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Determinants of farmers' responses to climate variability hazards in East Belesa district, Ethiopia

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Abstract
Climate variability hazards are becoming more pronounced globally. Ethiopia being highly vulnerable due to its dependence on agriculture and natural resources. Adaptation strategies and coping mechanism are critical in reducing the adverse impacts of climate change and building resilience in these regions. This study aimed to explore farmers' response to climate variability hazards and its determinants of adaptation strategies and coping mechanism at East Belesa District. The study area was purposively selected due to its vulnerability to climate variability hazards, and one hundred thirty-three households were selected using a simple random sampling technique. Data were collected through interviews. The collected data were analyzed using SPSS version 22.0, employing descriptive statistics and binary logistic regression models. This study identifies and analyzes critical environmental stressors affecting agricultural systems, with a focus on climate-related hazards. The most prevalent stressor, drought (91.72%), is a major contributor to food insecurity. Flooding (69.92%), snow/hailstorms (90.22%), and frost (67.66%) are also significant stressors that affect crop production through soil erosion, nutrient depletion, and direct physical damage. Dry winds (85.71%) exacerbate erosion and crop desiccation, while crop disorders (75.93%) are increasingly linked to pests, diseases, and erratic weather patterns. Widespread erosion (87.21%), often resulting from heavy rainfall or flooding, further degrades soil health. The findings reveal that older, more experienced farmers with larger farms are more likely to engage in traditional practices like fallowing and planting Acacia species. Education, extension services, and credit access are key drivers of adaptive capacity, enhancing the likelihood of adopting sustainable farming practices. Off-farm coping strategies, including remittances and migration, are influenced by factors such as age and farm size, with younger farmers more likely to migrate. These results show the need for targeted interventions that combine both traditional and modern knowledge, to enhance climate resilience in farming communities.

Key words: *Adaptation strategies; Belesa district; climate variability hazards; determinants; farmers*

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Introduction

Climate change and variability exert profound and quantifiable effects on agriculture and food security across global, regional, and local scales (Hasegawa *et al.,* 2018). These impacts are multifaceted, encompassing rising temperatures, shifting precipitation patterns, and an increasing frequency of extreme weather events, all of which collectively threaten agricultural productivity and food systems worldwide. Globally, the agricultural sector is facing unprecedented challenges due to climate change. Since the late 19th century, the global average temperature has risen by 1.2°C, with significant consequences for crop yields. For instance, studies indicate that for each 1°C increase in temperature, global maize yields could decline by 7.4%, wheat by 6%, and rice by 3.2% (Zhao *et al.,* 2017). These declines are attributed to heat stress, altered growing seasons, and increased pest and disease pressures.

In addition to rising temperatures, changing precipitation patterns have aggravated both droughts and floods, leading to substantial crop losses. In particularly severe drought years, crop losses can reach up to 40%, severely disrupting food supply chains (FAO, 2020). These climate-related disruptions have contributed to a surge in global food insecurity. For example, the number of undernourished people worldwide rose from 663 million in 2019 to 811 million by 2021, with climate variability playing a significant role in this increase (WFP, 2024).

In Africa, the agricultural sector is especially vulnerable to climate change due to its heavy reliance on rain-fed agriculture. The continent has already experienced a warming trend of 0.3°C per decade since the 1980s, and future projections suggest temperature increases of 2°C to 4°C by 2100 (WMO, 2020). This warming is associated with significant reductions in crop productivity, particularly for staple crops such as maize, sorghum, and wheat (Waqas *et al.,* 2021). Rainfall variability has also intensified across the continent. For example, parts of East Africa have experienced a 10% reduction in rainfall over the past four decades (Niang *et al.,* 2014). This variability, coupled with more frequent and severe droughts, poses a dire threat to agricultural output. Droughts, which are projected to increase by 50% by 2050, could lead to further declines of 30-50% in agricultural productivity, exacerbating food insecurity (Kumar *et al.,* 2018). Currently, approximately 346 million Africans are experiencing food insecurity, largely driven by existing climate variability and other compounding factors (FAO, 2020).

