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## Article

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Research in Globalization

## Provided in Cooperation with:

Elsevier

*Suggested Citation:* Tofu, Daniel Assefa; Wolka, Kebede (2023) : Transforming food insecure farmers from climate variability and land degradation susceptibility to resilient livelihoods, Research in Globalization, ISSN 2590-051X, Elsevier, Amsterdam, Vol. 7, pp. 1-9, <https://doi.org/10.1016/j.resglo.2023.100168>

This Version is available at:

<https://hdl.handle.net/10419/331101>

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# Transforming food insecure farmers from climate variability and land degradation susceptibility to resilient livelihoods

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## ARTICLE INFO

### Keywords:

Adaptation  
Climate  
Drought  
Food security  
Soil conservation

## ABSTRACT

This study sought to evaluate the food security status of climate variability and land degradation-susceptible farmers, and measures used to transform to resilient livelihood. A Mixed approach was used to sample respondents and discussants. In the study, 342 household heads were interviewed for quantitative data whereas 12 focused group discussions and 20 key informant interviewees were made to collect qualitative data. While semi-structured questionnaire was used to collect quantitative data, guiding questions were employed to gather qualitative data. The quantitative data were analyzed using descriptive statistics and the binary logit model, whereas qualitative data were presented using thematic procedures. The results show that farmers have demonstrated experience with the changing patterns of climate change-persuaded episodes and its impacts on their food production. In the study area, according to the respondents, low yield (98 %), land degradation (97 %), food shortage (96 %), reduced income (95 %), food insecurity (95 %), and prevalence of disease and pest (85 %) were the major direct and indirect impacts posed by climate change. Besides, based on the calorie intake, 73 % of the households were found food insecure with an average of 1,790 kca, which is below from country and global minimum average that is 2200 and 2100, respectively. To improve food security and the impacts of climatic extremes and increase the ability to either cope or adapt to climate-related problems, farmers were employing strategies including sowing time adjustment, and soil and water conservation. The results of the binary logit regression model showed that repeated drought, farmland size, credit access, the unpredictability of rain, fertilizers usage, amount of rainfall, and social assistance significantly ( $P < 0.05$ ) affect the food security status of the households. Strengthening integrated land rehabilitation to improve yield could transform the food insecure and land degradation-susceptible households to climate-resilient means of livelihood in semi-arid northern Ethiopia. Policymakers and development planners should emphasis on how to widen the practice of organic and inorganic fertilizers, soil and water conservation, tree planting, income diversification, access to credit services, and water harvesting to transform and sustain the livelihood of food insecure and vulnerable farmers towards resilient status.

## 1. Introduction

Climate change and climate variability-induced extreme episodes are causing severe challenges in humanity through their impact on health, environmental quality, ecosystem functioning, biodiversity depletion, and agriculture. Climate-related impacts to health, livelihoods (e.g., agriculture and livestock), food security, water supplies, human security and economic growth are projected to increase, especially in the global South, where global warming has reached 1.5 °C and continues to increase 2 °C (IPCC, 2019). Among many impacts of climate change and its

variability, the impacts related to agriculture receive more attention due to the concern for food and nutrition security. Kim (2009) indicated that climate change disturbs the agricultural ecosystem, resulting in a change in agricultural climatic elements such as temperature, precipitation, and sunlight, while further influencing the crop, livestock, biodiversity, and hydrology. Climate change, through heat extreme, and changes in the pattern of rainfall, has increased the incidence of pests and diseases, impacting global agricultural production (IPCC, 2022). The intensity of impacts of climate change are region specific, where the developing parts of the world relying more on agriculture are highly influenced due

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<https://doi.org/10.1016/j.resglo.2023.100168>

Received 29 June 2023; Received in revised form 28 October 2023; Accepted 28 October 2023

Available online 3 November 2023

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to fluctuation in water availability and increase in temperature (Farooq et al., 2023).

The impacts of climate change and its variability are severe for the nations depending on natural resources and fragile environments, which is common in developing countries (Maino & Emrullahu, 2022; Farooq et al., 2023). In developing regions, climate change increases the risks of hunger as it affects the food security components (Weldearegay & Tedla, 2018). The security components such as food availability, access to food, stability of supply and accessibility are affected by climate change (FAO, 2008). Climate-related shocks affect productivity, which together with high levels of poverty and low levels of technology, leave people with limited choices or resources to adapt, and the cumulative effects mostly hamper economic progress and exacerbate existing social and economic problems of the countries particularly in the global South (USAID, 2015). This is mainly because, in such nations, the global South, the challenge to ensure food security is confined to climate-related factors and associated socioeconomic and other production and yield constraining factors including land degradation and poor water resource management (NOAA, 2015).

In Ethiopia, the agricultural sector accounts for most of the national income, export earnings and employment opportunities (Manyeruke et al., 2013). Majority of the citizen rely on agriculture as their main livelihood, and the sector is dominated by smallholder agriculture with limited technological use (Frandsen et al., 2007). Crop production is dominated by small subsistence farmers who practice natural resource reliant and more traditional farming and are known for their low capacity to apply productivity-enhancing farming techniques (Tofu et al., 2022a). The country's mixed farming system on degraded and fragmented land is subjected to erratic rainfall (Degefa, 2002). Furthermore, Ethiopia is highly climatically variable, characterized by rising temperatures and changing precipitation patterns, posing serious challenges for rain-dependent agriculture (Tofu, 2018a). Given the high level of climate change, food insecurity has been a serious problem in Ethiopia for decades (Ayenew, 2015). Since the 1970 s, a series of production failures due to lack of rainfall and subsequent drought has led to chronic food insecurity in the country (Berhane et al., 2013; Haberli, 2013).

