9	82	22.4	58	16	166	46.7
2	Cultivating cash crops	9	2.5	7	1.9	9	2.5	335	93.1
3	Preparing alternative wetting	4	1.1	25	6.9	54	14.9	277	77.1
4	Adjusting planting season	26	7.2	145	40.3	86	23.9	103	28.6
5	Harvesting rainwater	4	1.1	43	11.9	63	17.5	250	69.5
6	Shorter duration crop cultivation	82	22.8	50	13.9	53	14.7	175	48.6
7	Crop diversification	15	4.2	55	15.3	75	20.8	215	59.7
8	Use of fertilizer	66	18.3	85	23.6	136	37.8	73	20.3
9	Use of improved seed	0	0.0	129	35.8	155	43.1	76	21.1
10	Livestock production	98	27.2	77	21.4	56	15.6	129	35.8

6.3.4 Households' choice of adaptation mechanisms to meteorological drought

Agricultural adaptation strategy practices are mostly different from households' choices of strategies (Siders and Pierce, 2021). This is mainly because adaptation practices require the involvement of multiple actors. According to a review of farmers' choices of agricultural adaptation strategies in Africa, crop diversification, planting drought-tolerant crops, adjusting planting dates, and cultivating early maturing crops have been identified as widely chosen strategies (Magesa *et al.*, 2023).

The Paired Comparative Analysis (PCA) results depicted in Table 6.5 show that food-insecure rural households in the six sub-districts had different preferences regarding the choice of agricultural adaptation mechanisms. While livestock production was the first chosen strategy for the *Wejerat* and *Irob* rural districts, it was not a prioritized strategy for the *Atsbi* district. In contrast, crop diversification was the least preferred agricultural adaptation strategy in almost all the sub-districts. In the Dabus watershed of Ethiopia, soil conservation measures in the agricultural land was the most prioritized adaptation strategy by the rural communities of the area (Asrat and Simane, 2018).

Table 6.5. Paired Comparative Analysis (PCA) of agricultural adaptation mechanisms

No.	Adaptation mechanisms	Rank					
		Atsbi		Wejerat		Irob	
		FG1	FG2	FG3	FG4	FG5	FG6
1	Cultivating drought-tolerant crops	1	2	3	2	4	3
2	Cultivating cash crops	8	8	4	6	4	5
3	Preparing alternative wetting	2	3	5	3	2	3
4	Adjusting planting season	7	6	2	8	8	7
5	Harvesting rainwater	5	7	6	5	3	4
6	Shorter duration crop cultivation	3	1	1	4	6	2
7	Crop diversification	7	6	7	7	7	8
8	Use of fertilizer	6	4	2	3	6	7
9	Use of improved seed	5	6	2	4	5	6
10	Livestock production	4	5	1	1	1	1

When averaged, livestock production, cultivating drought-tolerant crops, and cultivating shorter-duration crops were the first three prioritized agricultural adaptation mechanisms preferred by the food-insecure rural households. In contrast, crop diversification, adjusting planting season, and cultivating cash crops were relatively the least preferred agricultural adaptation mechanisms by the food-insecure rural households as shown in Figure 6.2. In contrast, crop diversification and adjusting planting season were the most preferred adaptation strategies by farmers in Ghana (Dasmani *et al.*, 2020).

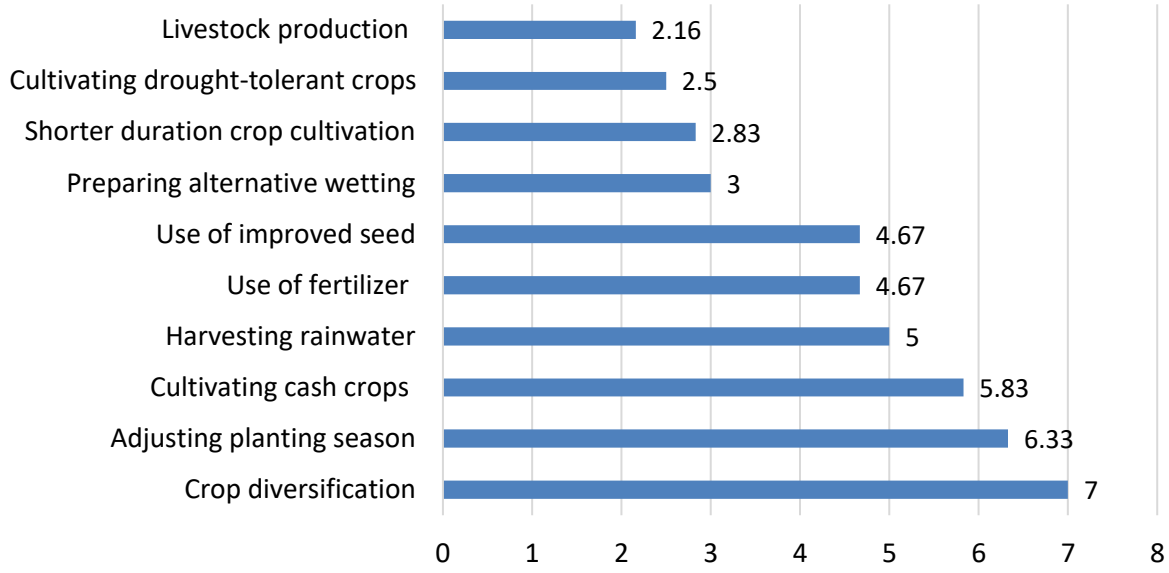


Figure 6.2. Average rank of choices of agricultural adaptation mechanisms

6.4 Conclusion

To cope with the prevailing food insecurity, vulnerable households have been mostly limiting portions of a household's meal size. Besides, depending on aid and consuming less quality and cheap food were the other frequently used coping strategies for food insecurity by rural households. In line with this, the higher average CSI score implies the severe food insecurity status of the households under the study.

A marked distinction was observed in the choice of food insecurity coping strategies from district to district, and even from sub-district to sub-district. Accordingly, consuming less quality and cheap food, reducing the meals of adults in favor of children, consuming food held for the next season, using savings to purchase food, and selling assets to purchase basic food items were the first group of choices of coping strategies in the respective six sub-districts of the study areas. Thus, additional researches are required to determine the factors that affect household's choice of coping strategies.

Further, taking a loan to purchase food, skipping part or entire days without eating, sending children or household members to eat elsewhere, and feeding working members of the household at the expense of non-working members were the most severe coping strategies ranked by rural households. And, many of the food-insecure rural households relied on the most severe coping

strategy, that is, skipping part or the entire day without eating. This may have a serious negative impact on their health. Hence, raising awareness that protects against the use of severe coping strategies should be one priority.

When looking at adaptation mechanisms to meteorological drought, many food-insecure rural households have never adopted alternative wetting and harvesting rainwater to cope with varying precipitation. Because rainwater is the most important determinant of agricultural production, stretching schemes to prudently utilize the rainwater is imperative.

Similar to the coping strategies, the food-insecure rural households had different preferences regarding their choice of adaptation strategies to meteorological drought. The studied rural households preferred to use livestock production, cultivating drought-tolerant crops, and cultivating shorter-duration crops to deal with meteorological drought. Whereas, crop diversification, adjusting planting season, and cultivating cash crops were the least preferred adaptation strategies by food-insecure rural households. The rationale behind their adaptation strategy preferences needs to be studied further.

The study therefore suggests that interventions by state and non-state actors should target enhancing households' ability to cope with precipitation variability and its subsequent food insecurity. In addition, the interventions should be guided by households' specific socio-economic characteristics and level of livelihood. In this regard, more studies should be conducted on how the practiced adaptation strategies are selected and what determines their decision-making.

CHAPTER SEVEN

Food Security Intervention Mechanisms in the Drought-Prone Rural Areas of Tigray

7.1 Introduction

Food insecurity is a condition when all people at all times do not have social, physical, and economic access to sufficient and nutritious foods that meet their requirements (FAO, 1996). Several interventions have been taken to halt food insecurity from the global to household levels. As a result, considerable stride was made globally in reducing hunger between 1990–1992 and 2014–2016, when the proportion of food-insecure people reduced from 23.3 to 12.9 percent (Jha, 2019). However, the number of severely food-insecure world population increased from 7.5 percent in 2017 to 9.2 percent in 2022 (FAO, 2023).

The international community has shown its commitment to combat food insecurity by adopting the 2030 agenda for the Sustainable Development Goals (SDGs) in 2015, including targets to end hunger (SDG 2) and ensure access to food by all people (target 2.1); end all forms of malnutrition (target 2.2) and double the agricultural productivity and incomes of small-scale rural food producers (target 2.3) (UN, 2017). Nevertheless, the number of global people facing hunger has been increasing since 2017 (FAO, 2023), implying the improbability of achieving the SDG target to eliminate hunger in time.

The number of food-insecure people is still prevalent in Eastern Africa, where nearly 30 percent (327.1 million people) of its population are food insecure (FAO, 2023). A recent assessment of food security projected that 15.8 million people in Ethiopia will face hunger and need food assistance in 2024 (UN, 2024). In Tigray, food insecurity is at a critical level as millions face extreme challenges to access food in many parts of the region. According to the Oxfam (2024) report, about one million (more than 20%) people in Tigray are facing acute hunger, and 3.5 million people are in urgent need of food aid. Unless efforts are seriously stepped up, more people in the vulnerable rural areas of the region could be starved.

Given the growing number of food-insecure population and the growing need to improve population health, there is wide interest in addressing food insecurity. The UN agencies are now calling for new ways of thinking to integrate food security concerns into different global and national development plans (Bahn *et al.,* 2021).

Achieving food security is a long-term and multi-sector process that requires a fundamental social transformation and timely financial and technical support to vulnerable households (Rahut *et al.*, 2022). In recognition of this, food security intervention mechanism is a central element in the pursuit of food security. A review of intervention mechanisms by Bizikova *et al.* (2020) revealed that a positive impact of food security intervention mechanisms was reported in 73 publications (67% of the reviewed publications). Similarly, another review indicated that intervention mechanisms at a community level that include agricultural strategies like raising agricultural awareness, improving soil and seeds, promoting gardening, and agroecological practices were reported to have improved food security (Doustmohammadian *et al.*, 2022).

In Ethiopia, several food security intervention mechanisms are in place. However, only the PSNP and agricultural interventions were repeatedly mentioned (Coll-Black *et al.*, 2013; Wordofa and Sassi, 2020 and Cordonnier *et al.*, 2022), and other food security intervention mechanisms are not scientifically reported. Further, Van der Veen and Gebrehiwot (2011) described the effect of policy intervention on food security in Tigray, but the study did not include other interventions.

To meet the ideal FAO's (1996) concept of food security, intervention mechanisms should address the four basic components of food security. However, scholars who studied food security intervention mechanisms like Saleth and Dinar (2009); Bizikova *et al.* (2020) and Nisbet *et al.* (2022) did not adequately report the integration of food security components into the intervention mechanisms. Therefore, this study tries to fill the knowledge gap by identifying the prominent interventions that can impact vulnerable households in relation to the basic pillars of food security.

Improving food security is frequently expressed as a goal of governments, multilateral development agencies, and non-governmental organizations (Weis, 2020). Thus, to better understand the scope of food security interventions by these entities, four categories of intervention mechanisms are identified in this study: international, national, regional, and community level food security intervention mechanisms. This study, therefore, aims to describe the existing food security intervention mechanisms of various levels in relation to the four pillars of food security.

Although food insecurity intervention mechanisms need to be developed for specific contexts, this study will provide valuable lessons for interventions to be successful. This chapter is published as a research article in a peer-reviewed journal. The study will serve as a base for other researchers interested in evaluating these intervention mechanisms' impact on food security.

7.2 Research Methods

This study aims to provide a wide-ranging description of food security intervention mechanisms in the Tigray region of Ethiopia. For this purpose, an integration of quantitative and qualitative research approaches was used to describe the existing food security intervention mechanisms. Both primary and secondary data were gathered from household heads, regional and local PSNP officers, and relevant policy archives.

Data were collected through survey-based questionnaires and key informant interviews. A descriptive data analysis method (mainly frequencies and percentages) was employed to analyze the quantitative data. Besides, the relevant policy documents, such as Ethiopia's Food Security Policy, Food Security Strategy, Food Security Program, and PSNP implementation manual were thematically analyzed.

7.3 Results and Discussion

7.3.1 Interventions at international level

Finance is a major enabler for sustainable agricultural growth and food security in Ethiopia. In this regard, external aid is one way that the international community can contribute to the well-being of humans. Ethiopia is one of the major recipients of international assistance. Ethiopia has been receiving external aid since the late 1940s (Furtado and Smith, 2007). Based on foreign aid and official development assistance received from 1960–2021, Ethiopia was ranked fifth out of 134 countries and second in Africa (Global Economy, 2023). This shows Ethiopia has been attracting international assistance to support its food security achievement efforts and this can be taken as a good opportunity for the country.

Food is one of the main sectors attracting international interventions in Ethiopia. During 1960–2003, food was the major sector that received the largest aid money in Ethiopia (Lemi, 2007). In 2012, Ethiopia was the top food aid recipient country in the world accounting for 16 percent of global food aid receipts (WFP, 2013). In 2022, Ethiopia was the largest recipient of development assistance to food programs (FSIN and GNAFC, 2024). According to OCHA (2024), in 2023, USD 572.6 million and USD 175 million were internationally donated to Ethiopia to the food and nutrition sector, respectively to respond to the food crises.

In addition to the national efforts, the international donor community, NGOs, and the United Nations have been contributing to the improvement of food security status in the affected

populations in Ethiopia. Based on the analysis of food-related international contributions to Ethiopia, the European Union (EU) was found to be the major contributor to food-related activities in Ethiopia. Similarly, Lemi (2007) indicated that the EU was a major multilateral donor to Ethiopia during 1960–2003 followed by the World Bank and World Food Program. The EU was supporting food-insecure households by providing food and non-food items distributed through ECHO (European Community Humanitarian Office) and channeled by the Relief Society of Tigray (REST) and the International Committee for the Development of People (CISP) in Tigray and Afar Regions.

Besides, the governments of Britain, Italy, Germany, Ireland, Norway, USA, Japan, France, Netherlands, and Switzerland have been the long-time consistent contributors to food-related support and activities in Ethiopia. Further, Belgium, Finland, Canada, Sweden, Spain, and Austria have also been contributing to food-related activities in Ethiopia in an irregular manner. According to Lemi (2007), USA, Italy, Germany, Sweden, and the Netherlands were the top donors in that order during 1960–2003. In 2023, USA, Germany, and Canada were the top contributors to Ethiopia's humanitarian response plan (OCHA, 2024).

On the other hand, the WFP has been an important UN agency for allocating food items in Ethiopia. During March 2021–May 2022, WFP reached 4.4 million food-insecure people in northern Ethiopia (WFP, 2022b). WFP has been using TSFP (targeted supplementary feeding program) and BSFP (blanket supplementary feeding program) nutrition activities to treat and prevent moderate acute malnutrition for 47,000 under five years of age children and pregnant and lactating women in Tigray region in February 2022 (WFP, 2022b). This indicates that WFP’s focus was on nutrition beyond the food availability.

A review of international interventions to food insecurity reveals that many international donors prefer to respond to food insecurity by providing direct donations to implementing agencies. Nonetheless, there have been some substantial food aid in the late 1990s and early 2020s. The review shows that displaced people were major recipients of the food and non-food aid.

Apart from food aid supplies, a promising international intervention was identified in supporting Ethiopia’s rural Productive Safety Net Program (PSNP). Unlike the food aid supplies, the rural PSNP aims at addressing the chronic food insecurity problem in selected vulnerable communities. According to the World Bank (2023b) phase four implementation report, the program has reached

nearly eight million people in 382 food-insecure rural districts of Ethiopia. However, there is no clear data about what food security components the program has been addressing and how.

Several development partners were active in financing the rural PSNP. A total of USD 3,021,019,353 was incurred for the implementation of the fourth phase of the program; of which 84.3 percent of the cost was financed by international donors. As indicated in Table 7.1, the World Bank was the major donor of the program followed by DFID and USAID.

Table 7.1. Multilateral donations to Ethiopia's PSNP fourth phase

No	Name of donors	Actual amount disbursed (USD)
1	World Bank	1,623,979,010
2	USAID	360,000,000
3	DFID (British Department for International Development)	502,953,948
4	Ireland Government (Irish Aid)	58,601,763
5	UN children's fund	16,464,689
6	World Food Program	29,990,990
7	Australian Development Agency	2,216,601
	Total	2,547,751,322

Source: World Bank (2023b)

After the completion of the fourth phase of rural PSNP, the fifth phase of the program was launched with a total of USD 2.2 billion investment to reach up to nine million food-insecure people (USAID, 2023). This shows the international community is ready to contribute to the achievement of food security in Ethiopia. Yet, there are a lack of clarity on how the rural PSNP can contribute to the four components of food security through the five sub-programs: public works, temporary direct support, permanent direct support, livelihoods services, and shock responsiveness.

Ethiopia's Agricultural Growth Program (AGP) has been the other major program where international financial intervention is visible to see. The program aims at enhancing agricultural productivity and access to a market with the active participation of women and the youth partly meeting the food availability and access to food pillars of the food security. According to GAFSP (2022), nearly 700,000 farmers were benefited from AGP–I.

The first phase of the program's total cost was USD 417,800,000 (IED, 2019); of which 94.8 percent was financed by international multilateral and bilateral donors. Based on Table 7.2, the World Bank was the major donor to the implementation of AGP-I.

Table 7.2. International donations to Agricultural Growth Program (AGP)-I

No	Name of donors	Actual amount disbursed (USD)
1	World Bank	256,200,000
2	USAID	81,400,000
3	UN Development Program	2,400,000
4	Other bilateral agencies	56,200,000
	Total	369,200,000

Source: IED (2019)

FAO, unlike the other donors, has been providing technical support for the effective implementation of Ethiopia's rural PSNP. It has also been supporting the adaptation strategies to agricultural drought in Ethiopia through strengthening institutional capacity for resilience; supporting early warning and information management systems; building community-level resilience; supporting communities through diversified livelihood options and supporting irrigation development activities (FAO, 2024). This initiative promotes the achievement of food security by enhancing agricultural productivity in general and food availability in particular.

Although there were several international interventions intended to halt food insecurity sustainably through financial aid, many of the interventions were found to be responding to humanitarian crises mainly the food shortages. This implies that due focus was given to the transitory food insecurities.