In Ethiopia, agricultural productivity is highly sensitive to climate change. The country's average temperature has increased by 1.3°C since 1960 (Hadgu *et al.,* 2015), and rainfall variability has become more pronounced. Reductions in rainfall during the Belg (short rainy season) and Kiremt (main rainy season) have led to a 15-25% decline in agricultural productivity (Niang *et al.*, 2014).

Droughts, such as the severe event in 2015, have had devastating impacts on Ethiopian agriculture. During this drought, crop yields were reduced by 50%, and livestock losses ranged from 35-40% in affected regions like Afar and Somali (Mera, 2018). These losses have had cascading effects on food security, livelihoods, and economic stability, particularly in rural areas where agriculture is the primary source of income.

At the local level, regions like North Gondar and East Belesa District are experiencing severe agricultural impacts due to rising temperatures and rainfall variability (Amene *et al.*, 2022; Ketema *et al.,* 2024). In these areas, annual temperatures have increased, leading to a 10-15% decline in the yields of key crops such as maize and teff (Miheretu and Yimer, 2018). In East Belesa, rainfall during the Belg season has decreased by 25-30%, contributing to recurrent droughts and a 30% reduction in agricultural productivity (Enyew and Wassie, 2024). These trends highlight the urgent need for effective climate adaptation strategies and coping mechanisms to safeguard agricultural systems and ensure food security in vulnerable regions like East Belesa.

The ability of individuals and communities to respond and adapt to climate variability varies significantly due to a complex interplay of environmental, historical, socio-economic, and institutional factors (Below *et al.,* 2015). A comprehensive understanding of these factors, as well as the concepts, approaches, and methodologies related to vulnerability and adaptation, is essential for developing effective coping mechanisms (Bedeke, 2023). Developing targeted adaptation strategies requires site-specific measurements and prioritization of investments in the most vulnerable areas (Gizachew and Shimelis, 2014). Understanding the local challenges and context-specific impacts of climate change is critical for designing sustainable solutions (Keenan, 2015). Achieving effective and sustainable responses to global environmental change, particularly climate variability, demands a deeper level of comprehension and a holistic approach (Leck *et al*., 2015).

Given the critical need for localized adaptation strategies, this study focuses on farmers' responses to climate variability hazards in the East Belesa District. It examines the determinants of adaptation strategies and coping mechanisms, aiming to provide insights that can inform the development of targeted and sustainable solutions. By understanding how farmers perceive and respond to climate risks, this study seeks to contribute to the broader goal of enhancing agricultural resilience and food security in the face of a changing climate.