The regions of Ethiopia most affected by recurrent drought, so far, include parts of the Tigray, Amhara, Afar, Somalia and Oromia (Taye & Temesgen, 2014). As a result, Ethiopia has been one of the largest recipients of food aid in the world and one of the largest recipients in Africa (Little et al., 2006). Food insecurity causes widespread human, material, economic or environmental damage, threatens lives and livelihoods, and is, sometimes, appeared beyond the capacity of affected communities and governments to cope (WFP, 2011). Thus, Ethiopia continues to receive external assistance even during normal periods without drought years, especially in the northern part of the country (USAID, 2015).

Although Ethiopia is a country with significant agricultural potential due to its diverse agro-ecology, water resources, and labor force, this potential goes largely underdeveloped (UN, 2010). The agricultural sector of Ethiopia is incredibly sensitive to shifts in weather because food grain production is entirely dependent on rainfall and the production is affected by extreme variability, as a result, vulnerability to famine is high (Frandsen et al., 2007). When rainfall is erratic or insufficient for even a few successive rainy seasons a worse food security situation often occurs (UN, 2010). That is, climate variability along with the low adaptive capacity of the people makes the country highly susceptible in the horn of Africa (Tofu, 2018a).

To reduce the food insecurity problem, the government of Ethiopia attempted to implement programs that meet the varying needs of vulnerable households (Endalew et al., 2015). The government is making significant investments and strides, particularly through its productive safety net program and agriculture-led economic growth that is tied to improved livelihoods and nutrition, which can become a long-lasting solution to Ethiopia's chronic poverty and food insecurity (USAID, 2015). The productive safety net program involved in some

interventions including incentives for labor needed in soil and water conservation structures construction, building rural public assets, and providing aid for the vulnerable community during food gap period (Cochrane and Tamiru, 2016). Through this program and others, promising impacts in natural resource restoration and impacts in food security claimed in some areas (Debela et al., 2015; Abera et al., 2019). For a transformation must come on food insecurity and livelihood susceptibility to climate variability and land degradation, diverse approaches should be applied sustainably.

Food availability depends, first and foremost, on the actual production of food, which is influenced by agro-ecological production potential as well as by available production technologies and input and output markets. Whether a household or a person can access food is determined by the income level unless the household produces the food itself. Also, the structure of the food supply chain, together with market and transport infrastructure, is an important additional factor. The stability of access to food depends on some political and economic factors, such as the stability of the political system and overall poverty levels (FAO, 2005). Besides, securing both sufficient and nutritionally recommended diversity and scale of food is essential to a human being (Abrol & Gupta, 2019). Hence, long-term development approaches including rehabilitation of degraded lands through the enactment of appropriate policies and supporting institutions and implementing useful techniques to adapt and mitigate climate change could contribute to food security transformations (Hamdy & Aly, 2014). As a short-term development path, capacity-building policies need to be executed to ensure food availability and a smooth transition to land rehabilitation. Because the rehabilitation policy has many advantages as it can avoid subsidy costs of the government and save hard currency which would otherwise be used to buy chemical fertilizers and pesticides, and most importantly, it is a policy through which building resilient livelihoods to shocks will not be disastrous (Ayenew & Kopainsky, 2014). Recapitalization of aid-reliant households in the medium-term and shifting from rainfall-dependent livelihoods in long-term strategies could help to meet the goal to eradicate hunger (FAO, 2019).

Transforming farmers from climate and land degradation-susceptible livelihoods to resilient means of living is less studied in the region. Documenting climate change impacts in relation to food security and farmers' adaptation and mitigation techniques could assist rural development policy and strategy to transform livelihood in a degraded and drought prone areas. The objectives of this study were to: (I) evaluate the impacts of climate variability and land degradation on food production; (II) evaluate the food security status of climate change vulnerable and land degradation-susceptible farmers; (III) assess measures used by farmers against climate extreme and land degradation; (IV) analyze challenges and opportunities to transform to resilient livelihood in climatic hazards and (V) identify determinants of food insecurity status of climate susceptible farmers.

## 2. Research methodology

### 2.1. The study area

The research was conducted in the North Wollo and Wag Hemira zones, which are among areas that are in the highlands of northern Ethiopia, in the Amhara Regional State. The geographic location of the area is 11° 30'–12° 50' N latitude and 38° 40'–39° 10' E longitudes (Fig. 1). Two districts: Sekota from Wag Hemira and Lasta from North Wollo, were included in this study. Both are dominantly mountainous and characterized by degraded steep slopes that are less suitable for agricultural crops. According to the CSA (2017) projection, total population of the North Wollo zone is 304,307 and the Wag Hemira zone is 89,652. While the total area of the North Wollo and the Wag Hemira zones covers 12,172.50 km<sup>2</sup> and 9,039.04 km<sup>2</sup>, respectively (CSA, 2013). Lasta has located 676 km from Addis Ababa whereas Sekota is a zonal town and 720 km away from the north of Addis Ababa (Tofu et al.,