In 2022, USD 15.1 Billion was funded to food sectors in food-crisis countries, which increased by 16 percent compared to 2021 (FSIN and GNAFC, 2024). According to OCHA (2024), out of the planned USD 3.995 Billion, USD 1.339 Billion was received and financed to respond to the food crises in Ethiopia in 2023. If these were to be financed to initiatives that work on achieving sustainable food security, the impact of these finances would have been much greater.

WHO (2021) reported that "*Investing one dollar per person per year could save seven million lives in low- and lower-middle-income countries*". Similarly, the National Institute of Building Sciences (2019) reported that every USD one invested in disaster mitigation saves extra responding costs of USD six. This shows a significant savings can be gained by investing in preparation and mitigation works. Further, proactive measures can contribute to achieving food security by increasing agricultural production and strengthening households' capacity to withstand shocks.

7.3.2 Interventions at national level

Public sector intervention mechanisms have a prominent role in addressing food insecurity at the household level. National policy is one of the fundamental ways to guide intervention mechanisms for food insecurity and its associated causes.

The FDRE (2018) 'Food and Nutrition Policy' was the first national food and nutrition policy in Ethiopia. The policy emphasizes on attaining optimal nutritional status for all age groups at all levels. The policy has generally seven directions to achieve its intended objectives: (1) Ensuring food availability, accessibility, and utilization of diversified, safe, and nutritious foods in a sustainable way; (2) Ensuring the safety and quality of foods from production to consumption; (3) Improving postharvest management of farm products; (4) Ensuring optimum nutrition at all age groups; (5) Providing timely and appropriate emergency response for food crises; (6) Strengthening food and nutrition communication and (7) Establishing and strengthening food and nutrition governance.

The food and nutrition policy of Ethiopia is generally found to be well-elaborated and logically linked to the four major components of food security. The policy is formulated with a broader scope and provides a base for multi-sectoral collaboration, interventions, and planning food security strategies. Nevertheless, the policy is found to be more sensitive to nutrition than the other pillars of food security. In addition, the rural people in general and the vulnerable food-insecure rural people in particular were not given appropriate emphasis in the policy.

Unlike the Food and Nutrition Policy of Ethiopia, the Food Security Program of Ethiopia exclusively emphasizes on vulnerable rural people. According to the Ministry of Agriculture and Rural Development (2009), the long-term goal of the Food Security Program of Ethiopia has been: achieving food security for the chronic and transitory food-insecure rural households in Ethiopia. Nevertheless, the program has no clear ways of addressing the pillars of food security.

The Food Security Program of Ethiopia has been under implementation since 2003 in 319 chronically food-insecure rural districts of Ethiopia with four distinct components: Productive Safety Net Program (PSNP), Household Asset Building Program (HABP), Complementary Community Investment (CCI) program, and resettlement program.

PSNP has been intended to provide transfers through labor-intensive public works for those who are able-bodied and direct support for those who are unable to work. According to the Ministry of

Agriculture (2020), the fifth PSNP has five sub-programs: public works, temporary direct support, permanent direct support, livelihood services, and shock responsiveness. During phases one and two, there were nearly 4.8 million PSNP beneficiaries (Bahru and Zeller, 2022). And, according to World Bank (2023b), there were 7,997,218 PSNP country-wide beneficiaries in 2022; of which 2,770,188 were under direct support of the program.

PSNP was first launched in 2005 and it is now in its fifth phase (USAID, 2023). The fourth phase of the PSNP was extended three times in 2020 and 2021, for a total of 18 months: from December 2020 to June 2021; June 2021 to December 2021 and December 2021 to June 2022 (World Bank, 2023b). The fourth phase of the program was ended in June 2022 and its project performance was rated as "moderately satisfactory" by the World Bank (World Bank, 2023b). In 2016, urban PSNP was launched and started to be implemented in 11 major urban areas of Ethiopia (MoUH, 2016).

Phase five of PSNP focuses on eliminating extreme poverty in drought-prone areas. Its target shifted from chronically food insecure households to extremely poor households, thereby targeting and addressing the needs of the extremely poor and the most vulnerable. While focusing on drought-prone areas is a good direction to reach vulnerable households, focusing on extreme poverty exclusively may not address the multi-faceted root causes of food insecurity. This is mainly because food insecurity in rural Ethiopia is mostly caused by low productivity in rainfed agriculture (Neglo *et al.*, 2021).

HABP aims at building productive assets and diversifying income sources of food-insecure households. The interventions include disseminating improved agricultural inputs, moisture conservation and utilization techniques, and farmers' training for generating additional income. CCI, on the other hand, aims at improving food-insecure households' access to basic social services and infrastructures.

The resettlement program, unlike the other components, aims to ensure the food security of vulnerable households by providing access to farmland in other areas. The food-insecure households must move to other areas to access the farmland. The settlers are provided with basic agricultural inputs and food assistance until their first production.

The food security program of Ethiopia is generally reasonable in that it gives due focus to the chronically food-insecure rural households. More importantly, the program has set to at least achieve food availability at a household level.

The limited emphasis given to the nutrition aspect is one major drawback of the program. The program hardly shows how nutritional security can be achieved in rural Ethiopia. Besides, food security in the program is viewed as a "relative" state of resilience rather than the globally accepted working concept. Further, the program lacks clarity in both the concept and standards of "graduation" of food-insecure households. The program set stable livelihood and increment in asset buildings as a requirement for graduation, but no method was designed to measure the requirements.

Ethiopia's Food Security Strategy is the other food-insecurity intervention mechanism at the national level. The strategy was first formulated in 1996 and updated in 2002. The FDRE (2002) Food Security Strategy of Ethiopia relies on three basic pillars to achieve food security: increasing food availability through enhanced domestic production; ensuring access to food in food-insecure areas and strengthening emergency response capacities. The strategy targets mainly the chronically food-insecure households living in drought-prone and pastoral areas.

Unlike the Food and Nutrition Policy and Food Security Program, the Food Security Strategy intends to address the causes of food insecurity in Ethiopia. Accordingly, environmental rehabilitation, water harvesting schemes, livestock and agro-forestry development, and cultivation of high-value crops were given a clearer focus on the strategy. In addition, the strategy explains that there are linkages between chronic and transitory food insecurity in that unless households are chronically food-insecure, unpredictable shocks cannot rapidly lead to transitory food insecurity. This is a good initial to address the stability component of food security.

What is so special about the Food Security Strategy of Ethiopia is that food insecurity is categorized into three categories: rural food insecurity, urban food insecurity, and others (displaced people and groups affected by instability). More importantly, it is highlighted that the causes to chronic and transitory food insecurity in these three categories are distinct. The various regions were also described based on poverty measures to indicate their susceptibility to food insecurity. This has a vital significance in guiding food security interventions at local levels.

Generally, the good quality of the Food Security Strategy of Ethiopia is that it explains the importance of understanding the nature of food security and coping mechanisms adopted by vulnerable households. Moreover, it states that addressing the root causes of food insecurity is an instant requirement to achieve food security. Key to this, boosting agricultural production, building

the resource base of chronically food-insecure households, diversifying income sources in both rural and urban areas, and providing transfers to targeted households are proposed as ways of achieving the intended outcomes of the strategy.

Nonetheless, like the Food Security Program of Ethiopia, less emphasis was given to the nutrition aspect in the Food Security Strategy of Ethiopia when compared to the other components of food security. In addition, much less emphasis is given to the small farm-size households living in drought-prone rural areas. The strategy directs a resettlement program for smallholder food-insecure households living in drought-prone rural areas. Given the positive effect of the resettlement program on food security, the strategy should have indicated alternative interventions for those households who are unable to resettle in other areas.

Concerning the food-insecure rural households living in drought-prone districts, the Food Security Pack (FSP) program was introduced in 2000 by the Ethiopian government with the aim of empowering vulnerable but viable farmers affected by recurrent droughts (MCDSS, 2021). The program has three major components namely: 1) Rainfed Cropping in which farmers are supported with fertilizer and seeds for two consecutive years; 2) Wetland Cropping in which farmers are supported with fertilizer and seeds for one cultivation season only and 3) Alternative Livelihood Initiative in which farmers are supported with non-crop agricultural inputs like goats, sheep, and chickens.

According to MCDSS (2021), the FSP program has been under implementation country-wide in selected 116 districts. The Alternative Livelihood Initiative of the program is a good opportunity to enhance food security of physically disabled and small farm-size households living in drought-prone areas. However, it is flawed to see that the two components of the FSP program target only able-bodied farmers with a minimum farm size of 0.5 hectares. Thus, attainment of the social access to food is in question.

7.3.3 Interventions at regional level

The FDRE (2002) Food Security Strategy dictates that food security interventions at the regional level should be designed based on the Food Security Strategy of Ethiopia. Based on Van der Veen and Gebrehiwot (2011), the food security interventions in Tigray were given utmost attention to agricultural extension services that include the use of fertilizers and improved seeds, facilitating farmers' access to rural credit, introducing better and improved agricultural practices, and

introducing a variety of water harvesting schemes. These interventions significantly contributed to a higher likelihood of household food security status in Tigray throughout 2000-2008 (Van der Veen and Gebrehiwot, 2011).

Soil and water conservation activities in Tigray have been one of the widely practiced interventions in the region. Until 1960, there were no soil and water conservation programs in Tigray, and the first conservation practices at the hillside scale took place in the early 1970s (Munro *et al.*, 2019). Since 1985, soil and water conservation activities have been implemented in Tigray on a wider scale (Hishe *et al.*, 2017). In September 2017, Tigray was awarded a gold medal by the World Future Policy for restoring land on a massive scale. A focused soil and water conservation interventions would contribute to the region's rural food availability and access by enhancing agricultural productivity.

Apart from PSNP and some ongoing projects including the WFP and FAO-led food security related projects, no regional strategy or program was found that deals with the rural or general food security issues of the region until February 21, 2024. All the regional interventions were guided by the national food security policy, program, and strategy. More than half of the geographical area of Tigray region is dry-land (Haftom *et al.*, 2019); to solve the higher vulnerability of the rural people to food insecurity, region-specific food security programs and strategies would have greater importance in guiding food security intervention mechanisms.

More importantly, no regional food security bureau or office that specifically deals with food security issues was found during the survey. The PSNP office was acting as food security office of the Tigray region. At the federal level, there was Disaster Risk Management and Food Security Sector under the National Disaster Risk Management Commission (NDRMC) until 2015. The Food Security Sector was later shifted to the Ministry of Agriculture and Natural Resources to deal with the PSNP (World Bank, 2023b).

In the Tigray region, the Bureau of Agriculture and Natural Resources had a Disaster Risk Management (DRM) Directorate and a Food Security Sector. The DRM Directorate coordinated the disaster management and implementation of the Humanitarian Food Assistance (HFA), while the food security sector was responsible only for the PSNP.

Hence, the PSNP office was found as the only regional office related to chronic food insecurity issues in Tigray region. According to data obtained from the PSNP office during January 2024,

there were a total of 1,010,752 rural PSNP beneficiary households in Tigray. This accounts for 12.6 percent of the total national PSNP beneficiary households in Ethiopia. Of the total rural PSNP beneficiaries in Tigray, 247,945 (24.5%) households were under the direct support program, as reported by the PSNP office.

More importantly, according to the Tigray region's PSNP office, out of the 34 rural districts, there were a total of 31 rural districts under the benefits of rural PSNP in 2019; following the administrative boundary restructuring that took place in 2020, the PSNP rural districts increased to 56 (out of the 57 total rural districts in the region). Accordingly, PSNP beneficiaries in rural districts of Tigray increased from 91 percent in 2019 to 98.2 percent in 2022.

HFA is the other widely practiced food security intervention in Tigray. HFA was intended for non-PSNP households who are affected by the transitory drought (Sabates-Wheeler *et al.*, 2022). HFA and PSNP are coordinated in a way that HFA targets those who are temporarily (transitory) food-insecure and PSNP targets chronically food-insecure; hence, there would be no overlap.

By the end of 2023, there were a total of 340 local and international humanitarian agencies registered in Tigray region, according to the Bureau of Social Affairs of Tigray. However, no data was available regarding which of these humanitarian agencies were dealing with food security issues of the region. During 2021, there were only ten international NGOs, three national NGOs, five UN agencies, the International Committee of the Red Cross (ICRC), and two donor entities operating inside Tigray (Stoddard *et al.*, 2021).

7.3.4 Interventions at community level

Community-level interventions play a vital role in addressing societal problems. A study by Durao *et al.* (2020) showed that community-level interventions had improved food security status in low and middle-income countries of Africa and Latin America. Similarly, Doustmohammadian *et al.* (2022) have reviewed the impact of community-level interventions on food security and its dimensions. The authors reported that all such interventions have significantly contributed to the intended food security targets.

Food aid has been one of the food security intervention mechanisms at the community level. According to Stoddard *et al.* (2021), food was the most needed and received type of aid in Tigray followed by medicines. OCHA (2024) reported that nearly 1.2 million households have received food aid in Tigray in 2023.

The food-insecure rural households living in the selected drought-prone rural areas of Tigray were asked if they received food aid from May 2022 to April 2023. Accordingly, 344 (94.8%) of the respondents claimed that they had received food aid during that time; however, almost all (96.2%) of the food aid recipients revealed that the food aid was not sufficient to cope with their food insecurity, as illustrated in Table 7.3. Stoddard *et al.* (2021) reported that 94 percent of surveyed Tigray people stated that they have needed aid since November 2020, but only 43 percent reported receiving food aid from 17 February to 8 March 2021.

Table 7.3. Responses related to food aid in the study areas

No	Questions	Yes		No	
		Frequency	Percent	Frequency	Percent
1	Have you received food aid during the last year?	344	94.8	19	5.2
2	Was the food aid sufficient?	13	3.8	331	96.2

The OCHA (2024) report additionally indicated that the food aid in Tigray was irregular and 61 districts, including the drought-affected areas, were reached with in-kind and cash-based assistance. In line with this, Figure 7.1 shows that more than half of the food aid recipients reported that they had received food aid only once; while 12.7 percent of the households had received the aid three times during May 2022 – April 2023.

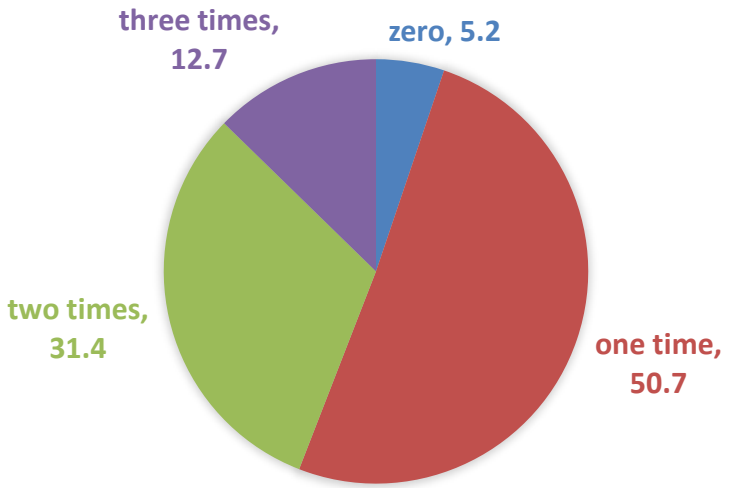


Figure 7.1. Frequency of food aid received by the food-insecure households (1st May 2022 – 30 April 2023)

Rural PSNP is the other widely practiced food security intervention mechanism at a community level. According to the program implementation manual designed by the Ministry of Agriculture (2020), the number of PSNP beneficiaries is determined by the established quotas per district and sub-districts, and not all households that meet the eligibility criteria are selected.

In the selection process, households are compared to each other and ranked based on the socio-economic status including land and livestock holding and people with disabilities, female-headed households, households with members suffering from chronic illness, elderly-headed households caring for orphans are prioritized. Subsequently, households are assigned to either the public works or to the direct support components based on their household characteristics and physical capability to work. This enhances the economic and social access to food.

Rural PSNP beneficiaries are reassessed annually to determine their eligibility to stay supported. If the socio-economic condition of beneficiaries is improved or if they have been in the program for at least three years, certification is done. Certified or graduated households will be replaced by other selected vulnerable households. In line with this, Demsash *et al.* (2023) reported that poor households in Ethiopia were 1.9 times more likely to receive PSNP benefits than rich households; rural households in Ethiopia were 2.2 times more likely to receive PSNP benefits than urban households.

Rural PSNP is the dominant food security intervention mechanism in Tigray and the study areas in particular. As shown in Table 7.4, there were a total of 77,010 (35.6% of the population) rural PSNP beneficiaries in the three drought-prone rural districts in December 2023. Of these, 20,019 (25.9% of the beneficiaries) were direct beneficiaries and the rest were public (food for work) participants.

Table 7.4. Rural PSNP beneficiaries in the study areas (December 2023)

PSNP beneficiaries	Atsbi	Irob	Wejerat	Total
Total population (as of July, 2023)	94,210	33,280	88,800	216,290
Direct beneficiaries	6,851	7,664	5,504	20,019
Public work beneficiaries	23,526	20,003	13,462	56,991
Total rural PSNP beneficiaries	30,377	27,667	18,966	77,010
Percentage of beneficiary/population	32.2	83.1	21.3	35.6

According to the food security team leaders of the respective rural districts, the transfer was ETB 225 (USD 3.98) per month up to June 2023. It was later raised to ETB 420 (USD 7.434, as of

January 01, 2024)[4] starting from July 2023. The transfer was not only much less to support household's access to food, but also it does not ensure that the purchasing power of the transfers keeps pace with food price changes. This is supported by studies made by Desalegn and Ali (2018) and Hirvonen and Hoddinott (2021).

Furthermore, there were quite contradicting findings concerning the impact of PSNP on food security status of the beneficiaries. A country-level study on the impact of PSNP found that PSNP reduces the initial impact of drought by 57 percent; it reduces the persistence of post-drought impacts from four to two years (Knippenberg and Hoddinott, 2017). In addition, a review of the impact of PSNP by Desalegn and Ali (2018) showed that PSNP had generally a positive impact on food security of households. Similarly, Tadesse and Gebremedhin (2022) indicated that PSNP has enhanced consumption expenditure, daily calorie intake, and annual income of participating households in Gedeo zone of Ethiopia. Further, a similar study in the Somali region of Ethiopia reported that PSNP had a positive and significant impact on household's food security status; participants of PSNP were reported to have more daily calorie intakes than the non-participants (Haji and Mumed, 2023).