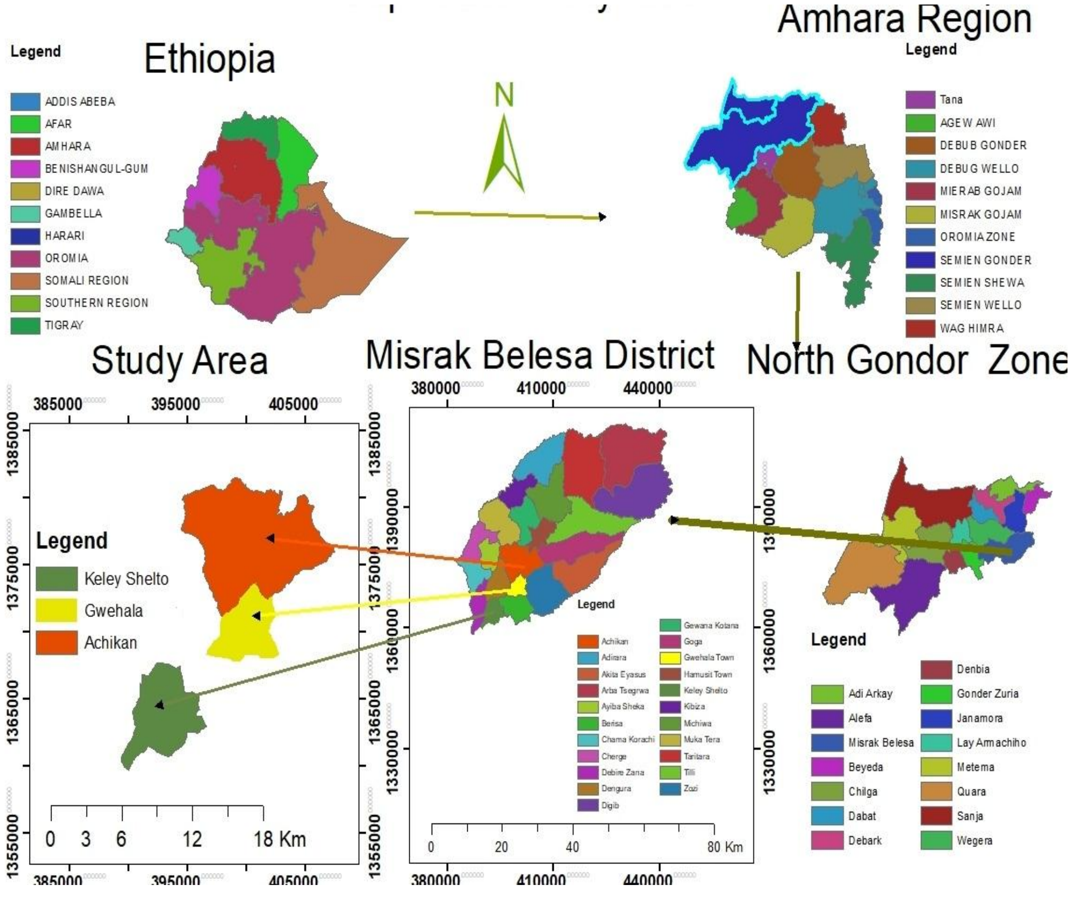
Materials and methods

Description of the study area

The study was conducted in East *Belesa* District, North *Gondar* Administrative Zone, Amhara Region, Ethiopia. This area lies within 12^{0} 16′ 45′′to 12^{0} 44′ 39′′ N latitude and 37^{0} 53′ 52′′ to 38^{0}29′ 01′′E longitudes at a distance of 729 km North-west of Addis Ababa and 164 km from Bahir Dar, the capital of Ethiopia and Amhara regional state, respectively (Figure 1).

Figure 1

Map of the study area hazards in East Belesa district, Ethiopia



Source: Author Arc GIS preparation

The latitudinal range of the district is from 1200 - 2000 meters above sea level. Topographically, the district is characterized by flat/plain, mountainous and rugged features, which constitute 55, 40, and 5% respectively. Soil erosion, land degradation, deforestation, increase rainfall variability and low soil fertility commonly mentioned environmental problems (Ketema *et al.,* 2024). According to the National meteorological station, annual rainfall in the district ranges from 651-965 mm per year and it is highly variable. Most of this rain is received during mid-June to early September. The mean annual temperature ranges from 14.4-33.6°C.

Sampling techniques and sample size

Both purposive and random sampling technique were used. The purposive sampling was used to select sample districts and *kebeles,* the lowest administrative units in the Ethiopian government structure, and the random sampling was used to select sample households. East Belesa district has 30 rural *Kebele*, which are classified into one agro-ecological zone of kola. The three *kebeles*, which were selected for this study, included *Keley shelto*, *Gwehala* and *Achikan*. In order to determine the sample size on which data were collected, the standard population survey formula was used (Cochran, 1977). The sample size was calculated as $n= Z^2pq/d^2$ Where Z= 1.96= is the standard of normal variable in the accepted level of d^2 confidence, P= is the proportion of the target population estimated to have the desired characteristics that are 90 %. From 3860 total house hold 133 households were selected as a sample for the survey study. Sample households were selected using a simple random sampling technique, which gives equal chance to be selected for all households. The first household was chosen randomly using a random number generator; subsequent households are chosen by applying a predetermined interval.