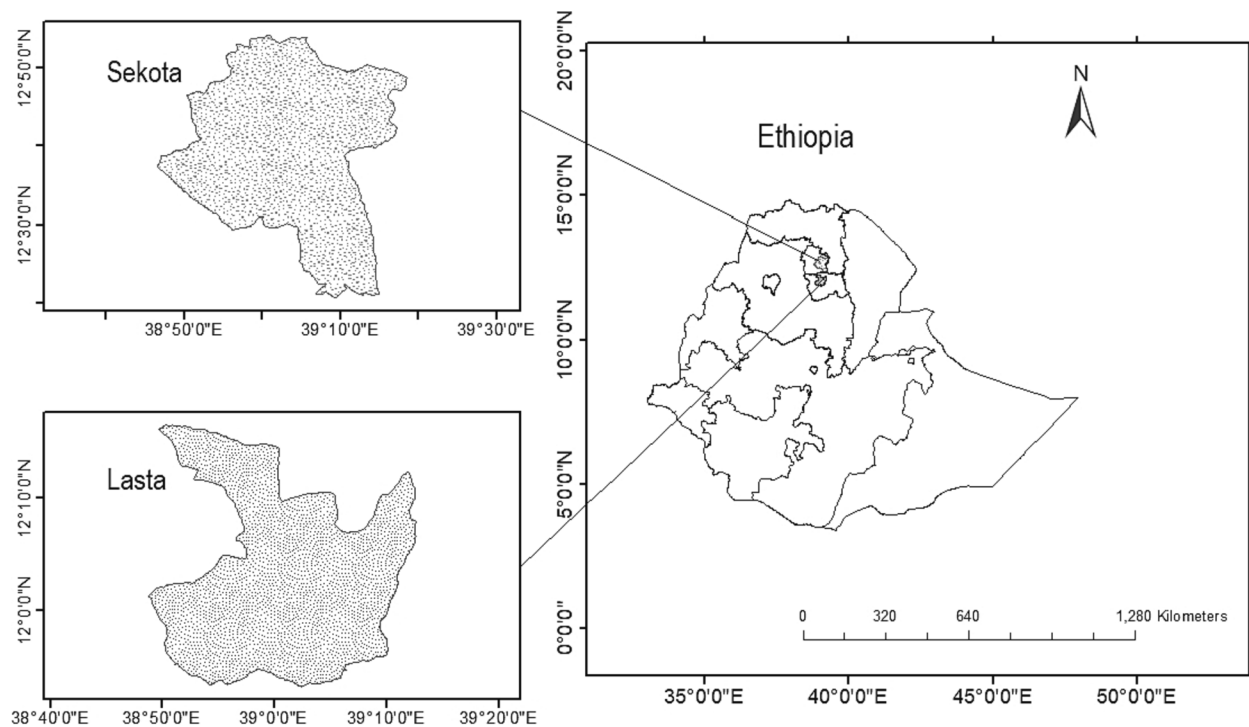


Fig. 1. Location of Sekota and Lasta woredas in northern Ethiopia.

2022b).

## 2.2. Method

### 2.2.1. Sampling procedures

Multistage sampling procedures were used to determine specific locations and individuals who participated during data collection. In the first stage, the North Wollo and Wag Hemira zones were purposefully selected given the high food insecurity and land degradation problem and susceptibility. In the second stage, the two districts, Lasta from North Wollo and Sekota from Wag Hemira, were purposively selected. In the third stage, a total of eight kebeles, four from each district, were randomly selected for primary data collection. Bilibala, Genete-Mariam, Erfa, and Yimrhane-Kristos kebeles were selected from the Lasta district, whereas Fikreselam, Wollehi, Abiya, and Tsemere kebeles were selected from the Sekota district. In the fourth stage, 342 heads of the household from both sexes were selected for survey data collection using the Yemane (1967) formula shown below (Eq. (1)). Poor and aid dependent farmers from both sexes were considered for quantitative data. This was because the study area was mostly aid dependent and the research was mainly intended to understand how donor fund reliant poor farmers transform from food insecurity due to climate variability and land degradation to food security and livelihood resilience.

$$n = N / (1 + N(e)^2) \quad (1)$$

where n is sample; N = total population; and e = error term.

Proportionate sample households' selection procedures were followed in the kebeles. Accordingly, from Bilibala, Genete-Mariam, Erfa, and Yimrhane-Kristos kebeles 43, 51, 43, and 42 households were selected, respectively, from the Lasta district, whereas from Fikreselam, Wollehi, Abiya, and Tsemere kebeles 40, 41, 43, and 39 households were sampled, respectively, from the Sekota district. In addition, 12 focus group discussions (FGD) including elder farmers, religious and kebele leaders, and experts were conducted. Participants for the FGD were selected in consultation with local agricultural development experts and kebele leaders with the assumption and understanding to acquire overall

information about the climate change impacts environmental situation and food security issues. Twenty-two key informants from kebele, woreda, and zone were responded on the semi-structured questionnaire. The experts and team leaders who have responsibility on activities of natural resource management, food security, disaster risk management, and climate were selected as key informants purposely. The district-level sectors and departments including agriculture and natural resources, environment and climate change, food security, disaster risk prevention and preparedness, and the Organization for Rehabilitation and Development in Amhara (ORDA) were visited for secondary data and key informant response.

**2.2.2.2. Approaches and design of the research.** In this research, mixes of quantitative and qualitative approaches were used to address the objectives. It is a paired research method to the traditional quantitative and qualitative research approaches (Dawadi et al., 2021). One of the most dominant traditional research paradigms is the positivism approach which considers that only the knowledge confirmed by the senses is affirmed as knowledge (Bryman, 2012). It follows the objective path in research and advocates that knowledge is gained through a gathering of objectively verifiable facts using quantitative data collection tools. Quantitative researchers are by far guided by positivism and they use quantitative tools to get objective findings in their study. The second traditional research approach is post-positivism, which is a minor form of positivism that follows the same principles but allows more interactions between the researcher and his/her research participants during data gathering (Taylor & Medina, 2011). When positivism focuses on the objectivity of the research process, post-positivism gives emphasis on the subjective process. This is why the present study used this approach, which holds the advantages of both positivist and post-positivist research schools of thought.