In contrast, Demsash *et al.* (2023), reported that PSNP was not effective in ensuring food security or children's dietary diversity in Ethiopia. Similarly, Bahru *et al.* (2020) reported that PSNP has not improved household food insecurity, child dietary diversity, and child malnutrition. Mustafa *et al.* (2023) also reported that PSNP had only increased current consumption patterns, and graduated households had to return to their previous food insecurity situations. Furthermore, Bahru and Zeller (2022) reported that no evidence was found to ensure that PSNP has improved households' agricultural technology adoption, time spent in agriculture, household's access to agricultural services, and women's asset ownership.

7.4 Conclusion

Food has been one of Ethiopia's main sectors attracting international intervention since the 1960s. Ethiopia has been one of the very few top food aid recipients in the world. A number of the

[4] One USD = ETB 56.477

international donor community, NGOs, and the United Nations have been contributing to the food security status in the affected populations in Ethiopia mainly in the form of food aid.

Although there were several international interventions intended to halt food insecurity sustainably through financial aid, many of the interventions were found to be responding to humanitarian crises mainly the food shortages. Rural PSNP, which has been under implementation since 2005, was predominantly funded by the international multilateral and bilateral donors. Nearly half a billion is funded annually to the PSNP implementation by international donors. Yet, more proactive measures that increase agricultural production and strengthen households' capacity to withstand shocks are much needed to achieve food security.

At the national level, Ethiopia's Food and Nutrition Policy, Food Security Program, Food Security Strategy, and Food Security Pack program were the food security intervention mechanisms. The Food and Nutrition Policy is found to be nutrition sensitive with lesser emphasis given to the vulnerable rural people. In contrast, the Food Security Program which consists of the PSNP, Household Asset Building Program, Complementary Community Investment Program, and resettlement program, mainly focuses on achieving food security for the chronic and transitory food-insecure rural households in Ethiopia. Similarly, the Food Security Strategy targets mainly the chronically food-insecure households living in drought-prone and pastoral areas. Yet, nutrition was the missing aspect in both the Food Security Program and Food Security Strategy of Ethiopia. Thus, more tasks are required to harmonize the end goals of the national food security intervention mechanisms.

In Tigray region, apart from PSNP and some ongoing non-governmental projects, no regional food security strategy or program was found. More notably, the region has no food security bureau or office that deals with food security issues of the region; it is the PSNP office in charge of regional food security issues. This shows limited political commitment of the regional government to sustainably address food insecurity. Thus, formulating a responsive and contextual regional food security policy or integrating food security into the other sectoral plans requires due attention to address food insecurity in Tigray.

At a community level, food aid and PSNP transfers have been the usual food security intervention mechanisms. The food aid and PSNP transfers were outrageously insufficient to cope with food insecurity. Further, relying on food aid to curb food insecurity in rural areas can never address the

problem sustainably. Therefore, it would be better to tackle not the symptoms, but the root causes of food insecurity by promoting enhanced agricultural and non-agricultural practices through engaging the rural households.

In general, few of the intervention mechanisms were giving considerable emphasis to the drought-prone rural areas. And, the four pillars of food security were not fully integrated into many of the international, national, regional, and community-level interventions, indicating an important task to carry out in the future. This includes a further assessment and clear insight about the impacts of these interventions on food security, and a critical analysis of the pros and cons of the current food security intervention mechanisms to better guide actions to address food insecurity.

CHAPTER EIGHT

OVERALL FINDINGS AND LESSONS

8.1 Conclusion

There is no way to talk about development if food security cannot be achieved. If national development must go through the sector that supports most of the population, then our development must start from the rural areas and agriculture sector, where more than 75 percent of Ethiopia's population and that of Tigray region are rural dwellers.

Achieving food security for "all people at all times" is an impractical concept universally. Food security achievement is a long-term process that requires a fundamental social transformation and timely financial and technical support to local needs. There have indeed been encouraging achievements in many parts of the world in reducing food insecurity. Nevertheless, the number of food-insecure people is still prevalent and increasing in many parts of Ethiopia, particularly in the Tigray region.

Overall food security situation in the study areas

The food security situation in the drought-prone rural areas of the Tigray region is life-threatening and requires immediate action. All the measurements show that the households living in the studied areas were critically food-insecure. In situations where their larger family size cannot be supported by the amount of their farms, the majority of food-insecure households rely on their farming activities to meet their food and other basic needs. This indicates that the high level of food insecurity in the community needs to be addressed and calls for careful action.

Food-insecure households were experiencing unacceptable levels of food availability and hunger. Almost all the study rural communities had to eat a lesser amount of food which might be the cause of famine and starvation. It has been even more challenging for these rural communities to get access to food because of their limited physical, social, and economic capacities. In times of food shortages at home, the study communities had to walk for longer and more challenging distances to purchase food with inadequate money in hand.

The FCS and HDDS findings indicate that there was a limited variety of food consumption that fell short of the accepted level. For this reason, children aged 6-59 months that live in food-insecure rural areas are at higher risk than any other age group. The SAM, MAM, and GAM results were

unacceptably high, which were greater than the WHO cut-off points for an emergency. Besides, because of the higher prevalence of Bitot's spot above the WHO standard, VAD in the food-insecure study areas was a public health concern. This calls for immediate attention and implies that much more has to be improved to curb the serious food insecurity prevailing in the study areas.

The study communities had very limited or no food supplies for their future consumption, which is more significant in such drought-prone rural areas. In this situation, the food insecurity status of the communities living in these drought-prone rural areas will get worse and might cost us lives. Thus, an integrated life-saving task is required provisionally, and diversifying livelihood sources of the food-insecure rural communities is a "must-to-do" task to sustainably achieve food security. In due course, attaining the food availability and access components of food security need to get priority.

This study argues that long-term plans for achieving food security are essential to guide intervention mechanisms to be undertaken by governments at all levels, international communities, and humanitarian agencies. In the meantime, elaborated short-term strategies are needed to address the PLW and children's malnutrition and households' food shortage in the drought-prone rural areas of Tigray.

Precipitation variability and its teleconnection with the global SST and ENSO indices

Precipitation is a major factor in food production, especially in regions where rain-fed agriculture dominates. Precipitation variability is the one natural element causing food insecurity in rural areas of Ethiopia. Variations in the amount, time, and space are the manifestations of the variation. The important point to be considered here is that precipitation variability does not affect all the pillars of food security equally; the impact of precipitation variability is more pronounced on the aspects of food availability and food stability.

Smallholder farming is the dominant agricultural practice in the Tigray region, where farmers primarily rely on precipitation. Since precipitation is a time- and space-varying natural event, minimizing potential risks to rural families can be achieved by comprehending the nature of precipitation variability. Additionally, it can considerably raise the lower rural community's level of food security.

The study areas, which are vulnerable to drought have experienced a very low and erratic precipitation pattern linked to global teleconnections. The three districts have shown a similarity in the magnitude and seasonality of precipitation. March–May (*Belg*) and June–September (*Kiremt*) were relatively the rainy seasons in the three districts. While the March–May average precipitation of the three districts has shown a decreasing trend, an insignificant increment was observed in the precipitation pattern of June–September. This implies that the current agricultural system needs to be quickly replaced by a climate-smart farming system or careful decisions should be made for some agricultural practices during these seasons.

On the other hand, there was a noticeable difference in the trend of the precipitation pattern among the three rural districts. Even though no notable trend in the precipitation patterns of *Atsbi* and *Irob* was discovered, a very substantial declining trend in the average precipitation of *Hintalo* during March–May and a considerable declining trend for the yearly average precipitation of the *Hintalo* area were noticed. As a result, proper and timely action is required to secure alternate water sources for rural areas where precipitation is the primary means of food production, which addresses the food availability pillar of food security.

More importantly, it was realized that the SST of the central and eastern equatorial Pacific Ocean and the northeast and northwest equatorial Atlantic Ocean was found to be correlated with the April's average precipitation across the three districts. Additionally, the SST of south, west, and southwest of the equatorial Indian Ocean, and west equatorial Pacific Ocean was associated with July–September average precipitation with greater variation in strength among the three districts. The ENSO indices, on the other hand, were significantly associated with the July average precipitation of the three districts, April average precipitation of *Atsbi* and *Irob*, and May precipitation of *Hintalo*.

In order to create an accurate precipitation forecast for the study areas, information about the SSTs of the central and eastern equatorial Pacific Ocean, northeast and northwest equatorial Atlantic Ocean, southwest equatorial Indian Ocean, and West equatorial Pacific Ocean, as well as information about the ENSO indices of JFM, FMA, MJJ, and MAM, can be utilized.

In general, the limited amount of precipitation, given its higher degree of variability, would be the major challenge in the task of achieving food security in the food-insecure rural areas. Consequently, these rural communities will continue to face the dire effects of food insecurity

unless adaptation strategies are arranged that meet the varying monthly, seasonal, and annual precipitation, or alternative water sources are exploited and the rainwater is harvested prudently.

It is important to note that there were significant differences in the strength of the precipitation pattern and its teleconnection with the global SST and ENSO indices among the three districts. Therefore, instead of studying precipitation as a whole, future researchers must examine precipitation at the cluster level and investigate the effects of local landscape features like vegetation cover and altitude on the temporal and spatial precipitation variability. This allows programs and actions related to food security to be successfully downscaled to the local level based on information about local precipitation patterns.

Household's response mechanism to food insecurity and associated precipitation variability

To deal with the current state of food insecurity, the majority of vulnerable households have been reducing the volume and frequency of their meals. In addition, relying on assistance and consuming inexpensive, low-quality meals were the other common coping mechanisms employed by rural households to deal with food insecurity. In line with this, the CSI average score was found higher implying that the rural communities in the study areas are experiencing acute food insecurity, which requires due attention.

There was a noticeable difference among districts and even sub-districts in the coping mechanisms chosen to deal with food insecurity. Accordingly, the first choices of coping strategies in the corresponding six sub-districts of the study areas were eating less nutritious and inexpensive food, cutting back on adult meals in favor of children, consuming food stored for the next season, using savings to buy food, and selling assets to buy necessities. Therefore, more research is needed to determine what characteristics influence the coping mechanisms that households use.

In addition, rural households listed the most severe coping mechanisms as borrowing money to buy food, going without food for a portion of the day or all of it, sending kids or other family members to eat elsewhere, and feeding working members of the home at the expense of non-working members. Additionally, a large number of food-insecure rural households were using the most extreme coping mechanism, which involved going without meals for part or the full day. Since this could have a detrimental effect on their health, it is important to prevent the use of extreme coping mechanisms, which may come as a result of improving the food insecurity situation in the drought-prone rural areas.

When considering how to adapt to meteorological droughts, a large number of rural food-insecure households have never considered making alternate wetting plans or harvesting rainwater to deal with fluctuating precipitation. The food-insecure rural households exhibited varying preferences in terms of their adaptation techniques to meteorological droughts, much like their coping mechanisms.

On average, the food-insecure rural households prioritized livestock production, cultivating drought-tolerant crops, and cultivating shorter-duration crops to deal with meteorological drought. Crop diversification, adjusting planting season, and cultivating cash crops, on the other hand, were comparatively the least preferred adaptation options among rural food-insecure households.

Accordingly, the study suggests that both state and non-state interventions should focus on enhancing vulnerable household's capacity to cope with precipitation variability and the ensuing food insecurity. Additionally, the interventions should be guided by the specific socioeconomic features of the rural households being addressed. In this regard, more research on the factors that influence decision-making and the selection of adaption techniques in vulnerable rural areas are recommended.

Food insecurity intervention mechanisms

Although the government and many other humanitarian agencies have been striving to achieve food security in Ethiopia for several years, very limited long-lasting and substantial achievements have been made to date in the drought-prone rural areas. The inability to exactly understand the food insecurity situation and its associated climate factors, and negligence to critically examine the impact of the food security intervention mechanisms were among the major reasons behind the failure to achieve food security in rural areas of Ethiopia.

Since the 1960s, one of the primary sectors attracting international interventions in Ethiopia has been food security. Ethiopia has been the world's top recipient of food aid. Several international donors, non-governmental organizations, and the United Nations have mostly provided food aid to the affected populations in Ethiopia to respond to their food security conditions.

Many international interventions were found to be responding to humanitarian emergencies, primarily the food shortages, despite the fact that there were interventions aimed at alleviating food insecurity sustainably through financial help. A promising international intervention was

found to assist Ethiopia's rural PSNP, which has been under implementation since 2005. International donors provide funding for the PSNP execution each year in the amount of around half a Billion US Dollars. To attain food security, however, more proactive measures that boost agricultural output and strengthen rural people's resilience to shocks are much needed.

At national level, food security intervention mechanisms include the Food and Nutrition Policy, Food Security Program, Food Security Strategy, and Food Security Pack program. It was found that the Food and Nutrition Policy was sensitive to nutrition, with less focus placed on the most vulnerable rural residents. On the other hand, the primary goal of the Food Security Program, which includes the PSNP, Household Asset Building Program, Complementary Community Investment Program, and Resettlement Program, is to ensure food security for the country's rural households that experience both temporary and chronic food insecurity. Similar to this, the primary focus of the Food Security Strategy is on households that experience chronic food insecurity and reside in pastoral and drought-prone areas. Nonetheless, nutrition was the missing aspect in both Ethiopia's Food Security Strategy and the Food Security Program. As a result, additional work is needed to harmonize the ultimate objectives of the food security intervention mechanisms at the national level.

There was no regional food security policy or program identified in the Tigray region, except the PSNP and a few continuing non-governmental projects. Most significantly, the PSNP office was in charge of regional food security issues. The region lacks a bureau or office dedicated to food security matters. In comparison to previous periods, this indicates a lower level of political commitment on the part of the regional government to address food insecurity sustainably. As such, this shall call for informed consideration to develop a responsive and contextual regional food security policy or incorporate food security into other sectoral plans.

Food assistance and PSNP transfers have been the usual interventions for addressing food security at the community level. The PSNP transfers and food aid were clearly inadequate to address food insecurity. Furthermore, addressing food insecurity in rural areas through food aid is never a sustainable solution. Therefore, by promoting enhanced agricultural and non-agricultural practices and involving rural households, it would be preferable to address the core causes of food insecurity rather than its symptoms.

The rural areas that are vulnerable to drought were often not receiving much attention from the intervention mechanisms. Furthermore, many of the international, national, regional, and community-level interventions did not properly integrate the four pillars of food security. To properly guide efforts to address food insecurity, researchers should provide distinct insights into the effects of the various interventions on food security as well as a critical evaluation of the advantages and disadvantages of the current systems for addressing food security sustainably.

Summing up, the unresolved issues about the universal applicability of the concept of food security are among the main challenges to achieving food security. Besides, the lack of attention to consider these issues in designing the intervention mechanisms contributed to the failure to achieve food security. Thus, first, there has to be a clear and pragmatic concept of food security to deal with the problem. Secondly, it is necessary to well understand the features of food insecurity. Furthermore, the intervention mechanisms intended to achieve food security have to be critically reviewed. These are the starting points to achieve food security in rural areas.

The contemporary concept of food security has complexities in understanding the true extent of the problem which will in turn challenge the task of responding to the problem. The source of the complexity emanates from the lack of clear boundaries in the measurement and aggregation of the four pillars of the concept. Besides, the four pillars of food security are stand-alone concepts that can never be aggregated to describe the food security of a specific area. Thus, it would be very crucial to deconstruct the concept of food security and use these four pillars disjointedly to direct the collective actions of addressing food insecurity more effectively before combining them all to see the changes to food security in drought-prone rural areas.

More importantly, food security in rural and urban areas exhibits two separable situations as the cause and intervention mechanisms for both areas are different. Because of the heavy reliance on precipitation, lower adaptive capacities, and isolation from basic public services (mainly in developing countries), the impact of food insecurity in rural areas is more chronic. In Ethiopia, given the dominant number of villagers with larger family sizes, the problem of food insecurity is more pervasive in rural areas. Since the cause and nature of food insecurity vary from urban to rural areas, and even from rural-to-rural areas, the adoption of site-specific intervention mechanisms is more required to address food insecurity in a sustainable manner.

8.2 Policy Recommendations

This study found that almost all the studied households were experiencing severe food crises. To rectify this situation, an integrated task is much needed now than ever. In addition, the monthly, seasonal, and annual amount of precipitation in the food-insecure rural areas was very insufficient and highly erratic to support sufficient food production practices. Once a drought occurs, the government, including many humanitarian organizations reacts to it by providing food aid. This could not be a long-lasting solution to food insecurity as it heavily relies on fund-raisings and the commitment of different organizations to allocate aid that solves immediate problems only.

Furthermore, the food security intervention mechanisms need to be duly revised to ensure that the food-insecure households living in the drought-prone rural areas are considered appropriately and prevention measures are set in place. Therefore, the following leading suggestions are forwarded to contribute to the improvement of rural households' food security situation in the drought-prone rural areas of Tigray by enhancing their capacity to cope with food crises and adapt to the varying precipitation.

Recommendations related to food insecurity:

- The international community, humanitarian agencies, and federal, regional, and local governments have to instantly respond to the life-threatening children and PLW malnutrition and the general food crises occurring in the study areas.
- Civic societies should advocate for effective and long-lasting response mechanisms for acute malnutrition levels in the affected drought-prone rural areas.
- To meet the current and future food requirements of the food-insecure rural households, governments at all levels should focus on diversifying livelihood strategies, enhancing agricultural (food) production, asset (including livestock) building activities, and resilience-building initiatives.
- The Ministry of Health and Tigray region health bureau have to jointly work on the prevention and treatment of children's and PLW malnutrition.
- To ensure elders and women access to food, the regional government in collaboration with other relevant organizations should work on connecting the remote rural areas to road networks.

Recommendations related to coping and adaptation mechanisms:

- Different local and international organizations working on rural development and related activities should work on building the resilience capacity of rural households to the short and varying precipitation.
- Tigray-based Universities and the Tigray Agricultural Research Institute (TARI) along with relevant stakeholders have to assess opportunities to practice climate-smart farming activities in the food-insecure rural areas of the region.
- Governments at all levels, along with relevant stakeholders should strive to capacitate vulnerable rural farmers' facilities to prudently harvest the limited rainwater and other sources of agricultural water.
- The government and other relevant organizations should exhaustively work on reversing the impacts of meteorological drought and its associated risks of food insecurity by enhancing households' coping and adaptation capacity.
- The Bureau of Agriculture and Rural Development in alliance with Tigray-based Universities should establish a center for weather forecasting to inform vulnerable rural farmers to adapt to the erratic precipitation.

Recommendations related to food security intervention mechanisms:

- Food security actions have to be integrated into national development plans with clear targets and indicators to achieve food security.
- National and regional development plans have to prioritize the attainment of food sufficiency in the vulnerable rural areas.
- National food security policies, strategies, and programs have to ensure that chronically food-insecure rural households in the vulnerable areas are appropriately considered.
- Coordination among key sectors including agriculture, health, education, and water has to be promoted to guide collective actions against hunger.
- The food policies and programs have to consider the precipitation variability and its associated factors while guiding food security interventions in rural areas.

- Federal and regional governments should promote investments in off-farm and non-farm rural farmers' employability in addition to their in-farm activities by linking them to the urban potential markets.
- International organizations should look for sustainable proactive measures to achieve food security along with their emergency responses.
- The federal government of Ethiopia should ensure the effective implementation of food security policies, strategies, and programs by applying a strong monitoring and evaluation system to evaluate its effectiveness.
- The Tigray government should either formulate a specific regional food policy or ensure the integration of food security objectives into the sectoral development plans.
- More importantly, the regional government of Tigray should take lessons from past and present food crises of the region and mobilize resources to sustainably achieve food security in the region.

Overall, achieving food security in rural Tigray requires a gradual, step-by-step approach in which due focus should be given to the food supply aspect. This requires addressing the region's complex challenges, including the lingering effects of recurrent drought, disrupted agricultural systems, and limited access to agricultural resources. To this effect, the suggestions mentioned above must be combined, recognizing that food security in Tigray hinges on addressing basic needs and empowering rural households to feed themselves. Meanwhile, coordination, funding, and local engagement will be the key to their success. By addressing the underlying causes of food insecurity in rural areas, Tigray can build a more resilient and sustainable food system that ensures long-term food security for its people.

REFERENCES

Abebe, B. A., Grum, B., Degu, A. M., and Goitom, H. (2022). Spatio-temporal rainfall variability and trend analysis in the Tekeze-Atbara river basin, northwestern Ethiopia. *Meteorological Applications*, *29*(2), e2059.

Addisu, S., Selassie, Y. G., Fissha, G., and Gedif, B. (2015). Time series trend analysis of temperature and rainfall in lake Tana Sub-basin, Ethiopia. *Environmental Systems Research*, *4*(1), 25.

Adebo, G. M., and Falowo, O. O. (2015). Rural household food security and coping strategies in southwest, Nigeria: A gender differentials perspective. *Food Science and Quality Management*, *41*, 44-50.

Afifi, T., Liwenga, E., and Kwezi, L. (2014). Rainfall-induced crop failure, food insecurity and out-migration in Same-Kilimanjaro, Tanzania. *Climate and Development*, *6*(1), 53-60.

Agarwal, B. (2018). Gender equality, food security and the sustainable development goals. Current opinion in environmental sustainability, 34, 26-32.

Agidew, A. M. A., and Singh, K. N. (2018). Determinants of food insecurity in the rural farm households in South Wollo Zone of Ethiopia: the case of the Teleyayen sub-watershed. *Agricultural and Food Economics*, *6*(1), 10.

Ahmadi Dehrashid, A., Bijani, M., Valizadeh, N., Ahmadi Dehrashid, H., Nasrollahizadeh, B., and Mohammadi, A. (2021). Food security assessment in rural areas: evidence from Iran. *Agriculture and food security*, *10*(1), 17.

Alemayehu, A., and Bewket, W. (2016). Local climate variability and crop production in the central highlands of Ethiopia. *Environmental Development*, *19*, 36-48.

Alhamshry, A., Fenta, A. A., Yasuda, H., Kimura, R., and Shimizu, K. (2020). Seasonal Rainfall Variability in Ethiopia and Its Long-Term Link to Global Sea Surface Temperatures. *Water*, *12*(1), 55.

Alkire, Sabina, Chatterje, Mihika, Conconi, Adriana, Seth, Suman, and Vaz, Ana. (2014). Poverty in Rural and Urban Areas: Direct comparisons using the global MPI 2014.

Ambaw, M. B., Shitaye, G., Taddele, M., and Aderaw, Z. (2021). Level of food consumption score and associated factors among pregnant women at SHEGAW MOTTA hospital, Northwest Ethiopia. *BMC public health*, *21*(1), 1-9.

Anato, A. (2022). Severe acute malnutrition and associated factors among children under-five years: A community based-cross sectional study in Ethiopia. *Heliyon*, *8*(10).

Arbuckle Jr, J. G., Morton, L. W., and Hobbs, J. (2015). Understanding farmer perspectives on climate change adaptation and mitigation: The roles of trust in sources of climate information, climate change beliefs, and perceived risk. *Environment and behavior*, *47*(2), 205-234.

Asesefa Kisi, M., Tamiru, D., Teshome, M. S., Tamiru, M., and Feyissa, G. T. (2018). Household food insecurity and coping strategies among pensioners in Jimma Town, South West Ethiopia. *BMC Public Health*, *18*, 1-8.

Asfaw, A., Simane, B., Hassen, A., and Bantider, A. (2018). Variability and time series trend analysis of rainfall and temperature in northcentral Ethiopia: A case study in Woleka sub-basin. *Weather and climate extremes*, *19*, 29-41.

Asrat, D., and Anteneh, A. (2020). Status of food insecurity in dryland areas of Ethiopia: A review. *Cogent Food and Agriculture*, *6*(1), 1853868.

Asrat, P., and Simane, B. (2018). Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia. *Ecological processes*, *7*(1), 1-13.

Associated Press News (2023). World News: Researchers have verified 1,329 hunger deaths in Ethiopia's Tigray region since the cease-fire there. Available at https://apnews.com/article/ethiopia-tigray-hunger-deaths-aid-6d5a15fa7cda213b86f41c87b1a185e7 Updated 11:33 AM GMT+3, September 26, 2023

Atube, F., Malinga, G. M., Nyeko, M., Okello, D. M., Alarakol, S. P., and Okello-Uma, I. (2021). Determinants of smallholder farmers' adaptation strategies to the effects of climate change: Evidence from northern Uganda. *Agriculture and Food Security*, *10*(1), 1-14.

Awoke, W., Eniyew, K., Agitew, G., and Meseret, B. (2022). Determinants of food security status of household in Central and North Gondar Zone, Ethiopia. *Cogent Social Sciences*, *8*(1), 2040138.

Ayal, D. Y., Getahun, A. B., Ture, K., Zeleke, T. T., and Tesfaye, B. (2023). Climate variability induced household food insecurity coping strategy in Gambella Zuria Woreda, Southwestern, Ethiopia. *Climate Services*, *30*, 100382.

Bahiru, A., Senapathy, M., and Bojago, E. (2023). Status of household food security, its determinants, and coping strategies in the Humbo district, Southern Ethiopia. *Journal of Agriculture and Food Research*, *11*, 100461.

Bahn, R. A., Hwalla, N., and El Labban, S. (2021). Leveraging nutrition for food security: The integration of nutrition in the four pillars of food security. In *Food Security and nutrition* (pp. 1-32). Academic Press.

Bahru, B. A., and Zeller, M. (2022). Gauging the impact of Ethiopia's productive safety net programme on agriculture: Application of targeted maximum likelihood estimation approach. *Journal of Agricultural Economics*, *73*(1), 257-276.

Bahru, B. A., Jebena, M. G., Birner, R., and Zeller, M. (2020). Impact of Ethiopia's productive safety net program on household food security and child nutrition: a marginal structural modeling approach. *SSM-population health*, *12*, 100660.

Bahta, Y. T., and Myeki, V. A. (2021). Adaptation, coping strategies and resilience of agricultural drought in South Africa: implication for the sustainability of livestock sector. *Heliyon*, *7*(11).

Bayable, G., Amare, G., Alemu, G., and Gashaw, T. (2021). Spatiotemporal variability and trends of rainfall and its association with Pacific Ocean Sea surface temperature in West Harerge Zone, Eastern Ethiopia. *Environmental Systems Research*, *10*(1), 1-21.

Beck, H. E., Zimmermann, N. E., McVicar, T. R., Vergopolan, N., Berg, A., and Wood, E. F. (2020). Publisher Correction: Present and future Köppen-Geiger climate classification maps at 1-km resolution. *Scientific data*, *7*.

Belay, A., Recha, J. W., Woldeamanuel, T., and Morton, J. F. (2017). Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agriculture and Food Security*, *6*(1), 1-13.

Berhe, A. G., Misgna, S. H., Abraha, G. G. S., and Abraha, A. Z. (2023). Variability and trend analysis of temperatures, rainfall, and characteristics of crop-growing season in the eastern zone of Tigray region, northern Ethiopia. *Theoretical and Applied Climatology*, *152*(1-2), 25-43.

Berry, P. M., Rounsevell, M. D. A., Harrison, P. A., and Audsley, E. (2006). Assessing the vulnerability of agricultural land use and species to climate change and the role of policy in facilitating adaptation. *Environmental science and policy*, *9*(2), 189-204.

Birhane, T., Shiferaw, S., Hagos, S., and Mohindra, K. S. (2014). Urban food insecurity in the context of high food prices: a community based cross sectional study in Addis Ababa, Ethiopia. *BMC public health*, *14*(1), 680.

Bitew, Z. W., Alemu, A., Ayele, E. G., and Worku, T. (2021). Dietary diversity and practice of pregnant and lactating women in Ethiopia: A systematic review and meta-analysis. *Food Science and Nutrition*, *9*(5), 2686-2702.

Bizikova, L., Jungcurt, S., McDougal, K., and Tyler, S. (2020). How can agricultural interventions enhance contribution to food security and SDG 2.1?. *Global Food Security*, *26*, 100450.

Black, R. E., Levin, C., Walker, N., Chou, D., Liu, L., and Temmerman, M. (2016). Reproductive, maternal, newborn, and child health: key messages from disease control priorities 3rd edition. *The Lancet*, *388*(10061), 2811-2824.

Bommaiah, K., SV, S., and Dechamma, S. (2020). Adaptation strategies by paddy-growing farmers to mitigate the climate crisis in Hyderabad-Karnataka region of Karnataka state, India. *International Journal of Climate Change Strategies and Management*, *12*(5), 541-556.

Bowbrick, P. (2022). Entitlement and food availability decline (FAD)–the use of fraud and abuse in famine economics. MPRA Paper No. 115162.

Braun, Joachim von (2007). *Rural-urban linkages for growth, employment, and poverty reduction.* International Conference on Ethiopian Economy, Addis Ababa, 7-9 June 2007, 1-21.

Brelle, F. (2016). How Do Irrigation and Drainage Interventions Secure Food Production and Livelihood for Rural Communities? *Irrigation and drainage*, *65*(2), 210-213.

Carletto, C., Zezza, A., and Banerjee, R. (2013). Towards better measurement of household food security: Harmonizing indicators and the role of household surveys. *Global food security*, *2*(1), 30-40.

Carr, E. R. (2006). Postmodern conceptualizations, modernist applications: Rethinking the role of society in food security. *Food Policy*, *31*(1), 14-29.

Chalmers, A. F. (2013). *What is this thing called science?* Hackett Publishing.

Chambers, R. (1988). Sustainable livelihoods, environment and development: putting poor rural people first. Available at https://opendocs.ids.ac.uk/articles/report/Sustainable_livelihoods_environment_and_development_putting_poor_rural_people_first/26446072/1/files/48094432.pdf

Clay, E. (2002). Food security: concepts and measurement. *Trade reforms and food security: conceptualizing the linkages*, Rome, 11-12 July, 2002, 25-34.

Coates, J. (2004). Experience and Expression of Food Insecurity Across Cultures: Practical Implications for Valid Measurement. Washington, D.C.: Food and Nutrition Technical Assistance Project, Academy for Educational Development

Coates, J. (2013). Build it back better: Deconstructing food security for improved measurement and action. *Global Food Security*, *2*(3), 188-194.

Cohen, M. J., and Garrett, J. L. (2010). The food price crisis and urban food (in) security. *Environment and Urbanization*, *22*(2), 467-482.

Coll-Black, S., Gilligan, D. O., Hoddinott, J., Kumar, N., Taffesse, A. S., and Wiseman, W. (2013). Targeting food security interventions: The case of Ethiopia's productive safety net programme. *ESSP Res Note*, *26*, 1-2.

Cook, K. H., Fitzpatrick, R. G., Liu, W., and Vizy, E. K. (2020). Seasonal asymmetry of equatorial East African rainfall projections: understanding differences between the response of the long rains and the short rains to increased greenhouse gases. *Climate Dynamics*, *55*(7), 1759-1777.

Cordonnier, V., Covarrubias, K. A., and De la O Campos, A. P. (2022). Agricultural interventions and food security in Ethiopia–What is the role of adjusting livelihood strategies? FAO Agricultural Development Economics Working Paper, No. 22-23.

CSA (2017). 2016 Ethiopia Demographic and Health Survey: Key Findings. Addis Ababa, Ethiopia, and Rockville, Maryland, USA. CSA and ICF.

Darwin, Roy (2001). Climate change and food security. *Agriculture information bulletin*, *765*(8), 1-2.

Dasmani, I., Darfor, K. N., and Karakara, A. A. W. (2020). Farmers' choice of adaptation strategies towards weather variability: Empirical evidence from the three agro-ecological zones in Ghana. *Cogent Social Sciences*, *6*(1), 1751531.

Degefu, M. A., Rowell, D. P., and Bewket, W. (2017). Teleconnections between Ethiopian rainfall variability and global SSTs: observations and methods for model evaluation. *Meteorology and Atmospheric Physics*, *129*(2), 173-186.

Del Ninno, C., Dorosh, P. A., and Subbarao, K. (2005). *Food aid and food security in the short and long run: Country experience from Asia and sub-Saharan Africa*. World Bank.

Demeke, A. B., Keil, A., and Zeller, M. (2011). Using panel data to estimate the effect of rainfall shocks on smallholders food security and vulnerability in rural Ethiopia. *Climatic change*, *108*(1-2), 185-206.

Demem, M. S. (2023). Impact and adaptation of climate variability and change on small-holders and agriculture in Ethiopia: A review. *Heliyon*.

Demsash, A. W., Emanu, M. D., and Walle, A. D. (2023). Exploring spatial patterns, and identifying factors associated with insufficient cash or food received from a productive safety net program among eligible households in Ethiopia: a spatial and multilevel analysis as an input for international food aid programmers. *BMC Public Health*, *23*(1), 1141.

Deressa, T. T., Hassan, R. M., Ringler, C., Alemu, T., and Yesuf, M. (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global environmental change*, *19*(2), 248-255.

Desalegn, G., and Ali, S. N. (2018). Review of the impact of productive safety net program (PSNP) on rural welfare in Ethiopia. ZEF Working Paper Series 173, Center for Development Research, University of Bonn.

Destaw, F., and Fenta, M. (2021). Climate change adaptation strategies and their predictors amongst rural farmers in Ambassel district, Northern Ethiopia. *Jàmbá: Journal of Disaster Risk Studies*, *13*(1), 1-11.

Devereux, S. (2000). *Food insecurity in Ethiopia*. A discussion paper for DFID. Institute for Development Studies*, Sussex*.

Dile, Y. T., and Srinivasan, R. (2014). Evaluation of CFSR climate data for hydrologic prediction in data-scarce watersheds: an application in the Blue Nile River Basin. *JAWRA Journal of the American Water Resources Association*, *50*(5), 1226-1241.

Dittus, A. J., Karoly, D. J., Donat, M. G., Lewis, S. C., and Alexander, L. V. (2018). Understanding the role of sea surface temperature-forcing for variability in global temperature and precipitation extremes. *Weather and climate extremes*, *21*, 1-9.

Dlamini, S. N., Craig, A., Mtintsilana, A., Malanga, W., Du Toot, J., Ware, L. J., and Norris, S. A. (2023). Food insecurity and coping strategies and their association with anxiety and depression: a nationally representative South African survey. *Public Health Nutrition*, *26*(4), 705-715.

Doustmohammadian, A., Mohammadi-Nasrabadi, F., Keshavarz-Mohammadi, N., Hajjar, M., Alibeyk, S., and Hajigholam-Saryazdi, M. (2022). Community-based participatory interventions to improve food security: A systematic review. *Frontiers in nutrition*, *9*, 1028394.

Dreze, J., & Sen, A. (1990). Hunger and public action. Clarendon Press.

Drysdale, R. E., Moshabela, M., and Bob, U. (2019). Adapting the Coping Strategies Index to measure food insecurity in the rural district of iLembe, South Africa. *Food, Culture and Society, 22*(1), 95-110.

Dubache, G., Ogwang, B. A., Ongoma, V., and Islam, A. R. M. T. (2019). The effect of Indian Ocean on Ethiopian seasonal rainfall. *Meteorology and Atmospheric Physics*, *131*(6), 1753-1761.
Durao, S., Visser, M. E., Ramokolo, V., Oliveira, J. M., Schmidt, B. M., Balakrishna, Y., ... and Schoonees, A. (2020). Community-level interventions for improving access to food in low-and middle-income countries. *Cochrane Database of Systematic Reviews*, (7).

Endalew, B., Muche, M., and Tadesse, S. (2015). Assessment of food security situation in Ethiopia: A Review. *Asian Journal of Agricultural Research*, *9*(2), 55-68.

Eshetu, F., and Guye, A. (2021). Determinants of households vulnerability to food insecurity: evidence from Southern Ethiopia. *Journal of Land and Rural Studies*, *9*(1), 35-61.

Etana, D., and Tolossa, D. (2017). Unemployment and food insecurity in urban Ethiopia. *African Development Review*, *29*(1), 56-68.

FAO (1983). *World Food Security: A Reappraisal of the Concepts and Approaches*. Director Generals Report, Rome.

FAO (1986). *Irrigation Water Management: Irrigation Water Needs*. Tranining Manual no. 3. FAO, Rome.

FAO (1996). *Rome Declaration on World Food Security and World Food Summit Plan of Action*. World Food Summit 13-17 November 1996. Rome.

FAO (2000). *The causes of food insecurity in rural areas*. Retrieved from http://www.fao.org/3/x8406e/X8406e02.htm on April 18, 2019.

FAO (2002). *The State of Food Insecurity in the World 2001*. FAO, Rome, Italy.

FAO (2005). *Insurance of crops in developing countries*. FAO, Rome, Italy.

FAO (2008). *An introduction to the basic concepts of food security.* FAO, Rome, Italy.