To achieve these, different methods and tools of data collection were utilized. Kale-Lostuvali (2007) stated that it is important to enrich the sources of data by using a combination of quantitative and qualitative methodologies, including participant observation and intensive interviewing. Accordingly, while household survey methods were used to collect quantitative data collection, FGD, and key informant interviews



(KII) were intensively used as methods to gather the required qualitative data from the study community. Regarding tools of data collection, while a semi-structured questionnaire was used for objective data, open-ended questions were used to guide iterative discussions and gather subjective responses from participants of the FGD and key informants. The questionnaire responded by the household head contains issues related to socio-economic, institutional, and biophysical conditions. Key informant interviews and focus group discussions were also focused on land degradation, food security, climate variability and its impacts, and adaptation of climate variability and land degradation challenges.

**2.2.2.3. Data analysis.** The study employed both descriptive and inferential statistics. Descriptive statistics were mainly used to analyze the perception of head of the households, food security status of the household, impacts of the climate change-induced episodes, and to assess the response strategies used by farmers to reduce susceptibility and build resilient livelihoods to climate change-persuaded extremes. The inferential statistics such as binary logistic regression model was used to know the association between dependent and independent variables in determining food insecurity and land degradation-susceptible farm households. The analyses of the data were carried out by using STATA version 64.

First, the food security status of the households was estimated. Food security is defined by calorie availability and consumption needs of calories. Therefore, household food security is determined by the difference between calorie availabilities and needs (Feleke et al., 2003). World Food Program (WFP) recommends food consumption score (FCS) and kilo-calorie intake as well to measure food security status (WEP, 2005). Compared to the two, the calorie intake model is a more direct indicator to measure the food security status of the households (Huang et al., 2015). Considering the advantage, this study used the calorie intake model to estimate the food security status of the households.

Accordingly, the type and quantity of food items consumed by the household for seven consecutive days were carefully collected using weighed records method. Then, it was converted to a standard kilocalorie and then divided into household size measured in adult equivalent (AE) and the number of days by employing an excel sheet. Following this, the amount of energy utilized in kilocalories by the household was compared with the minimum subsistence requirement per adult per day (i.e., 2100 kcal) (Feleke et al., 2003; Kidane et al., 2005; Awoke et al., 2022). This implies that the households whose per day kilocalorie intake is above the minimum threshold, which is 2100 kcal, are considered as food secured and represented by 1, whereas households whose per day kilocalorie intake is below 2100 kcal are understood as food insecure and represented by zero (0).

In this study, the dependent variable (i.e., household food security status) is a dummy variable (binary), which takes a value of 1 if the household is food secure and 0 otherwise. For the data with a dependent variable like this, we have two commonly used models, logit and probit. However, both give almost similar parameter estimations the binary logit model, has an advantage over probit in the analysis of dummy outcome variables because it is simple, flexible, and easily used (Babatunde et al., 2007; Awoke et al., 2022). Hence, this study adopted a binary logit model to identify the socioeconomic and biophysical determinants of food security status between food-secure and insecure groups of households. According to Gujarati (2004), the logistic distribution function for determining factors driving the food security status of smallholders can be specified as follow (Eq. (2) and (3):

$$A(x) = \frac{1}{1 + e^{-Z_i}} \quad (2)$$

where  $A(x)$  is the probability of being food secure and  $Z_i$  is the log of the odds ratio.

$$Z_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n \quad (3)$$

where  $\beta_0$  is an intercept;  $\beta_1, \beta_2 \dots \beta_n$  are coefficients to be estimated;  $X_i$  refers to independent variables.

The qualitative data collected through focus group discussions, key informant interviews, and personal observation was verbally transcribed and interpreted. It is the procedure to convert voice data into written forms. Next, the identification of themes or patterns of ideas or concepts was done to organize them into coherent categories that summarize and bring meaningful information to the conclusion. Finally, the organized data was analyzed thematically. Thematic analysis is a very important approach because it is one that looks across all the data to identify the common issues that recur and the main themes that summarize all the views you have collected (Quinn-Patton & Cochran, 2002).

### 3. Results and discussion

#### 3.1. Livelihood strategies of the community

In the study area, a mixed farming of crop and livestock by smallholder is the main source of income for the rural community. About 56 % of households are mainly dependent on agricultural activities. The farmers are very poor in terms of supporting their household needs. Manufacturing and selling the home-made alcoholic beverage 'Tella' (4 %), getting support from food aid through productive safety net program (PSNP), 32 %, post-harvest hay collection and sale to livestock owners (3 %), participating in daily labor works (3 %) and working share on other farmer fields (4 %) and temporary migration (2 %) in search of work within the country are additional livelihood activities practiced by food-insecure families. Residents with limited arable land are one of the most food-insecure segments of communities and are considered the poorest of the poor. For them, the existing opportunities to meet their consumption needs are not sufficient to ensure and sustain their well-being. Thus, in the study area, for long time, many farmers rely on external food aid provided by both local and international organizations as a means of livelihood option (Elias and Fantaye, 2000; Tofu et al., 2022b; Tofu & Wolka, 2022).