FAO (2009). *Food Security Information for Action: Food Security Policies Formulation and Implementation*. Lesson 1: Establishment of a food security policy framework. FAO, Rome, Italy.

FAO (2015). *Information systems for Food Security and Nutrition*: Food and Agriculture Organization of the United States. Rome, Italy.

FAO (2017). *Rural areas, too long seen as poverty traps, key to economic growth in developing countries*. Retrieved from http://www.fao.org/news/story/en/item/1042091/icode/ on April 17, 2019.

FAO (2018). *Ending Extreme Poverty in Rural Areas: Sustaining livelihoods to leave no one behind*. Food and Agricultural Organization of the United Nations, Rome.

FAO (2023). *FAOSTAT: Suite of Food Security Indicators*. Food and Agricultural Organization of the United Nations, Rome.

FAO (2024). *FAO in Ethiopia: programs and projects*. Retrieved from https://www.fao.org/ethiopia/programmes-and-projects/fr/ on February 13, 2024.

FAO, IFAD, UNICEF, WFP and WHO (2023). *The State of Food Security and Nutrition in the World 2023. Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum*. FAO, Rome.

FAO, IFAD, UNICEF, WFP and WHO (2024). *The State of Food Security and Nutrition in the World 2024. Financing to end hunger, food insecurity and malnutrition in all its forms*. FAO, Rome.

FDRE (2002). *Food Security Strategy*. Federal Democratic Republic of Ethiopia. Addis Ababa.

FDRE (2018). *Food and Nutrition Policy of Ethiopia*. Federal Democratic Republic of Ethiopia, Addis Ababa.

Fentaw, A. E., Yimer, A. A., & Zeleke, G. A. (2023). Monitoring spatio-temporal drought dynamics using multiple indices in the dry land of the upper Tekeze Basin, Ethiopia. Environmental Challenges, 13, 100781.

Fite, M. B., Tura, A. K., Yadeta, T. A., Oljira, L., and Roba, K. T. (2022). Factors associated with food consumption score among pregnant women in Eastern Ethiopia: a community-based study. *Journal of Health, Population and Nutrition*, *41*(1), 6.

FSIN and GNAFC (2024). *Global Report on Food Crisis 2024*. Rome. Available at https://www.fsinplatform.org/grfc2024

Fuka, D. R., Walter, M. T., MacAlister, C., Degaetano, A. T., Steenhuis, T. S., and Easton, Z. M. (2014). Using the Climate Forecast System Reanalysis as weather input data for watershed models. *Hydrological Processes, 28*(22), 5613-5623.

Furtado, X., and Smith, J. (2007). *Ethiopia: Aid, ownership, and sovereignty* (No. 2007/28). GEG Working Paper. The Global Economic Governance Program University College, Oxford.

GAFSP (2022). Agricultural Growth program (AGP – I). Retrieved from https://www.gafspfund.org/projects/agricultural-growth-program-agp-i on February 14, 2024.

Gebre, B., Ayenew, H. Y., and Biadgilign, S. (2021). Drought, hunger and coping mechanisms among rural household in Southeast Ethiopia. *Heliyon, 7*(3).

Gebre, T., Abraha, Z., Zenebe, A., and Zeweld, W. (2024). Precipitation variability and its teleconnection with the global SST and ENSO indices in the food-insecure rural areas of Tigray. *Theoretical and Applied Climatology*, *155*(3), 1699-1711.

Gebre, T., and Gebremedhin, B. (2019). The mutual benefits of promoting rural-urban interdependence through linked ecosystem services. *Global Ecology and Conservation*, *20*, e00707.

Gebrehiwot, T., and Van Der Veen, A. (2013). Farm level adaptation to climate change: the case of farmer's in the Ethiopian Highlands. *Environmental management*, *52*(1), 29-44.

Gebru, G. W., Ichoku, H. E., and Phil-Eze, P. O. (2020). Determinants of smallholder farmers' adoption of adaptation strategies to climate change in Eastern Tigray National Regional State of Ethiopia. *Heliyon*, *6*(7).

Gebru, T. A. (2020). Rainfall Intensity-Duration-Frequency Relations under Changing Climate for Selected Stations in the Tigray Region, Ethiopia. *Journal of Hydrologic Engineering*, *25*(11), 05020041.

Getaneh, Y., Alemu, A., Ganewo, Z., and Haile, A. (2022). Food security status and determinants in North-Eastern rift valley of Ethiopia. *Journal of Agriculture and Food Research*, *8*, 100290.

Ghimire, U., Aryal, B. K., Gupta, A. K., and Sapkota, S. (2020). Severe acute malnutrition and its associated factors among children under-five years: a facility-based cross-sectional study. *BMC pediatrics*, *20*(1), 1-9.

Gibson, M. (2012). Food Security: A Commentary: What Is It and Why Is It So Complicated? *Foods*, *1*(1), 18-27.

Global Economy (2023). Foreign aid - country rankings. Retrieved from https://www.theglobaleconomy.com/rankings/foreign_aid/ on February 12, 2024.

Global Food Security index (2022). Ethiopia country report. Retrieved from https://impact.economist.com/sustainability/project/food-security-index/explore countries/ethiopia on January 05, 2023.

Global Hunger Index (2023). Ethiopia. Retrieved from https://www.globalhungerindex.org/ethiopia.html on November 17, 2023.

Gobie, B. G., and Miheretu, B. A. (2021). Effects of El Nino southern oscillation events on rainfall variability over northeast Ethiopia. *Modeling Earth Systems and Environment*, 1-7.

Grigorieva, E., Livenets, A., and Stelmakh, E. (2023). Adaptation of Agriculture to Climate Change: A Scoping Review. *Climate*, *11*(10), 202.

Guerrero, N., Walsh, M. C., Malecki, K. C., and Nieto, F. J. (2014). Urban-rural and regional variability in the prevalence of food insecurity: the survey of the health of Wisconsin. *WMJ: official publication of the State Medical Society of Wisconsin*, *113*(4), 133.

Haftom, H., Haftu, A., Goitom, K., and Meseret, H. (2019). Agroclimatic zonation of Tigray region of Ethiopia based on aridity index and traditional agro-climatic zones. *Journal of Agrometeorology*, *21*(2), 176-181.

Haile, Menghestab. (2005). Weather patterns, food security and humanitarian response in sub-Saharan Africa. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *360*(1463), 2169-2182.

Haji, M. A., and Mumed, A. A. (2023). Impact of Productive Safety Net Program on Rural Household Food Security in Somali Regional State: A Case of Kebri Dehar District, Ethiopia. *Journal of Environmental Issues and Climate Change*, *2*(1), 78-90.

Hayelom, B., Chen, Y., Marsie, Z., and Negash, M. (2017). Temperature and precipitation trend analysis over the last 30 years in Southern Tigray Regional State, Ethiopia.
Helland, J., and Sørbø, G. M. (2014). Food securities and social conflict. *CMI Report*.

Hirvonen, K., and Hoddinott, J. (2021). Beneficiary views on cash and in-kind payments: Evidence from Ethiopia's Productive Safety Net Programme. *The World Bank Economic Review*, *35*(2), 398-413.

Hishe, S., Lyimo, J., and Bewket, W. (2017). Effects of soil and water conservation on vegetation cover: a remote sensing based study in the Middle Suluh River Basin, northern Ethiopia. *Environmental Systems Research*, *6*, 1-16.

Holman, I. P., Hess, T. M., Rey, D., and Knox, J. W. (2021). A multi-level framework for adaptation to drought within temperate agriculture. *Frontiers in Environmental Science*, *8*, 589871.

Howard, Ebenezer. (2013). *Garden cities of to-morrow*: Routledge.

IDEP (2023). Building Blocks for Diet-related Food Security Analysis, Version 2.0. Tufts University, Boston, MA.

IED (2019). Agricultural growth program implementation completion report. Independent evaluation group. Report Number: ICRR0021055

Jateno, W., Alemu, B. A., and Shete, M. (2023). Household dietary diversity across regions in Ethiopia: Evidence from Ethiopian socio-economic survey data. *Plos one*, *18*(4), e0283496.

Jha, R. (2019). Introduction: Hunger and Malnutrition as Major Challenges in the 21st Century. In *Hunger and Malnutrition as Major Challenges of the 21st Century* (pp. 3-33).

Kabeta, T., Holst, R., Wondafrash, B., Frigessi, A., and Gebremariam, M. K. (2023). Determinants of household dietary diversity in rural Ethiopia: A household panel study. *Journal of Agriculture and Food Research*, *12*, 100550.

Kahsay, H. T., Guta, D. D., Birhanu, B. S., and Gidey, T. G. (2019). Farmers' perceptions of climate change trends and adaptation strategies in semiarid highlands of Eastern Tigray, Northern Ethiopia. *Advances in Meteorology*, *2019*.
Kasie, T. A., Demissie, B. S., Bahry, M. J., Gessesse, G. M., and Wale, L. E. (2019). The impact of the 2015 El Niño-induced drought on household consumption: evidence from rural Ethiopia. *Climate and Development*, 1-10.

Kendall, M.G. (1975). Rank Correlation Methods, 4th edition, Charles Griffin, London.

Kennedy, G., Ballard, T., and Dop, M. C. (2011). *Guidelines for measuring household and individual dietary diversity*. Food and Agriculture Organization of the United Nations.

Kinda, S. R., and Badolo, F. (2019). Does rainfall variability matter for food security in developing countries? *Cogent Economics and Finance*, *7*(1), 1640098.

Knippenberg, E and J. Hoddinott (2017). *Shocks, social protection, and resilience: Evidence from Ethiopia*, Strategy Support Program Working Paper 109, IFPRI/EDRI, Addis Ababa, August.

Labeyrie, V., Renard, D., Aumeeruddy-Thomas, Y., Benyei, P., Caillon, S., Calvet-Mir, L., ... and Reyes-García, V. (2021). The role of crop diversity in climate change adaptation: Insights from local observations to inform decision making in agriculture. *Current Opinion in Environmental Sustainability*, *51*, 15-23.

Lemi, A. (2007). Anatomy of Foreign Aid to Ethiopia: 1960-2003. *Economics Faculty Publication Series*. 13. Available at: https://scholarworks.umb.edu/econ_faculty_pubs/13.

Lewis, K. (2017). Understanding climate as a driver of food insecurity in Ethiopia. *Climatic Change*, *144*(2), 317-328.

Li, X., Yang, Y., Poon, J., Liu, Y., and Liu, H. (2018). Anti-drought measures and their effectiveness: A study of farmers' actions and government support in China. *Ecological indicators*, *87*, 285-295.

Lindsey, R. (2009). Climate variability: Oceanic niño index. News and Features, retrieved from https://www.climate.gov/news-features/understandingclimate/climate-variability-oceanic-niño-index on June 15, 2019.

Locke, Hugh. (2017). Smallholder Farmers Are The New Global Food Frontier. Retrieved from https://www.huffingtonpost.com/hugh-locke/smallholder-farmers-are-t_b_7865848.html

Looby, E. L. (2019). *Late Holocene Climate Change in the Tigray Plateau, Ethiopia*. Doctoral dissertation, The University of Utah.

Magesa, B. A., Mohan, G., Matsuda, H., Melts, I., Kefi, M., and Fukushi, K. (2023). Understanding the farmers' choices and adoption of adaptation strategies, and plans to climate change impact in Africa: A systematic review. *Climate Services*, *30*, 100362.

Manikas, I., Ali, B. M., and Sundarakani, B. (2023). A systematic literature review of indicators measuring food security. *Agriculture and Food Security*, *12*(1), 10.

Mann, H. B. (1945). *Econometrica*: Nonparametric tests against trend. *Journal of the econometric society*, 245-259.

Maxwell, D., Vaitla, B., Tesfay, G. and Abadi, N. (2013). *Resilience, Food Security Dynamics, and Poverty Traps in Northern Ethiopia: Analysis of a Biannual Panel Dataset, 2011-2013*. Feinstein International Centre, Tufts University, USA.

Maxwell, D., Watkins, B., Wheeler, R., and Collins, G. (2003). The coping strategies index: A tool for rapidly measuring food security and the impact of food aid programs in emergencies.

Nairobi: CARE Eastern and Central Africa Regional Management Unit and the World Food Programme Vulnerability Assessment and Mapping Unit.

Maxwell, S. (1996). Food security: a post-modern perspective. *Food policy*, *21*(2), 155-170.

Maxwell, S., and Smith, M. (1992). Household food security: a conceptual review. *Household food security: Concepts, indicators, measurements*, 1-72.

Mayo-Wilson, E., Imdad, A., Herzer, K., Yakoob, M. Y., and Bhutta, Z. A. (2011). Vitamin A supplements for preventing mortality, illness, and blindness in children aged under 5: systematic review and meta-analysis. *Bmj*, *343*.

McClain-Nhlapo, C. (2004). Implementing a human rights approach to food security. 2020 Africa Conference Brief; Issue Brief. 13; 29. Available at https://hdl.handle.net/10568/155997

MCDSS (2021). Food Security Pack (FSP) program. Ministry of Community Development and Social Services, Addis Ababa.

Mekonnen, D. A., and Gerber, N. (2017). Aspirations and food security in rural Ethiopia. *Food security*, *9*(2), 371-385.

Melese, M., Tilahun, M., and Alemu, M. (2021). Household food insecurity and coping strategies in Southern Ethiopia. *Agriculture and Food Security*, *10*, 1-12.

Ministry of Agriculture (2020). PSNP: General Program Implementation Manual. Ministry of Agriculture, Addis Ababa.

Ministry of Agriculture and Rural Development (2009). Food Security Program of Ethiopia (2010-2014). Addis Ababa, Ethiopia.

Mock, Nancy, Morrow, Nathan, and Papendieck, Adam. (2013). From complexity to food security decision-support: Novel methods of assessment and their role in enhancing the timeliness and relevance of food and nutrition security information. *Global Food Security, 2*(1), 41-49.

Mohamed, Abduselam Abdulahi. (2017). Food security situation in Ethiopia: a review study. *International Journal of Health Economy Policy, 2*(3), 86-96.

Molla, M. (2020). Teleconnections between Ocean-Atmosphere Coupled Phenomenon and Droughts in Tigray Region: Northern Ethiopia. *American Journal of Climate Change, 9*(3), 274-296.

Moroda, G. T., Tolossa, D., and Semie, N. (2018). Food insecurity of rural households in Boset district of Ethiopia: a suite of indicators analysis. *Agriculture and Food Security*, *7*(1), 65.

MoUH (2016). Urban Productive Safety Net Program implementation manual. Ministry of Urban Development and Housing, Addis Ababa.

Mulugeta, A., and Gebregziabher, M. (2022). Saving children from man-made acute malnutrition in Tigray, Ethiopia: a call to action. *The Lancet Global Health*, *10*(4), e469-e470.

Muluneh, M. G. (2021). Impact of climate change on biodiversity and food security: a global perspective—a review article. *Agriculture and Food Security*, *10*(1), 1-25.

Munro, R. N., Woldegerima, T., Hailu, B., Zenebe, A., Gebremedhin, Z., Hailemichael, A., and Nyssen, J. (2019). A history of soil and water conservation in Tigray. *Geo-trekking in Ethiopia's Tropical Mountains: The Dogu'a Tembien District*, 477-493. Springer Nature. Cham, Switzerland.

Mustafa, N. M., Asfaw, F. F., Endris, E. A., and Bojago, E. (2023). Evaluating the impact of productive safety net program on rural household food security achievement: Endogenous switching regression model. *Journal of Agriculture and Food Research*, 14, 100674.

Nagesso, H., Ayele, T., and Nigussie, B. (2019). Accessibility of Rural Public Infrastructures and Food Security among Rural Households in Kersa District, South Western Ethiopia. *Research and Science Today*, (1), 45-59.

Nakamura, S., Bundervoet, T., and Nuru, M. (2020). Rural roads, poverty, and resilience: Evidence from Ethiopia. *The Journal of Development Studies*, *56*(10), 1838-1855.

Nakasone, E., and Torero, M. (2016). A text message away: ICTs as a tool to improve food security. *Agricultural Economics*, *47*(S1), 49-59.

Napoli, M., De Muro, P., and Mazziotta, M. (2011). Towards a food insecurity multidimensional index. Master Thesis. Universita Deglistudi. Available at *https://pdfs.semanticscholar.org/e37d/ad6f2c3e6d3f159ab68e6c7867b3ea3034ad.pdf*

National Drought Mitigation Center (2024). Types of Drought. University of Nebraska-Lincoln. Available at https://drought.unl.edu/Education/DroughtIn-depth/TypesofDrought.aspx

National Institute of Building Sciences (2019). Mitigation Saves: Federal Grants Provide a $6 Benefit for Each $1 Invested. Retrieved from https://www.google.com/url?sa=tandrct=jandq=andesrc=sandsource=webandcd=andcad=rjaanduact=8andved=2ahUKEwjnkrq7sqqEAxUyU6QEHVYSCpMQFnoECBcQAQandurl=https%3A%2F%2Fwww.nibs.org%2Ffiles%2Fpdfs%2Fms_v3_federalgrants.pdfandusg=AOvVaw3zHUCXZHjZbzEuPieuF6HYandopi=89978449 on March 11, 2024.

Neela, S., and Fanta, S. W. (2020). Injera (An ethnic, traditional staple food of Ethiopia): A review on traditional practice to scientific developments. *Journal of Ethnic Foods*, *7*(1), 32.

Negash, T., and Alemu, S. (2013). Determinants and coping strategies of household food insecurity in rural areas of Tigray: The case of rural Adwa Woreda. *Ethiopian Journal of Agricultural Sciences*, *23*(1-2), 119-144.

Negesse, A., Jara, D., Temesgen, H., Dessie, G., Getaneh, T., Mulugeta, H., ... and Negesse, Y. (2020). The impact of being of the female gender for household head on the prevalence of food insecurity in Ethiopia: a systematic-review and meta-analysis. *Public Health Reviews*, *41*(1), 1-14.

Neglo, K. A. W., Gebrekidan, T., and Lyu, K. (2021). The Role of agriculture and non-farm economy in addressing food insecurity in Ethiopia: A Review. *Sustainability*, *13*(7), 3874.

Nisbet, C., Lestrat, K. E., and Vatanparast, H. (2022). Food security interventions among refugees around the globe: a scoping review. *Nutrients*, *14*(3), 522.

Nord, M. (2000). Does it cost less to live in rural areas? Evidence from new data on food security and hunger. *Rural Sociology*, *65*(1), 104-125.