#### 3.2. Impacts of climate variability and land degradation on food production

Food production in the study area is poor. Soil degradation and consequent soil barrenness, reported by 97 % of the respondents, is the main cause of low productivity. Continuous deforestation, topography, and poor land management and repeated droughts have been the main causes of agricultural land degradation. Food security is adversely affected by land degradation that reduce agricultural productivity and yields (Midler, 2022). Ayenew (2015) reported that in Ethiopia, land degradation contributes significantly to the country's low average productivity. A study conducted in Zimbabwe reported that soil degradation had a significant impact on productivity (Manyeruke et al., 2013).

In the study area, about 96 % of farmers responded that they were facing severe challenges from food shortages and wait for the government or donor assistance. Morota et al. (2018) indicated that droughts are frequent in Ethiopia and have a significant impact on household food insecurity. Practically, reduced yields and lost agricultural production could reduce household income and reduced government revenue (Sultan et al., 2019). Crop yield and quality, and operational aspects of agricultural production, are directly affected by changes in climate parameters that influence the availability of water in the soil as well as for irrigation (World Bank, 2015). In different parts of Africa where livelihood is rain-fed subsistence farming, rainfall is the dominant determinant of food production, implying that higher food production is harvested in a wetter year with favorable weather, whereas lower production is obtained when the year experiences dry weather (Mwaniki, 2005; Nath & Behera, 2011; Morede, 2012; World Bank, 2015; Weldearegay & Tedla, 2018).

About 85 % of the respondents stated that climate variability-induced episodes added their own part by creating food-insecure households by crafting favorable conditions for the prevalence of crop pests and livestock diseases. The respondent households and individuals involved in the focus group discussion and key informant interview ranked the impacts of climate variability such as low yield, land degradation, food shortage, reduced income, food insecurity, exposition of the household to external aid, and the prevalence of pests and diseases. The discussants and interviewees underlined the challenge of food insecurity in all the studied kebeles, which is primarily associated with climate variability and historic land degradation.

For decades, most farmers in the study area could only live on their produce for six months. Six months of food shortages were covered by external helpers. Therefore, they receive external assistance from local authorities and international organizations in emergencies and on a regular basis. The main international agency providing regular support is the USIAD through different approaches (DFID, 2014). USIAD provides direct assistance to the poorest who cannot participate in the labor force (such as pregnant women, elderly, and disabled). Indirect food aid is provided in the form of wages to the poorest farmers for work in the PSNP.

The PSNP helps farmers establish soil and water conservation practices and builds their capacity to invest in sustainable land management and other public works to ensure the long-term food security of the vulnerable community. It is a program working to improve sustainable land management by increasing land use (Agitew & Singh, 2018). The program aims to rehabilitate degraded land and improve local productive capacity, thereby increasing their own adaptability and resilience among poor farmers in the study area. The aim was to build a livelihood system for the poorly, but progress has not been promising as recent study reported (Tofu et al., 2022a). This requires strategic development efforts and dynamic implementation of sound technologies for the food-insecure and growing population.

### 3.3. Estimating food security status

From the surveyed households ( $n = 342$ ) the majority (73 %) of the respondents were food insecure and 27 % of the households were food secured during data collection for this study. The average per day kilo calorie of food insecure households was 1,790 kcal, whereas the food secured households, on average, consume 2,850 kcal. This shows that majority of the households were under the minimum kilo-calorie intake requirement. Because, this is below from the country minimum, 2,200 kcal (Zemedu & Mesfin, 2014) and global minimum subsistence energy requirement for adult per day 2,100 kcal (Aragie and Genanu, 2017). Dependence of households on the small size of land with low farming capital and highly degraded land compounded with multiple biophysical and socio-economic hazards are factors responsible for food insecurity in the area. From the very beginning, the north Wollo area is initially impacted due to the historic drought, land degradation, highly vulnerable to climate change, and little adaptation to climate variability affects production and results in yield reduction and food insecurity (Belloumi, 2014).

In countrywide, millions require immediate food assistance and as a result, the country has been the largest recipient of food aid in sub-Saharan Africa (Ayenew & Kopainsky, 2014). In Ethiopia, about 10 % of the citizens are chronically food insecure and this figure rises to more than 15 % during frequent drought years (UNICEF, 2014). Another indicator of the presence and status of food insecurity at a national level is the prevalence of undernourishment of a large proportion of the population over the last one and half decades, particularly in the study area (Ayenew & Kopainsky, 2014). Due to this fact, the entire inhabitants of the study area were beneficiaries of the PSNP.

### 3.4. Farmers susceptibility to climate variability-persuaded episodes

Findings from qualitative data from FGD and KII participants and secondary data from desk reviews indicate that farmers in the study area are highly vulnerable to extreme episodes caused by climate change. The biggest impacts of climate change mentioned by respondents and discussants were heat waves, rainfall, frequent droughts, damaging floods, crop pests and animal diseases. Household reliance on rain-fed farming combined with climate variability contributes to existing vulnerabilities in the region. The vulnerability of human systems stems from the region's underdevelopment, high poverty rates, and livelihood choices.