OCHA (2024). Ethiopia. Situation report. Retrieved from https://reports.unocha.org/en/country/ethiopia/ on February 14, 2024.

Ogundeji, A. A., and Okolie, C. C. (2022). Perception and adaptation strategies of smallholder farmers to drought risk: a scientometric analysis. *Agriculture*, *12*(8), 1129.

Ongoma, V., Chen, H., and Gao, C. (2018). Projected changes in mean rainfall and temperature over East Africa based on CMIP5 models. *International Journal of Climatology*, *38*(3), 1375-1392.

Onyutha, C., Tabari, H., Taye, M. T., Nyandwaro, G. N., and Willems, P. (2016). Analyses of rainfall trends in the Nile River Basin. *Journal of Hydro-Environment Research*, *13*, 36-51.

Oxfam (2024). Oxfam warns of growing hunger crisis in Tigray and Amhara regions as families resort to extreme measures to survive. Press releases. Available at https://www.oxfam.org/en/press-releases/oxfam-warns-growing-hunger-crisis-tigray-and-amhara-regions-families-resort-extreme

Pateman, T. (2011). Rural and urban areas: comparing lives using rural/urban classifications. *Regional trends*, *43*(1), 11-86.

Philip, S., Kew, S. F., Jan van Oldenborgh, G., Otto, F., O'Keefe, S., Haustein, K., ... and Cullen, H. (2018). Attribution analysis of the Ethiopian drought of 2015. *Journal of Climate*, *31*(6), 2465-2486.

Pinstrup-Andersen, Per. (2009). Food security: definition and measurement. *Food security*, *1*(1), 5-7.

Plecher, H. (2020). Sub-Saharan Africa: Gross domestic product (GDP) per capita in current prices from 2014 to 2024. Retrieved from https://www.statista.com/statistics/805567/gross-domestic-product-gdp-per-capita-in-sub-saharan-africa/ on July 31, 2020.

Purdie, E., Diehl, A. and Iimi, A. (2016). On the road to sustainable growth: measuring access for rural populations. World Bank blogs. Available at https://blogs.worldbank.org/en/opendata/road-sustainable-growth-measuring-access-rural-populations-0

Rahut, D. B., Aryal, J. P., Manchanda, N., and Sonobe, T. (2022). Chapter 6-Expectations for household food security in the coming decades: A global scenario. Editor (s): Bhat, R. Future Foods.

Ranganathan, T., Mishra, A. K., and Kumar, A. (2018). *Crop insurance and food security: evidence from rice farmers in Eastern India* (No. 2172-2018-8200). A conference paper, Agricultural and Applied Economics Association, Allied Social Sciences Association Annual Meeting, January 4-6, 2019, Atlanta, Georgia.

Regasa Megerssa, G., Negash, R., Bekele, A. E., and Nemera, D. B. (2020). Smallholder market participation and its associated factors: Evidence from Ethiopian vegetable producers. *Cogent Food and Agriculture*, *6*(1), 1783173.

Reid, K. (2018). 1980s Ethiopian Famine: Facts, FAQs, and how to help. World Vision, Ethiopia.

Roberfroid, D., Hammami, N., Mehta, P., Lachat, C., Verstraeten, R., Weise Prinzo, Z., ... and Kolsteren, P. (2013). Management of oedematous malnutrition in infants and children aged> 6 months: a systematic review of the evidence.

Roberts, M., Tolar-Peterson, T., Reynolds, A., Wall, C., Reeder, N., and Rico Mendez, G. (2022). The effects of nutritional interventions on the cognitive development of preschool-age children: A systematic review. *Nutrients*, *14*(3), 532.

Robeyns, I. (2005). The capability approach: a theoretical survey. Journal of human development, 6(1), 93-117.

Sabates-Wheeler, R., Hirvonen, K., Lind, J., and Hoddinott, J. (2022). Expanding social protection coverage with humanitarian aid: Lessons on targeting and transfer values from Ethiopia. *The Journal of Development Studies*, *58*(10), 1981-2000.

Saleth, R. M., and Dinar, A. (2009). The impact of multiple policy interventions on food security. *Journal of Policy Modeling*, *31*(6), 923-938.

Sani, S., and Kemaw, B. (2019). Analysis of households food insecurity and its coping mechanisms in Western Ethiopia. *Agricultural and food economics*, *7*(1), 5.

Schmidhuber, Josef, and Tubiello, Francesco N. (2007). Global food security under climate change. *Proceedings of the National Academy of Sciences*, *104*(50), 19703-19708.

Schmidt, E., Dorosh, P. A., Kedir Jemal, M., and Smart, J. (2020). Urbanization and structural transformation. *Ethiopia's agrifood system: Past trends, present challenges, and future scenarios*, 379.

Schwei, R. J., Tesfay, H., Asfaw, F., Jogo, W., and Busse, H. (2017). Household dietary diversity, vitamin A consumption and food security in rural Tigray, Ethiopia. *Public health nutrition*, *20*(9), 1540-1547.

Seleshi, Yilma, and Demaree, GR. (1995). Rainfall variability in the Ethiopian and Eritrean highlands and its links with the Southern Oscillation Index. *Journal of Biogeography*, 945-952.

Sen, A. (1982). Poverty and famines: an essay on entitlement and deprivation. Oxford university press.

Sewnet, Y. (2015). Causes and coping mechanisms of food insecurity in rural Ethiopia. *Agricultural and Biology Journal of North America*, *6*(5), 123-133.

Shaw, D. J. (2007). World food security: A History since 1945. Palgrave Macmillan, New York.

Shaw, D. J., and Clay, E. J. (1998). Global hunger and food security after the World Food Summit. *Canadian Journal of Development Studies*, *19*(4), 55-76.

Shiferaw, H., Girma, A., Hadush, K., Mariam, H. G., Yazew, E., and Zenebe, A. (2023). Long-term hydroclimatic variability over the semi-arid Ethiopian highlands in relation to ENSO and IOD teleconnection signals. *Theoretical and Applied Climatology*, 1-19.

Siders, A. R., and Pierce, A. L. (2021). Deciding how to make climate change adaptation decisions. *Current Opinion in Environmental Sustainability*, *52*, 1-8.

Sileshi, M., Sieber, S., Lejissa, T., and Ndyetabula, D. W. (2023). Drivers of rural households' food insecurity in Ethiopia: a comprehensive approach of calorie intake and food consumption score. *Agrekon*, *62*(2), 152-163.

Singh, R., Worku, M., Bogale, S., Cullis, A., Adem, A., Irwin, B., Lim, S., Bosi, L., and Venton, C. C. (2016). Reality of resilience: Perspectives of the 2015-16 drought in Ethiopia. *BRACED Resilience Intel*, (6), 1-28.

Stoddard, A., Harvey, P., Czwarno, M., and Breckenridge, M. J. (2021). Humanitarian access SCORE report: Tigray, Ethiopia. *Survey on the coverage, operational reach, and effectiveness of humanitarian aid. Humanitarian Outcomes*. Retrieved from https://humanitarianoutcomes.org/sites/default/files/publications/score_tigray_report_2021_v2.pdf on April 03, 2024.

Sun, Y., Liu, B., Rong, S., Du, Y., Xu, G., Snetselaar, L. G., ... and Bao, W. (2020). Food insecurity is associated with cardiovascular and all-cause mortality among adults in the United States. *Journal of the American Heart Association*, *9*(19), e014629.

Survey Monkey (2019). Sample Size Calculator. Retrieved from https://www.surveymonkey.com/mp/sample-size-calculator/ on January 26, 2019.

Suryabhagavan, K. V. (2017). GIS-based climate variability and drought characterization in Ethiopia over three decades. *Weather and climate extremes*, *15*, 11-23.

Swindale, A. and Bilinsky, P. (2006). Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access: Indicator Guide (Version 2). Washington, D.C.: Food and Nutrition Technical Assistance Project, Academy for Educational Development.

Tadesse, T., and Gebremedhin Zeleke, T. (2022). The impact of the productive safety net program (PSNP) on food security and asset accumulation of rural households': evidence from Gedeo zone, Southern Ethiopia. *Cogent Economics and Finance*, *10*(1), 2087285.

Tang, Y., Zhang, R. H., Liu, T., Duan, W., Yang, D., Zheng, F., ... and Mu, M. (2018). Progress in ENSO prediction and predictability study. *National Science Review*, *5*(6), 826-839.

Tefera, A. S., Ayoade, J. O., and Bello, N. J. (2020). Analyses of the relationship between drought occurrences and their causal factors in Tigray Region, Northern Ethiopia. *Tellus A: Dynamic Meteorology and Oceanography*, *72*(1), 1-18.

Teklewold, H., Gebrehiwot, T., and Bezabih, M. (2019). Climate smart agricultural practices and gender differentiated nutrition outcome: An empirical evidence from Ethiopia. *World Development*, *122*, 38-53.

Teklewold, H., Mekonnen, A., and Kohlin, G. (2019). Climate change adaptation: a study of multiple climate-smart practices in the Nile Basin of Ethiopia. *Climate and Development*, *11*(2), 180-192.

Tigray Region Productive Safety Net Program (PSNP) Office (2019). Periodic report. PSNP, Mekelle, Ethiopia.

Tigray Region Productive Safety Net Program (PSNP) Office (2024). Periodic report. PSNP, Mekelle, Ethiopia.

Tomayko, E. J., Mosso, K. L., Cronin, K. A., Carmichael, L., Kim, K., Parker, T., ... and Adams, A. K. (2017). Household food insecurity and dietary patterns in rural and urban American Indian families with young children. *BMC Public Health*, *17*(1), 611.

Tora, T. T. (2023). Reviewing the deployment of multiple indicators at micro-level food in/security investigations in Eastern Africa: Evidence from Ethiopia. *Cogent Social Sciences*, *9*(2), 2267742.

Torres, M., Howitt, R., and Rodrigues, L. (2019). Analyzing Rainfall Effects on Agricultural Income: Why Timing Matters. *EconomiA*, Article in press.

Trading Economics (2023). Ethiopia: Age dependency ratio. Retrieved from https://tradingeconomics.com/ethiopia/age-dependency-ratio-percent-of-working-age-population-wb-data.html on December 26, 2023.

UDHR (1948). Universal Declaration of Human Rights. Retrieved from https://www.un.org/en/udhrbook/pdf/udhr_booklet_en_web.pdf on April 08, 2019.

UN (2017). The Sustainable Development Goals Report. United Nations, New York.

UN (2023). Outrageous a Person Dies of Hunger Every Few Seconds, Secretary-General Declares in Message on World Food Day, Calls for Crisis to Be Top of Global Agenda. Press release, United Nations.

UN (2024). UN food agency ramps up deliveries amid worsening food security in Ethiopia. UN News. available at https://news.un.org/en/story/2024/02/1146252

UNDP (1994). *Human Development Report 1994.* Oxford University Press, New York.

UNICEF, WHO and World Bank (2021). Levels and trends in child malnutrition: key findings of the 2021 edition of the joint child malnutrition estimates. World Health Organization, Geneva.

United Nations (1975). *Report of the World Food Conference, Rome 5-16 November 1974.* New York.

USAID (2023). U.S. and Ethiopia Launch New $2.2 Billion Phase of the Productive Safety Net Program. Retrieved from https://www.usaid.gov/ethiopia/press-release/us-and-ethiopia-launch-new-22-billion-phase-productive-safety-net-program on February 13, 2024.

Van der Veen, A., and Gebrehiwot, T. (2011). Effect of policy interventions on food security in Tigray, Northern Ethiopia. *Ecology and Society, 16*(1).

Von Braun J. (1991). A policy agenda for famine prevention in Africa. Food Policy Statement No.13. IFPRI, Washington DC.

Von Braun, J., and Olofinbiyi, T. (2007). Famine and food security in Ethiopia. *Food Policy for Developing Countries: the role of government in the global food system, Case study*, 7-4.

Vorley, B., and Lançon, F. (2016). Food consumption, urbanisation and rural transformation: The trade dimensions. IIED, London.

Walsh, C. M., and Van Rooyen, F. C. (2015). Household food security and hunger in rural and urban communities in the Free State Province, South Africa. *Ecology of food and nutrition*, *54*(2), 118-137.

Weis, T. (2020). Food security and food sovereignty. Food Security and Food Sovereignty. *International Encyclopedia of Human Geography* (pp. 191-196). Elsevier.

Weldearegay, S. K., and Tedla, D. G. (2018). Impact of climate variability on household food availability in Tigray, Ethiopia. *Agriculture and Food Security*, *7*(1), 6.

Weldegiargis, A. W., Abebe, H. T., Abraha, H. E., Abrha, M. M., Tesfay, T. B., Belay, R. E., ... and Mulugeta, A. (2023). Armed conflict and household food insecurity: evidence from war-torn Tigray, Ethiopia. *Conflict and Health*, *17*(1), 22.

Weldemariam, L. F., Sakdapolrak, P., and Ayanlade, A. (2023). Household food-security strategies and migration in Tigray, Northern Ethiopia. *Scientific African, 21*, e01801.

Welteji, D., Mohammed, K., and Hussein, K. (2017). The contribution of Productive Safety Net Program for food security of the rural households in the case of Bale Zone, Southeast Ethiopia. *Agriculture and Food Security*, *6*(1), 53.

WFP (2009). Food security and vulnerability in selected towns of Tigray: Vulnerability Assessment and Mapping (VAM). World Food program, Addis Ababa, Ethiopia.
WFP (2013). 2012 food aid flows: International food aid information system. Retrieved from https://www.calpnetwork.org/publication/food-aid-flows-2012-report/ on February 12, 2024.

WFP (2020). WFP Ethiopia, Country Brief. Retrieved from https://docs.wfp.org/api/documents/WFP-0000115065/download/ on July 31, 2020.

WFP (2022a). Tigray Emergency Food Security Assessment: Tigray crisis response. World Food program, Addis Ababa, Ethiopia.

WFP (2022b). Northern Ethiopia Emergency Response situation report. Retrieved from https://reliefweb.int/report/ethiopia/northern-ethiopia-emergency-response-situation-report-07 on February 12, 2024.

WFP (2023). Ethiopia. Country brief. Retrieved from https://www.wfp.org/countries/ethiopia on December 16, 2023.

Wheeler, Tim, and Von Braun, Joachim. (2013). Climate change impacts on global food security. *Science*, *341*(6145), 508-513.

WHO (2000). *The Management of Nutrition in Major Emergencies*. World Health Organization, Geneva.

WHO (2004). *Vitamin and mineral requirements in human nutrition*. World Health Organization, Geneva.

WHO (2008). Indicators for assessing infant and young child feeding practices. Part I: definition. Available at: http://www.who.int/maternal_child_adolescent/documents/9789241596664/en/.

WHO (2018). Nutrition. Available at https://www.who.int/news-room/facts-in-pictures/detail/nutrition

WHO (2021). Investing 1 dollar per person per year could save 7 million lives in low- and lower-middle-income countries. Retrieved from https://www.who.int/news/item/13-12-2021-investing-1-dollar-per-person-per-year-could-save-7-million-lives-in-low-and-lower-middle-income-countries on February 14, 2024.

WHO (2023). Income level: the global health observatory. Retrieved from https://www.who.int/data/gho/indicator-metadata-registry/imr-details/193 on December 28, 2023.

Wiesmann, D., Bassett, L., Benson, T. and Hoddinott, J. (2006). *Validation of the World Food Programme's Food Consumption Score and Alternative Indicators of Household Food Security*. Discussion Paper. IFPRI, Washington, USA.

Woldehanna, Tassew (2000). *Economic analysis and policy implications of farm and off-farm employment: A case study in the Tigray region of Northern Ethiopia*. Dissertation, Agricultural Economics and Rural Policy Group, Wageningen University and Research.

Wolteji, B. N., Bedhadha, S. T., Gebre, S. L., Alemayehu, E., and Gemeda, D. O. (2022). Multiple indices based agricultural drought assessment in the Rift Valley region of Ethiopia. *Environmental Challenges*, *7*, 100488.

Wordofa, M. G., and Sassi, M. (2020). Impact of agricultural interventions on food and nutrition security in Ethiopia: uncovering pathways linking agriculture to improved nutrition. *Cogent food and agriculture*, *6*(1), 1724386.

World Bank (1986). Poverty and Hunger: Issues and Options for Food Security in Developing Countries. Washington DC.

World Bank (2010). Development and Climate Change: 2010 World Development Report. The World Bank, Washington DC, New York.

World Bank (2016). Poverty and Shared Prosperity 2016: Taking on Inequality. The World Bank Group, Washington, DC.

World Bank (2023a). Food security update. International Bank for Reconstruction and Development, Washington DC.

World Bank (2023b). Implementation Completion and Results Report on A Grant to The Federal Democratic Republic of Ethiopia for The Ethiopia Rural Productive Safety Net Project. Social Protection and Jobs Global Practice, Eastern and Southern Africa Region. Report No: ICR00006154

World Data Atlas (2023). Ethiopia – National Rainfall Index. Retrieved from https://knoema.com/atlas/Ethiopia/Rainfall-index on December 01, 2023.

World Finance (2017). Ethiopia Economy: Poverty in Ethiopia. Retrieved from http://www.eiiff.com/economy/ethiopia/poverty.html on April 16, 2019.

Wudad, A., Naser, S., and Lameso, L. (2021). The impact of improved road networks on marketing of vegetables and households' income in Dedo district, Oromia regional state, Ethiopia. *Heliyon*, *7*(10).

Yibrah, M., Korecha, D., and Dandesa, T. (2018). Characterization of Rainfall and Temperature Variability to Guide Wheat (Triticum aestivum) and Barley (Horduem vulgare) Production in Enderta District, Southeastern Tigray, Ethiopia. *International Journal of Research in Environmental Science*, *4*(2), 35-41.

Yisak, H., Elmneh, R., Taklual, W., Ewunetei, A., and Kefale, B. (2020). Prevalence and associated factors of clinical vitamin A deficiency among pre-school children 1–5 years of age in rural Kebeles in Farta District, South Gondar Zone, Ethiopia: a mixed methods study. *Journal of multidisciplinary healthcare*, 1191-1201.

Yohannes, G., Wolka, E., Bati, T., and Yohannes, T. (2023). Household food insecurity and coping strategies among rural households in Kedida Gamela District, Kembata-Tembaro zone, Southern Ethiopia: mixed-methods concurrent triangulation design. *BMC nutrition*, *9*(1), 1-13.