If farmers rely on endangered and delicate livelihoods, they are very likely to be affected by climate change. The more farmers rely on climate-sensitive sectors for their livelihoods and incomes, the more vulnerable they are to climate change. In areas where rain-dependent livelihoods are the main source of livelihoods, farmers' adaptability is low and both sensitivity and exposure are considered very high, interviewees and key informants pointed out. This means that farmers are highly vulnerable and the conditions for building resilience are being questioned. Extreme episodes of rain-dependent agriculture due to climate change and variability have severe implications for livelihoods and food security (Williams et al., 2018). The rural poor, such as subsistence farmers who rely on rain-fed agriculture, are particularly vulnerable to disasters (Tofu, 2018b). Severe droughts and other climate extremes can reduce incomes and cause loss of assets, thereby eroding the future earning capacity of subsistence farmers and daily farm workers, and their ability to reduce their resilience (El Bilal et al., 2020).

### 3.5. Challenges to build resilience to climatic hazards

In the study area, the average size of arable land is 0.75 ha, which is slightly smaller than the national average land size. Moreover, declining soil fertility due to land degradation is a major problem of reduced productivity, food scarcity, food insecurity, low income, vicious cycle of poverty and high pre-existing vulnerability. The challenge army implies high exposure and sensitivity on the one hand and low adaptability to extreme episodes induced by climate change on the other. Protecting human health and livelihoods and ending the suffering of undernourished people is, of course, an issue of global importance (Schoch et al., 2017).

Focus group discussants and key informants were commented on importance of building sustainable livelihoods for these vulnerable farmers. Poverty, and land degradation expose communities to disproportionate impacts from climate hazards that can exacerbate socioeconomic crisis and undermine their ability to build resilience. Dependence on subsistence is the biggest barrier to building resilience for the poorest farmers. Farmers are the poorest because most of them are unable to meet the annual food needs of their households and therefore rely on external assistance for about half of the year to fill this gap, and in both study areas, farmers were supported by the PSNP program. Low productivity, land degradation, limited income, forced low capital, natural resources degradation and small land sizes are the main challenges that make farmers miserable, leading to food insecurity and high poverty levels. Oxfam (2010) found that climate change in Ethiopia is rapidly pushing the poorest and most marginalized communities beyond their capacity to cope, deepening the challenges to building resilience. Food insecurity patterns are seasonal and related to rainfall patterns, and the lack of seasonal rainfall in various regions of Ethiopia has dramatically increased hunger trends (USAID, 2015).

### 3.6. Opportunities to bounce back the impacts

Existing opportunities to offset vulnerability and increase resilience to the impacts of extreme events caused by climate change can be grouped into socioeconomic, biophysical, and institutional categories. Understanding the dynamics between different factors (i.e., biophysical,

social, economic, institutional) and involving local stakeholders in planning and decisions is a context-specific approach to increasing resilience (Nagy & Braatz, 2012). Investments require all necessary resources, so decisions to build resilience to climate risks should be guided by the lowest indicators of livelihood improvement for the vulnerable (Danda et al., 2022). Agriculture, water systems, the natural environment, and infrastructure are some key development areas to focus on when adapting to increasing climate shocks and stresses (GCA, 2019).

According to focused group discussions and key informants, farmers' experience is an asset-cumulated experience of existing conditions, social restraints and supports, surplus personnel, and repeated droughts. Land, natural climate (seasonal rainfall and temperature), and water resources are grouped under biophysical assets to build resilient livelihoods. On the other hand, institutional capital, such as the willingness of institutions (both local and international) and their accumulated experience in problem-solving, can be used to restore vulnerability and build resilient livelihoods in the study area. These multiple opportunities are used as important strategies for adaptation and mitigation of the impacts of climate change. Schoch et al. (2017) suggests that climate change adaptation interventions cannot achieve sustainable outcomes unless they address the root causes of poverty and vulnerability.

Climate change therefore requires approaches to sustainable development that consider the complex interactions between climate, society, and ecosystems. Climate resilient pathways are development pathways that combine adaptation and mitigation to achieve sustainable development goals (IPCC, 2014). In addition, risk mitigation through the lens of sustainable development could reduce people's exposure and vulnerability to current and future risks and strengthen the capacity of communities to anticipate, absorb and adapt to shocks (Bahamas, 2019). Thus, managing climate risks for the long term through the short-term humanitarian responses could build resilience of the most disadvantaged and vulnerable communities (Bahamas, 2019).

It is essential to build resilience of the community and achieve sustainable development goals at local and national levels (Schoch et al., 2017). Resilience is a state in which humans and nature are closely connected and influence each other in often unpredictable ways (Cote and Nightingale, 2012; Vasseur, 2015). Humans cannot survive without the environment and the ecosystem services. Therefore, resilience should focus on how socio-economic activities of the household and ecosystem cope with change by transforming complex risks into new opportunities (Kaur et al., 2019). In the study area, there are opportunities to improve the environment and ecosystem services mainly through integrated management of the local natural resource.

### 3.7. Local responses to transform from climate vulnerability and land degradation

To cope with an already changed climate, they used a two-dimensional response strategy involving coping and adaptation. Coping is the measures employed to deal with emergencies, and adaptation is the strategies applied to deal with changing climate realities. Adaptation helps build the resilience of affected households and is almost always pursued with the aim of building wealth and reluctance to address the erosion of the asset base of affected households. While coping, farmers will mostly use all their assets to survive difficult situations, making it more likely that their asset base will wear down in the future and the system will become more vulnerable.

Table 1 presents the response strategies used by food insecurity, climate change and land degradation prone farmers in the study area, which are mainly called 'autonomous response strategies'. Each adaptation option was subjected to principal component analysis before focusing on evaluating which strategies and how many farmers would be employed. The goal is to show that the identified adaptation options are consistent with each other, reduce the larger set of variables to a smaller set called 'principal components', and reduce commonly used response strategies identified by observation to It was to pick out. Response

**Table 1**

Strategies used by farmers to mitigate the impacts of climatic extremes in northern Ethiopia.