Young, H., Jaspers, S., Brown, R., Frize, J., & Khogali, H. (2001). Food-security assessments in emergencies: a livelihoods approach. London, UK: Overseas Development Institute.

Zeleke, T. T., Giorgi, F., Diro, G. T., and Zaitchik, B. F. (2017). Trend and periodicity of drought over Ethiopia. *International journal of climatology*, *37*(13), 4733-4748.

ANNEXES

Annex I: Author Biodata

Tewelde Gebre Berhe, an instructor and researcher at Mekelle University, was born in July 1986 in Freweini town, Tigray region of Ethiopia. He completed his primary school in Freweini primary school, Freweini town, and attended his high school and preparatory school in Edagahamus secondary school, Edagahamus town. He earned his first degree in Geography and Environmental Studies from Jimma University in 2008. After his first-degree graduation, Tewelde began to work in the Benshangul-Gumuz region of Ethiopia following his placement by the Ministry of Education. A year later, he started to work for Tekli-Swuat comprehensive secondary school as an Economics teacher.

In 2012, he got a governmental scholarship to pursue his Master's degree at the Ethiopian Civil Service University (ECSU). After two years of course and research work, he got his MSc degree in Urban Environment and Climate Change Management in 2014. This time he got an opportunity to work for Mekelle University.

Tewelde has been working for Mekelle University since December 2014 at the Institute of Environment, Gender, and Development Studies (IEGDS). He joined the PhD program in September 2019. He has done his dissertation on "*Food Insecurity in the Drought-prone Rural Areas of Tigray, Ethiopia: Associated Precipitation Variability and Response Mechanisms*" under the supervision of Dr. Zenebe Abraha, Dr. Amanuel Zenebe, and Dr. Woldegebrial Zeweld.

Annex II: Survey questionnaire and FGD questions

Questionnaire to be filled by selected rural households

Dear Respondents,

I thank you in advance for your consent to answer the following questions. The main aim of this questionnaire is to collect data on your area's food insecurity status. The findings will only be used for academic purposes, and your answers will be kept private.

Your honest and accurate information is much appreciated.

With regards,

Name of the rural district: _____

Name of the sub-district: _____

Name of the enumerator: _____

General questions

1. Sex of household head: 1. Male 2. Female
2. Age: _____
3. Formal schooling year: _____
4. Family size: female, _____ Male: _____ total: _____
5. Number of children less than five years of age: _____
6. Number of economically active members of the household: _____
7. Average annual income: _____
8. Source of income:
    1. On-farm activities
    2. Off-farm activities
    3. Non-farm activities
    4. Remittance
    5. Aid
    6. Other, _____
9. Nature of farming: 1. Rainfed 2. Irrigation 3. Mixed
10. Asset ownership:
    a. Total number of cattle: _____
    b. Total number of donkeys/horses: _____
    c. Total number camel: _____
    d. Total number of sheep/goats: _____
    e. Total number of chickens: _____
    f. Land size in Tsimad: _____

11. What is your major source of food?
    1. Own farm/non-farm production
    2. Purchased food
    3. Borrowed, exchanged (bartered)
    4. Food aid
    5. Work-based food aid
    6. Supplies from families or relatives
    7. Other: _____
12. What month do you face hunger mostly? _____

Questions related to Food availability

13. Did you or any household member ever eat less than you felt you should?
    1. Yes 2. No
14. If yes, how often did this happen?
    1. Almost every day
    2. 1 to 3 days in a week
    3. Very rarely
15. Did you or any household member ever cut the size of the Household meals?
    1. Yes 2. No
16. If yes, how often did this happen?
    1. Almost every day
    2. 1 to 3 days in a week
    3. Very rarely
17. Was there ever no food to eat of any kind in your household because of lack of resources to get food?
    1. Yes 2. No
18. If yes, how often did this happen?
    1. Almost every day
    2. 1 to 3 days in a week
    3. Very rarely
19. Were you or any household member ever hungry?
    1. Yes 2. No
20. If yes, how often did this happen?
    4. Almost every day
    5. 1 to 3 days in a week
    6. Very rarely

Questions related to Food access

21. What is the average time (in hours) it takes you to go to nearest town/city? _____

22. What is the mode of transport to go to food market?
    a. Motor transport (bus, motorcycle, …)
    b. Bicycle
    c. Animal driven cart
    d. Pack animals
    e. Walking
23. Do the elders have access to the food market? 1. Yes 2. No
24. Do the women have access to food market? 1. Yes 2. No
25. In the last three months, what was the average amount of money you spent on food? _____
26. Was that money enough to purchase your required food?
    1. Yes 2. No
27. In the last three months, were you or any household member hungry because there was no money to buy food?
    1. Yes 2. No
28. Have you ever received humanitarian aid? 1. Yes 2. No
29. If yes, how many times did you get humanitarian aid in the last year? _____
30. Was the humanitarian aid sufficient? 1. Yes 2. No

Questions related to food utilization (nutrition)

31. Were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources? 1. Yes 2. No
32. If yes, how often did this happen?
    1. Almost every day
    2. 1 to 3 days in a week
    3. Very rarely
33. Did you or any household member have to eat a limited variety of foods due to a lack of resources? 1. Yes 2. No
34. If yes, how often did this happen?
    1. Almost every day
    2. 1 to 3 days in a week
    3. Very rarely
35. Please describe the foods that you ate or drank yesterday.
    - Breakfast: _____
    - Lunch: _____
    - Snack: _____
    - Dinner: _____
36. Oedema test of a child: 1. Yes 2. No
37. MUAC result of a child: _____
38. Bitot's spot (Xerophthalmia) test of a child: 1. Yes 2. No

Food consumption score and Household Dietary Diversity Score (HDDS)

No.	Food types	Did most members of your household eat the following food items over the last day?		Consumption frequency of the following food items over the last week?
		Yes	No	
1	Pulses, legumes, nuts			
2	Meat			
3	Eggs			
4	Honey			
5	Oil/fat			
6	Milk and other dairy products			
7	Vegetables			
8	Fruits			
9	Cereal, grains			
10	Main staples			

Questions related to Food stability

39. Do you have any stored food for future use?

    1. Yes 2. No

40. If yes, how long you think can serve you the stored food?

    a. For days
    b. For weeks
    c. For months
    d. For more than a year

41. In the last three months, did you worry that your household would not have enough food?

    1. Yes 2. No

42. Did you worry that your household would not have enough money to purchase food?

    1. Yes 2. No

43. Did you worry that any of the children, women, or the elders would not have enough food?

    1. Yes 2. No

44. Did you worry that your household would not have variety of food (like meat, egg, milk & milk products …)?

    1. Yes 2. No

Questions related to coping strategy index (CSI)

No.	What do you do when you don't have adequate food, and don't have the money to buy food?	Extent of practice				
		Every day	Most days	Half the time	Rarely	Never
1	Consume less quality & less expensive food					
2	Reduce the meals of adults in favor of children					
3	Limit the portion of meals for all household members					
4	Consume food held for next season					
5	Reduce the number of meals per day					
6	Purchase food on credit					
7	Send children or household members to eat elsewhere					
8	Send children or household members to work for food					
9	Depend on aid from family, friends, or external bodies					
10	Use all or part of your savings to purchase food					
11	Sell any assets to purchase basic food items					
12	Reduce other expenses to meet food needs					
13	Take a loan to purchase food					
14	Skip part or entire days without eating					
15	Feed working members of the household at the expense of non-working members					

Questions related to agricultural adaptation mechanisms

No.	Questions	Extent of practice			
		Regularly	Occasionally	Rarely	Never
1	Cultivating drought-tolerant crops				
2	Cultivating forest foods				
3	Preparing alternative wetting				
4	Adjusting planting season				
5	Harvesting rainwater				
6	Shorter duration crop cultivation				
7	Crop diversification				
8	Use of fertilizer				
9	Use of improved seeds				
10	Livestock rearing				

FGD questions for Paired Comparative Analysis (PCA) of food insecurity coping strategies

No.	Strategies	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Consume less quality & less expensive food															
2	Reduce the meals of adults in favor of children															
3	Limit the portion of meals for all household members															
4	Consume food held for next season															
5	Reduce the number of meals per day															
6	Purchase food on credit															
7	Send children or household members to eat elsewhere															
8	Send children or household members to work for food															
9	Depend on aid from family, friends, or external bodies															
10	Use all or part of your savings to purchase food															
11	Sell any assets to purchase basic food items															
12	Reduce other expenses to meet food needs															
13	Take a loan to purchase food															
14	Skip part or entire days without eating															
15	Feed working members of the household at the expense of non-working members															

FGD questions for Paired Comparative Analysis (PCA) of adaptation strategies for drought

No.	Strategies	Cultivating drought-tolerant crops	Cultivating forest foods	Preparing alternative wetting	Adjusting planting season	Harvesting rainwater	Shorter duration crop cultivation	Crop diversification	Use of fertilizer	Use of improved seeds	Livestock rearing
1	Cultivating drought-tolerant crops										
2	Cultivating forest foods										
3	Preparing alternative wetting										
4	Adjusting planting season										
5	Harvesting rainwater										
6	Shorter duration crop cultivation										
7	Crop diversification										
8	Use of fertilizer										
9	Use of improved seeds										
10	Livestock rearing										

Annex III: Course Summary

Courses required to complete the study (Course Name and Code): list of all courses, seminars, and other activities as per the program requirement.	**Year and Semester**	**Credit in ECTS**	**Accomplished**	**If not accomplished, proposed year and Semester**	**Reason for re-scheduling**
Scientific Inquiry (CCRD 7111)	2018/19, Sem. I	9	Yes		
Contemporary Issue in Rural Development (CCRD 7211)	2018/19, Sem. I	9	Yes		
Environment, Climate Change, and Development (CCRD 7311)	2018/19, Sem. I	12	Yes		
Scientific Research Writing (CCRD 7411)	2018/19, Sem. I	12	Yes		
PhD Research proposal development and defense	2018/19, Sem. II	9	Yes		
Thematic Seminar I	2023/24, Sem. I	1.5	Yes		
Thematic Seminar II	2023/24, Sem. II	1.5	Yes		
Paper presentation – National Conference	2023/24, Sem. II	2	Yes		
Paper presentation – International Conference	2022/23, Sem. II	2	Yes		

Annex IV: Articles published in Journals

- **Tewelde Gebre**, Zenebe Abraha, Amanuel Zenebe and Weldegebrial Zeweld (2024). Precipitation variability and its teleconnection with the global SST and ENSO indices in the food-insecure rural areas of Tigray. *Theoretical and Applied Climatology*. *155*(3), 1699-1711. https://doi.org/10.1007/s00704-023-04717-5
- **Tewelde Gebre**, Zenebe Abraha, Amanuel Zenebe and Weldegebrial Zeweld (2024). A comprehensive analysis of food insecurity in the drought-prone areas of Tigray. *Journal of Health, Population and Nutrition 43*(1):66. https://doi.org/10.1186/s41043-024-00564-w
- **Tewelde Gebre**, Zenebe Abraha, Amanuel Zenebe and Weldegebrial Zeweld (2024). Food security intervention mechanisms in the drought-prone rural areas of Tigray. *Front. Nutr.* 11:1413017. https://doi.org/10.3389/fnut.2024.1413017
- **Tewelde Gebre**, Zenebe Abraha, Amanuel Zenebe and Woldegebrial Zeweld (2025). Food insecurity, associated climate factors and intervention mechanisms: a theoretical and empirical analysis of Ethiopia's case. *Nutrition & Food Science*, 55(2), 275-293. https://doi.org/10.1108/NFS-05-2024-0183

Theoretical and Applied Climatology (2024) 155:1699–1711
https://doi.org/10.1007/s00704-023-04717-5

RESEARCH

Precipitation variability and its teleconnection with the global SST and ENSO indices in the food-insecure rural areas of Tigray

Tewelde Gebre[1] · Zenebe Abraha[2] · Amanuel Zenebe[3] · Woldegebrial Zeweld[2]

Received: 30 May 2023 / Accepted: 20 October 2023 / Published online: 3 November 2023

Abstract
The impact of precipitation variability on food production is very significant. For food-insecure rural areas, understanding the nature of precipitation variability and its teleconnection has paramount importance in guiding regional and local-level decisions. In this study, we analyzed the monthly, seasonal, and annual precipitation variability and the strength of its teleconnection with the global sea-surface temperature (SST) and El Niño/La Niña Southern Oscillation (ENSO) indices in the food-insecure rural areas of Tigray region, Ethiopia. The precipitation, SST, and ENSO indices data for the study were used from 1979 to 2019. A summary of descriptive statistics and Mann-Kendall test methods were applied to detect the existence of trends, and Sen's slope and coefficient of variation are used to analyze the magnitude of the trend and degree of variation in the precipitation pattern. Further, Pearson's correlation is used to determine the effect of ENSO, and SST variations on the precipitation using the canonical correlation analysis. The results revealed that the precipitation over the three districts is characterized by a distinctive bimodal pattern with limited rains in March–May preceding the main rainy season June–September. The limited amount of precipitation, exacerbated by a higher degree of variability, makes the food production in the three districts more uncertain. Besides, there was a very significant decline in the trend of March–May average precipitation and a significant decline in the trend of the annual average precipitation in Hintalo area. The SST of central and eastern equatorial Pacific Ocean, and northeast and northwest equatorial Atlantic Ocean was strongly correlated with the April average precipitation of the three districts. Further, SST of the south, west, and southwest of the equatorial Indian Ocean, and west equatorial Pacific Ocean was associated with July–September average precipitation with greater variation in strength among of the three districts. Moreover, July's average precipitation of the three districts, April's average precipitation of Atsbi and Eirop, and May's precipitation of Hintalo are found significantly associated with the ENSO indices of JFM, FMA, MJJ, and MAM. Therefore, the task of achieving food security in the three districts should incorporate the design of informed food production strategies that can adapt to the limited and variable precipitation based on these SST and ENSO indices.

1 Introduction

Climate change, the catchy phrase, is the major threat to food security in rural areas. Because of the limited capacities to cope up with the varying climate, food insecurity is higher in rural areas of developing countries, where much of their population depends on rain to produce food. World Bank (2016) reported that rural farmers are more than four times as likely to be food-insecure as compared to urban dwellers engaged in non-agricultural sectors. According to the findings of a research conducted across 105 countries by Alkire et al. (2014), 86% of food-insecure people of sub-Saharan Africa and South Asia live in rural areas.

Food insecurity, in many parts of the developing world, is associated with shortages and variability of precipitation (Darwin 2001; Schmidhuber and Tubiello 2007; Wheeler and Braun 2013; and Afifi et al. 2014). A similar study by Kinda and Badolo (2019) showed that precipitation variability has reduced food availability per capita and increased fluctuation in food production for 71 developing countries. According to Von Braun (1991), a 10% decline in the

✉ Tewelde Gebre
tewelde.gebre@mu.edu.et

[1] Institute of Environment, Gender and Development Studies, Mekelle University, Mekelle, Ethiopia

[2] College of Dryland Agriculture and Natural Resources, Mekelle University, Mekelle, Ethiopia

[3] Institute of Climate and Society, Mekelle University, Mekelle, Ethiopia

Gebre et al.
Journal of Health, Population and Nutrition (2024) 43:66
https://doi.org/10.1186/s41043-024-00564-w

Journal of Health, Population and Nutrition

RESEARCH Open Access

A comprehensive analysis of food insecurity in the drought–prone rural areas of Tigray

Tewelde Gebre[1*], Zenebe Abraha[2], Amanuel Zenebe[3] and Woldegebrial Zeweld[2]

Abstract

Background The number of globally food-insecure people is increasing since 2017. Sub-Saharan Africa has the highest proportion of severely food-insecure people in the world. Tigray region of Ethiopia is one of the food-insecure regions, which, over the past many decades has been affected by recurrent food insecurities. In the drought–prone rural areas of Tigray, many people are living under the condition of chronic hunger. Proper food security studies are vital for proper intervention mechanisms. Yet, previous food security studies have rarely addressed the four pillars of food security: availability, access, utilization, and stability. In this study, all components are duly considered to assess the food insecurity status in the drought–prone rural areas of Tigray, Ethiopia. Of the 34 rural districts in Tigray, 363 households from three drought–prone rural districts were studied.

Results Household Food Insecurity Access Scale and Food Insecurity Experience Scale were adapted to measure the food availability, access to food, and stability components of food security; and, Household Dietary Diversity Score (HDDS), Food Consumption Score (FCS), mid-upper arm circumference, and Bitot's spot were used to analyze the food utilization aspect. Findings show that 68% of the studied community frequently ate less food than they felt they needed and 82.1% of the households have experienced hunger because of lack of food. The study rural districts were unconnected to road networks; hence, 87.9% of the elderly and 20.4% of the women and girls had no access to food markets. Regarding the food utilization, 81.5% of the studied households had poor FCS; and the average HDDS and FCS for the study areas were 2.47 and 18.9, respectively. The prevalence of Global acute malnutrition, severe acute malnutrition (SAM), and moderate acute malnutrition (MAM) for 6–59 months of age children in the study areas were 50.3, 4.2, and 46.1%, respectively. More notably, the prevalence of SAM for children from the food-insecure households was 21.2%. The prevalence of MAM for pregnant and lactating women (PLW) in the study areas was 59.5. Further, the prevalence of Bitot's spot among 6–59 months of age children was 1.9%. On the other hand, all the rural households had anxiety about their future food demands.

Conclusion The rural households living in the studied areas were critically food-insecure. All the measurements implied that the food insecurity situation in the study areas was unacceptably worrisome and life-threatening. This calls for an instant action to avert the occurrence of famine and starvation in the drought–prone rural areas of Tigray region. Thus, interventions should primarily target the vulnerable rural people and need to be planned based on attaining food availability first rather than concurrently addressing all components of food security. Further, due emphasis should be given to diversifying livelihood strategies of the vulnerable villagers.

Keywords Food insecurity, Rural, Food availability, Access to food, Utilization, Stability

*Correspondence:
Tewelde Gebre
tewelde.gebre@mu.edu.et
Full list of author information is available at the end of the article

frontiers | Frontiers in Nutrition

TYPE Original Research
PUBLISHED 13 August 2024
DOI 10.3389/fnut.2024.1413017

OPEN ACCESS

EDITED BY
Ademola Adenle,
Technical University of Denmark, Denmark

REVIEWED BY
Farirai Rusere,
University of the Witwatersrand, South Africa
Moses Nyangito,
University of Nairobi, Kenya

*CORRESPONDENCE
Tewelde Gebre
tewelde.gebre@mu.edu.et

RECEIVED 06 April 2024
ACCEPTED 24 July 2024
PUBLISHED 13 August 2024

CITATION
Gebre T, Abraha Z, Zenebe A and Zeweld W (2024) Food security intervention mechanisms in the drought-prone rural areas of Tigray. *Front. Nutr.* 11:1413017. doi: 10.3389/fnut.2024.1413017

Food security intervention mechanisms in the drought-prone rural areas of Tigray

Tewelde Gebre*, Zenebe Abraha, Amanuel Zenebe and Woldegebrial Zeweld

Institute of Environment, Gender and Development Studies, Mekelle University, Mekelle, Ethiopia

Introduction: Tigray is one of the food-insecure regions with many people living under the condition of chronic hunger. Proper intervention mechanisms are vital for addressing food insecurity. Yet, food security intervention mechanisms of various levels are not researched well. Besides, previous studies have rarely addressed the objectives of food security intervention mechanisms in relation to the four pillars of food security: availability, access, utilization, and stability. Thus, this study aims to investigate the food security intervention mechanisms in the drought-prone rural areas of Tigray in relation with the major components of food security.

Methodology: This study has employed a cross-sectional study design based on a mixed research approach with primary and secondary data. For this, 363 households from three selected drought-prone rural districts, i.e., Atsbi-wenberta, Irob, and Hintalo- wejerat were studied. Primary data were collected using questionnaires and key-informant interviews. And, secondary data were collected from relevant archives and policy documents. The obtained data were analyzed descriptively and content-wise.

Results: Findings show that there were several international interventions intended to halt food insecurity sustainably through financial aid, but many of the interventions were found to be responding to humanitarian crises mainly the food shortages. Ethiopia's Food and Nutrition Policy, Food Security Program, Food Security Strategy, and Food Security Pack program were the food security intervention mechanisms at the national level. These interventions were found to be inconsistent with each other in their intended goals. Regionally, no food security strategy or program was found intervening to the prevailing food insecurity in Tigray. More notably, the region has no food security bureau or office that deals with food security issues of the region. At a community level, food aid, and PSNP transfers have been the usual food security intervention mechanisms. 35.6% (77,010) of the population in the study rural districts were found to be rural PSNP beneficiaries. The food aid and PSNP transfers were outrageously insufficient for the recipients to cope with food insecurity.

Conclusion: Intervention mechanisms should focus on enhancing vulnerable households' coping and adaptive capacities to deal with food security problems. In this regard, all the food security intervention mechanisms of various levels should be integrated into the common goal of achieving food security.

KEYWORDS

food policy, Safety Net, drought, rural, interventions, food aid, humanitarian assistance

Nutrition & Food Science

275

Food insecurity, associated climate factors and intervention mechanisms: a theoretical and empirical analysis of Ethiopia's case

Tewelde Gebre, Zenebe Abraha, Amanuel Zenebe and Woldegebrial Zeweld
Mekelle University, Mekelle, Ethiopia

Received 21 May 2024
Revised 10 August 2024
2 September 2024
Accepted 30 September 2024

Abstract

Purpose – In our world, nearly nine million people die every year from hunger, losing one person to hunger every few seconds. Ethiopia is among the leading countries in the total number of people facing hunger. Several actions have been taken to achieve food security globally and at the household level. However, the problem of food insecurity is still high in many parts of the world. Why are we failing to achieve food security? And where should we start? This study aims to answer these main questions.

Design/methodology/approach – Relevant quantitative and qualitative data were duly used to describe food insecurity and associated climate factors globally and nationally. For this, PRISMA review methodology was used to help the systematic review. More than 90 relevant empirical and theoretical literature in the field were reviewed in an integrated way with practical evidence from Ethiopia. Governmental technical reports, NGOs reviews and other relevant empirical data referring to Ethiopia are thematically analyzed.

Findings – The subjectivity, dynamism and complexity of the concept of food security are found to be some of the issues challenging the practice of achieving food security. The unresolved issues in the combination and interaction of the four pillars of food security (food availability, access to food, food utilization and stability) are affecting its measurement. In this study, it is emphasized that food insecurity in rural and urban areas should be treated differently, as food insecurity in rural areas is directly related to food production which depends on rainfall patterns. In rural Ethiopia, rainfall variability was among the main causes of food insecurity. More importantly, it is indicated that rainfall variability does not affect all pillars of food security equally; its effect is more pronounced on food availability and stability aspects. Deconstructing the concept of food security to make it more pragmatic, and understanding the factors behind the rainfall variability should be the starting tasks in achieving food security. Further, even though food aid is preferred to react to transitory food insecurity, focusing on long-lasting preventive measures that address the root causes of the recurring food insecurity in rural areas of Ethiopia would be an effective way of addressing the problem.

Practical implications – Policy makers and other governmental and humanitarian agencies working on food security can make an evidence-based decision, shape policies and programs if they have clear information about the features of food insecurity, the nature of rainfall variability and critiques of the reacting mechanisms to food insecurity. Shortages of food in some place and food price crises in the other places have been both referring to food insecurity. This makes the understanding of food security situations more difficult to explain and communicate.

Originality/value – This study primarily clarifies the conceptual complexity surrounding food security as it currently exists. Further, it provides a comprehensive and quantitative description of the state of global to national food security, along with the associated variability of rainfall patterns that are related to it. It also provides a brief overview of the intervention mechanisms for addressing food security, with a specific focus on Ethiopia. This study has set a clear demarcation to assess food security in rural and urban areas.

Keywords Food security, Rainfall pattern, Agriculture, Rural, Coping mechanisms

Paper type Research paper

Nutrition & Food Science
Vol. 55 No. 2, 2025
pp. 275-293

0034-6659
DOI 10.1108/NFS-05-2024-0163

Annex V: ENSO data sets

Oceanic Nino Index (1948-2019)

Year	JF	FM	MA	AM	MJ	JJ	JA	AS	SO	ON	ND	DJ
1948	0.181	0.338	0.633	0.736	0.374	0.236	0.207	0.054	-0.292	-0.387	-0.193	-0.011
1949	0.055	-0.239	-0.333	-0.013	-0.248	-0.251	-0.126	-0.271	**-0.569**	**-1.001**	**-1.079**	**-1.079**
1950	**-1.248**	**-1.412**	**-1.393**	**-1.455**	**-1.180**	**-0.835**	**-0.654**	**-0.705**	**-0.866**	**-1.009**	**-1.133**	**-0.973**
1951	**-0.833**	**-0.664**	**-0.428**	-0.112	**0.524**	**0.825**	**0.732**	**0.643**	**0.761**	**0.728**	**0.443**	0.315
1952	0.401	0.317	0.295	0.214	-0.068	-0.113	0.031	0.254	0.194	0.066	-0.013	0.067
1953	0.375	**0.477**	**0.398**	**0.628**	**0.478**	**0.611**	**0.634**	**0.611**	0.341	0.101	0.081	-0.007
1954	-0.052	-0.037	-0.385	**-0.696**	**-0.598**	**-0.690**	**-0.743**	**-0.694**	**-0.729**	**-0.842**	**-1.001**	**-0.738**
1955	**-0.615**	**-0.872**	**-0.855**	**-1.019**	**-0.989**	**-0.982**	**-1.186**	**-1.288**	**-1.418**	**-1.487**	**-1.320**	**-1.146**
1956	**-1.044**	**-0.936**	**-0.951**	**-1.217**	**-1.074**	**-0.991**	**-0.792**	**-0.569**	**-0.597**	**-0.483**	-0.306	-0.223
1957	0.027	**0.390**	**0.622**	**0.936**	**1.429**	**1.596**	**1.586**	**1.542**	**1.287**	**1.465**	**1.560**	**1.394**
1958	**1.474**	**1.351**	**1.218**	**1.087**	**1.009**	**0.740**	**0.513**	**0.450**	**0.596**	**0.564**	**0.685**	**0.670**
1959	**0.813**	**0.718**	**0.549**	**0.615**	**0.561**	0.312	0.270	0.248	0.238	0.178	0.007	0.046
1960	0.090	0.132	0.212	0.129	0.299	0.215	0.076	0.146	0.131	0.003	-0.034	0.098
1961	0.066	0.251	0.388	0.155	0.261	0.231	-0.049	-0.163	-0.039	-0.094	-0.309	-0.563
1962	-0.417	-0.249	-0.573	-0.873	-0.760	-0.327	-0.281	-0.343	**-0.434**	**-0.387**	**-0.352**	**-0.508**
1963	**-0.499**	-0.216	-0.003	0.090	**0.590**	**0.819**	**0.872**	**0.945**	**1.044**	**0.908**	**0.883**	**0.840**
1964	**0.560**	0.172	**-0.471**	**-0.841**	**-0.855**	**-1.024**	**-0.966**	**-0.989**	**-0.958**	**-0.767**	**-0.578**	**-0.372**
1965	-0.177	-0.089	0.231	**0.483**	**0.805**	**1.081**	**1.225**	**1.228**	**1.332**	**1.533**	**1.409**	**1.271**
1966	**1.146**	**0.828**	**0.797**	**0.641**	0.107	0.156	0.271	0.068	0.220	0.252	0.078	-0.260
1967	-0.524	-0.586	-0.488	-0.164	-0.097	-0.304	-0.277	-0.420	-0.270	-0.051	0.037	-0.194
1968	-0.359	-0.423	-0.449	-0.254	-0.334	-0.116	0.240	**0.531**	**0.712**	**0.931**	**0.947**	**1.105**
1969	**1.312**	**1.159**	**1.213**	**1.323**	**1.027**	**0.795**	**0.518**	**0.715**	**0.977**	**0.979**	**0.749**	**0.768**
1970	**0.787**	**0.660**	**0.407**	0.202	**-0.439**	**-1.011**	**-1.196**	**-1.123**	**-1.004**	**-0.981**	**-1.068**	**-1.066**

1971	**-1.270**	**-1.555**	**-1.601**	**-1.527**	**-1.418**	**-1.160**	**-1.171**	**-1.345**	**-1.244**	**-0.973**	**-0.717**	**-0.420**
1972	-0.347	-0.353	0.077	**0.685**	**1.155**	**1.674**	**1.745**	**1.594**	**1.801**	**1.755**	**1.662**	**1.577**
1973	**1.472**	**1.168**	**0.610**	0.221	**-0.568**	**-0.994**	**-1.218**	**-1.471**	**-1.385**	**-1.367**	**-1.559**	**-1.636**
1974	**-1.663**	**-1.547**	**-1.299**	**-1.141**	**-0.988**	**-1.070**	**-0.746**	**-0.694**	**-0.844**	**-0.716**	**-0.499**	-0.297
1975	**-0.511**	**-0.845**	**-0.877**	**-1.105**	**-1.346**	**-1.728**	**-1.747**	**-1.829**	**-1.905**	**-1.606**	**-1.639**	**-1.628**
1976	**-1.492**	**-1.298**	**-1.003**	**-0.716**	-0.313	0.331	**0.496**	**0.790**	**0.735**	**0.524**	**0.719**	**0.766**
1977	**0.487**	**0.543**	**0.780**	**0.586**	**0.394**	**0.661**	**0.565**	**0.538**	**0.671**	**0.723**	**0.894**	**0.625**
1978	**0.686**	**0.755**	0.149	-0.126	-0.171	-0.277	-0.217	-0.313	-0.180	0.124	0.285	0.389
1979	0.223	0.005	0.299	0.516	0.109	0.098	**0.539**	**0.587**	**0.650**	**0.748**	**0.778**	**0.703**
1980	**0.411**	**0.744**	**0.904**	**0.923**	**0.888**	**0.555**	0.123	0.135	0.112	0.013	0.096	-0.178
1981	-0.325	0.097	0.241	-0.204	-0.404	-0.550	-0.443	-0.167	-0.065	-0.027	-0.047	-0.050
1982	-0.164	-0.156	-0.055	**0.548**	**1.060**	**1.488**	**1.657**	**1.715**	**1.936**	**2.277**	**2.323**	**2.473**
1983	**2.641**	**2.646**	**2.523**	**2.206**	**1.453**	**1.244**	**0.811**	0.325	0.190	-0.120	-0.175	-0.313
1984	-0.488	-0.164	-0.031	-0.431	-0.447	-0.472	-0.413	-0.267	-0.254	**-0.425**	**-0.580**	**-0.543**
1985	**-0.779**	**-0.991**	**-0.916**	**-0.889**	-0.235	-0.337	-0.603	-0.606	-0.356	-0.195	-0.299	-0.371
1986	-0.318	-0.281	-0.426	-0.087	0.162	0.146	**0.650**	**0.950**	**0.600**	**0.834**	**1.115**	**1.065**
1987	**1.281**	**1.561**	**1.681**	**1.806**	**1.554**	**1.853**	**1.690**	**1.539**	**1.445**	**1.139**	**1.037**	**0.867**
1988	**0.661**	**0.423**	0.061	**-0.286**	**-1.034**	**-1.614**	**-1.698**	**-1.646**	**-1.492**	**-1.584**	**-1.584**	**-1.394**
1989	**-1.321**	**-1.380**	**-1.497**	**-1.372**	**-1.077**	**-1.081**	**-0.821**	**-0.607**	**-0.586**	-0.351	-0.137	-0.066
1990	0.172	0.409	0.066	-0.076	0.118	-0.083	-0.156	0.066	-0.031	0.031	0.187	0.052
1991	0.018	0.148	0.111	**0.346**	**0.789**	**0.749**	**0.475**	**0.553**	**0.735**	**0.814**	**1.085**	**1.417**
1992	**1.298**	**1.390**	**1.706**	**1.320**	**1.137**	**0.531**	-0.005	0.021	0.192	0.256	0.326	0.376
1993	**0.531**	**0.614**	**0.836**	**1.062**	**0.717**	**0.473**	0.280	0.250	0.413	0.322	0.048	0.021
1994	-0.163	-0.182	0.064	0.186	0.281	0.485	0.402	**0.532**	**0.799**	**0.818**	**0.812**	**0.812**
1995	**0.638**	0.342	0.158	0.211	0.072	-0.096	**-0.435**	**-0.709**	**-0.660**	**-0.737**	**-0.602**	**-0.656**
1996	**-0.862**	**-0.804**	**-0.943**	**-0.893**	**-1.053**	**-0.911**	**-0.774**	**-0.509**	**-0.495**	-0.332	-0.344	-0.554
1997	-0.747	-0.350	0.293	**0.730**	**1.588**	**1.893**	**2.237**	**2.337**	**2.326**	**2.295**	**2.182**	**2.232**

1998	**2.305**	**2.369**	**2.355**	**1.800**	0.349	**-0.544**	**-0.816**	**-0.775**	**-0.800**	**-0.913**	**-0.983**	**-1.240**
1999	**-1.457**	**-1.334**	**-1.517**	**-1.479**	**-1.395**	**-1.426**	**-1.410**	**-1.225**	**-1.362**	**-1.409**	**-1.464**	**-1.443**
2000	**-1.471**	**-1.477**	**-1.237**	**-1.118**	**-1.296**	**-1.068**	**-0.766**	**-0.730**	**-0.772**	**-0.873**	**-0.788**	**-0.793**
2001	**-0.882**	**-0.713**	**-0.503**	**-0.488**	**-0.359**	-0.210	-0.008	-0.160	-0.293	-0.323	-0.104	-0.055
2002	-0.138	0.116	0.021	0.089	**0.506**	**0.607**	**0.850**	**0.713**	**0.787**	**0.802**	**0.875**	**0.923**
2003	**0.774**	**0.617**	0.198	-0.371	-0.150	-0.195	-0.006	0.146	0.202	0.338	0.206	0.322
2004	0.197	-0.069	0.049	-0.276	-0.228	0.054	0.240	0.316	0.259	**0.516**	**0.637**	**0.379**
2005	**0.685**	**0.807**	**0.450**	0.246	0.367	0.184	0.194	0.136	-0.293	**-0.551**	**-0.569**	**-0.656**
2006	**-0.462**	**-0.407**	**-0.639**	-0.249	-0.086	0.075	**0.571**	**0.732**	**0.831**	**0.970**	**0.722**	**0.741**
2007	**0.568**	0.122	-0.084	-0.163	**-0.413**	**-0.499**	**-0.789**	**-1.080**	**-1.143**	**-1.361**	**-1.467**	**-1.435**
2008	**-1.589**	**-1.675**	**-1.433**	**-1.228**	**-0.910**	**-0.843**	**-0.773**	**-0.699**	**-0.770**	**-0.899**	**-0.956**	**-0.864**
2009	**-0.831**	**-0.799**	**-0.569**	-0.248	**0.535**	**0.621**	**0.750**	**0.707**	**0.808**	**1.008**	**1.017**	**1.094**
2010	**1.308**	**1.276**	**0.721**	0.016	**-0.830**	**-1.673**	**-2.075**	**-2.138**	**-2.119**	**-2.057**	**-1.981**	**-2.028**
2011	**-1.864**	**-1.910**	**-1.882**	**-1.573**	**-1.267**	**-0.914**	**-0.929**	**-1.107**	**-1.331**	**-1.322**	**-1.408**	**-1.321**
2012	**-0.951**	**-0.759**	**-0.507**	**-0.330**	-0.015	0.303	0.154	0.013	-0.016	-0.078	-0.098	-0.099
2013	-0.121	-0.212	-0.353	**-0.530**	**-0.654**	**-0.745**	**-0.659**	**-0.396**	-0.319	-0.343	-0.398	-0.416
2014	-0.346	-0.043	0.089	0.099	0.231	0.618	0.445	0.193	0.239	**0.390**	**0.416**	**0.442**
2015	0.399	**0.526**	**0.790**	**1.188**	**1.488**	**2.124**	**2.401**	**2.558**	**2.515**	**2.171**	**2.081**	**2.263**
2016	**2.241**	**2.103**	**2.097**	**1.597**	**0.963**	**0.480**	0.256	-0.028	-0.161	-0.188	-0.113	-0.077
2017	0.018	0.134	0.446	0.546	0.143	0.039	-0.249	**-0.441**	**-0.489**	**-0.717**	**-0.815**	**-0.800**
2018	**-0.721**	**-0.677**	**-1.037**	**-0.621**	-0.230	0.230	0.492	0.626	0.465	0.382	0.328	0.360
2019	0.753	0.915										

Note: red fonts indicate El Niño years; blue fonts indicate La Niña years and black fonts indicate normal years

Annex VI: Selected field survey photos