Adaptation measures	Adaptation (%)
Changing planting dates	82
Storing crop residue	74
Increased use of organic fertilizers	62
Soil and stone bund conservation	76
Tree planting	62
Off-farm diversification	37
Access to credit services	57
Use of inorganic fertilizers	69
Water harvesting	71

strategies using stress factors above 0.5 were used to describe adaptive (active) or coping (passive) strategies adopted by vulnerable farmers to extreme events, especially recurring droughts.

Among strategies, as responded by the 82 % of the farmers, the most common instrument used by food-insecure and climate-vulnerable farmers to mitigate the impacts of extreme events and improve adaptation to moderate impacts is changing the planting time. Soil and water conservation is the second most important adaptation strategy, used by approximately 76 % of respondents. This is an important strategy for retaining soil moisture and increasing yield. In fact, the land they live on is degraded and known for its low soil fertility. A variety of measures, including biological and physical techniques, are required in integrated approach to realize sustainable transformation from climate vulnerability and land degradation. This can be done by having local governments and encouraging farmers to take various measures to protect their degraded lands (Van et al., 2020).

About 74 % of respondents consider crop residue and hay storage as important adaptation strategy. The provision and use of rainwater harvesting systems is an adaptation strategy used by 70 % of food-insecure and climate-vulnerable farmers to the impacts of climate change. Increasing the use of inorganic and organic fertilizers is another response strategy, usually employed to increase productivity and yields, responded by 69 % and 62 % of the farmers, respectively. Farmers with good incomes use inorganic fertilizers, while poor farmers mostly use organic fertilizers. The recent unprecedented rise in fertilizer prices on international markets has incurred about 100 % of inflation in Ethiopia could hit many farmers.

About 57 % and 37 % of farmers reported using credit services and off-farm activities to increase their ability to purchase inputs and income streams, respectively. Loans may solve the investment challenges of poor farmers in purchasing inputs, such as installing irrigation canals. They were expected to be more resilient to droughts and other economic shocks than their counterparts due to their ability to accommodate more agricultural inputs and farm tools (O'Brien et al., 2004).

### 3.8. Determinants of food insecurity status of climate susceptible farmers'

Results of the binomial logit regression model for the determinants of food security status are shown in Table 2. Of the 13 explanatory variables believed to influence the food security status of subsistence farmers, 8 variables were found to be statistically significant, whereas 5 variables found non-significant ( $P < 0.05$ ) effect on security status. Detailed results of the model output are presented below.

As expected, age of the head of the household had a significant negative impact on home energy intake ( $P < 0.05$ ). A calculated odd ratio of 0.498 with an inverse odd ratio of 2.01 indicates that the elderly farmer is 2.01 times more food insecure compared to households with food security. This means that farms owned by older household heads are more likely to be food insecure and more vulnerable to climate change episodes than households headed by younger farmers. This reflects a lack of flexibility among older farmers to adopt different



**Table 2**

Explanatory variables influenced food security status of the farmers in northern Ethiopia.

Explanatory variables	Odds Ratio	Std. Err.	z	P > z	Inverse Odds Ratio
Age	0.498	0.197573	-1.76	0.079	2.01
Gender	0.702	0.317162	-0.78	0.434	1.42
Repeated drought	0.148	0.052539	-5.38	0.000	6.75
Farmland size	0.162	0.057665	-5.12	0.000	6.16
Dependent family size	0.560	0.222263	-1.46	0.144	1.79
Awareness to climate change	0.560	0.228547	-1.42	0.155	1.79
Credit access	4.603	1.88992	3.72	0.000	0.22
Unpredictability of rain	0.331	0.178045	-2.06	0.040	3.03
Fertilizer usage	2.891	1.18851	2.58	0.010	0.35
Off-farm income	1.724	0.686792	1.37	0.172	0.58
Amount of rainfall	0.404	0.18094	-2.02	0.043	2.47
Temperature change	0.602	0.274958	-1.11	0.266	1.66
Social assistance	2.883	1.27643	2.39	0.017	0.35
_cons	9.082	3.059714	6.55	0.000	
N	342				
KMO	0.820				
Bartlett's Test of Sphericity	0.000				
R <sup>2</sup>	0.3429				

Significance is  $p > 0.05$ .

technologies and strategies, and a weaker capacity to seek potential opportunities to mitigate the potential impacts of climate change and food production. Some previous studies have also shown a negative effect of age on household food security status (Mota et al., 2019; Agidew and Singh, 2018; Getaneh et al., 2022).

As hypothesized, repeated drought had negatively and significantly ( $P < 0.05$ ) influenced the food security status of the farm household. The calculated inverse odds ratio indicates that the impact of frequent droughts on food security for farmers in the region is 6.75 times that of subsistence farmers who have not faced such episodes. This may be because frequent climate shocks are taking a toll on rain-dependent agriculture, making households more food insecure and vulnerable to climate change. In the global South, where most production and livelihoods depend on rainfall, recurring droughts have a significant impact on food security for poor farmers (Holden & Shiferaw, 2004; Ngcamu & Felix Chari, 2020).

Farmland size had a negative impact on rural food production and its security status. The results show that a decrease of 1 ha in arable land increases food insecurity by 6.16 while all other variables remain constant. This means that increasing arable land increases yields. This is because greater farm size can give the opportunity to have production alternatives and yield. Higher yields are likely to improve food security status and reduce household vulnerability to climate change impacts (Haile et al., 2005; Astemir, 2014; Mekonnen et al., 2021).

As expected, access to and use of credit services has positively and significantly ( $P < 0.05$ ) influenced the food security status of subsistence farmers in the study area. The results suggest that when access and availability of credit services for poor farmers are improved, the ability of farmers to increase food security and reduce vulnerability to climate change compared to inaccessible farmers is enhanced. Poor farmers with access to credit services can help solve their capital problems by investing in a variety of improved agricultural technologies, such as improved seeds, fertilizers, pests and insecticides, and farm tools. The ability of this variable to resolve liquidity constraints for smallholder farmers positively contributes to food security in various sectors and settings (Debebe, 2017; Mohammed et al., 2021).

Unpredictability of rain, as expected, had negatively and significantly ( $P < 0.05$ ) affected the food security status of farmers. The results show that when other variables are held constant, the likelihood of food insecurity and vulnerability to climate change-induced episodes and

land degradation increases as precipitation unpredictability increases. This means that higher unpredictability of rainfall can lead to lower agricultural productivity, lower yields, and higher potential for food insecurity.

As expected, the use of agricultural inputs such as seed, and fertilizer had positively and significantly ( $P < 0.05$ ) impacted food security. The inverse odds ratio results show that agricultural productivity increases when households use more agricultural inputs, which increases food security status by 0.35. This suggests that households with access to improved seeds and fertilizers have higher yields and are therefore more likely to be food secure than the same households. This is directly related to the productivity and high yield and possibly food security situation of farmers in the study area. This result is consistent with previous studies that reported that favoring adoption of agricultural techniques has a positive effect on household food security (Beyene & Muche, 2010; Debebe, 2017; Mohammed et al., 2021).

Amount of rainfall received is a variable that is negatively and significantly ( $P < 0.05$ ) related to household food security. A calculated odds ratio of 0.404 with an inverse odds ratio of 2.47 indicates that a farmer perceiving a decrease in rainfall faces food insecurity by 2.47 times. Since the area is exposed for recurrent drought, reductions in rainfall from optimal levels primarily affect the productivity of crop production, leading to low yields and consequent food insecurity among subsistence farmers. This is consistent with previous studies (Demeke, 2011; Astemir, 2014; Abegaz, 2017).

Social assistance had a positive and statistically significant ( $P < 0.05$ ) impact on the food security status of farmers. The results show that farmers with access to social assistance in both emergencies and annual food shortages are 0.35 times better able to cope with emergencies and household vulnerability to climate change-induced episodes. This means that farmers who received food aid during the most difficult times were better mitigate the effects of food insecurity. Informal institutions that facilitate crop sharing arrangements and other forms of assistance to the poor, especially land leases, therefore play an important role (Beyene & Muche, 2010). Food assistance is also top ranked in communities vulnerable to recurrent droughts and in areas suffering from chronic and frequent food insecurity problems (Asefaw, 2022).

#### 4. Conclusions and recommendation

Extreme events related to climate change and variability are factors exacerbating the existing challenges of land degradation, and drought-prone farmers. In the region, current climate change and variability exacerbate existing challenges such as land degradation, low yields, reduced income, and food insecurity among subsistence farmers. As a result of the intertwined impacts, food insecurity is challenge for farmers. Food security status measured using the caloric intake approach showed that approximately 73 % of farmers were food insecure (1,790 kcal) and 27 % of respondents were food secure (2,850 kcal). When farmers rely solely on endangered and delicate livelihoods, they are likely affected by food insecurity. The more farmers rely on climate-sensitive sectors such as rain-fed agriculture on degraded soil for their livelihoods and income, the less resilient they are to climate impacts. To transform vulnerable community to the resilient means of living, site specific technologies (e.g., use of organic and inorganic fertilizers, soil and water conservation, tree planting and water harvesting) and livelihoods options (e.g., diversifying income and following sustainable livelihood strategy by emphasizing on biological and physical conservation activities on the degraded land) are needed. The technologies and practices to change existing land degradation, water scarcity and economic conditions, and increasing employment opportunities for the labor force can help. To reduce existing household vulnerabilities and capitalize on opportunities, farmers adopted a variety of response strategies, including changing seeding timing and soil and water conservation. But there were many factors that contributed to the vulnerability and food insecurity. Recurrent droughts, size of cultivated land,



unpredictable precipitation are among variables with significant negative impacts on food security. Credit services, fertilizer use, and social support could improve food security. Policymakers and development planners should consider those variables to transform and sustain the livelihood of food insecure and vulnerable farmers towards resilient status.

## Authors' contributions

Daniel Assefa Tofu initiated the idea and designed the data collection tools, undertook fieldwork and most of the analysis, and developed the manuscript. Kebede Wolka contributed in formatting the manuscript, subsidized through reading, edited the manuscript, and intensively worked on revising the manuscript.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

USAID is acknowledged for supporting field data collection for this research. World Vision Ethiopia arranged conditions to get financial support from USAID. International Livestock Research Institute provided technical support during field work. Authors would like to acknowledge Ambo University for hosting the project and coordination. Respondent farmers and experts in the study area are acknowledged for providing relevant data and hospitable cooperation during field work. Manuscript writing by second author was supported by the Norhed II project in Climate Smart Agriculture in Sub-Saharan Africa (funded by NORAD and coordinated by NMBU).

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