Data collection

This study employed a structured data collection approach aimed at capturing farm-level responses to climate variability-related hazards, focusing on three categories: adaptation strategies, on-farm coping mechanisms, and off-farm coping mechanisms. Data were collected through household surveys administered to a representative sample of farming households within the study area. To measure exposure to climate hazards, respondents explored their experiences with events such as drought, erratic rainfall, and temperature extremes. The study examined five common farm-level adaptation strategies fallowing, mulching, and application of farmyard manure, reduction in tillage frequency, and planting Acacia species. Similarly, farm-level coping mechanisms, including changes in planting date, use of drought-resistant seeds, intercropping, and leaving land for grazing, were captured as binary indicators of adoption during climate-related stress. Off-farm coping mechanisms to assess livelihood diversification, such as remittance income, migration for work, engagement in trade, and income from house rent, were also recorded. All data collection instruments were initially developed in English, reviewed by peers and revised based on the feedback received. Subsequently, they were translated into Amharic to ensure accurate understanding by respondents.

Both dependent and independent variables were clearly defined to analyze farm-level responses to climate variability-related hazards. The dependent variables captured household-level adoption of various strategies, including farm-level adaptation measures, on-farm coping mechanisms, and off-farm coping mechanisms designed to manage climate variability hazards. The independent variables were selected as potential explanatory factors influencing these adaptations and coping decisions. These included household head characteristics such as age, educational level, farm size, and farming experience. In addition, socioeconomic and institutional variables such as source of income, type of farming practiced, access to credit services, and access to agricultural extension services were incorporated into the analysis to account for their potential roles in shaping households' adaptive capacities.

Descriptive and Econometric Data Analysis

The data analysis for the study on climate variability-related hazards and farmers' adaptation strategies and coping mechanism involved both quantitative and qualitative approaches. Quantitative data, collected via closed-ended questionnaires, were analysed using SPSS (version 22.0). The data were coded, and descriptive statistics such as frequencies, percentages, and mean values were calculated to identify prevalent hazards and adaptation strategies. In contrast, qualitative data from semi-structured interviews were transcribed, coded, and thematically analysed to uncover underlying patterns and themes in farmers' experiences. Both datasets were integrated to provide a comprehensive understanding of the challenges and strategies related to climate variability.

Binary logistic regression model was employed to know determinant the factors affecting the choice of specific coping mechanisms related to climate variability hazards. adopted by the sample households in the study area. The empirical model is indicated here below:

$$Yi=\beta 0+\beta 1X_1+\ldots+\beta 2X_{10}$$

$$Yi=\beta 0+\beta 1\,AGEHH+\beta 3\,EDUSHH+\beta 4\,FAMHH+\beta 5\,HMHH+\beta 6\,FEHH+\beta 7\,SIHH+\beta 8\,KFP+\beta 9\,ACS+\beta 10\,AAE$$ *change in the independent variable.*

Where; Yi is local indicators of coping mechanism measures (dependent variables).

$\beta 0$- *is the constant term and* $\beta 1+\ldots+\beta 11$ *is parameter to be estimated.*

Additionally, the predictor variables were employed in estimating a binary logistic regression model to identify the determinant factors influencing farmers' responses to climate variability. This type of regression was utilized to predict a categorical dichotomous dependent variable using a set of predictor variables, which encompassed both continuous and discreet variables.

Results

Climate Variability Hazards in East Belesa District

The data presented in Figure 2 highlights several critical environmental stressors affecting agricultural systems in East Belesa District, each of which carries significant implications for the development of effective adaptation strategies. These hazards, driven by climate variability, pose substantial challenges to agricultural productivity, food security, and the livelihoods of farming communities. Drought emerged as the most prevalent hazard, with 91.72% of respondents identifying it as a major concern. Drought is particularly devastating in regions like East Belesa, where agriculture is predominantly rain-fed. Prolonged periods of water scarcity can lead to crop failure, reduced yields, and severe food insecurity, threatening the survival of both rural households and local economies. The high prevalence of drought underscores the urgent need for water conservation techniques, drought-resistant crop varieties, and improved irrigation systems to mitigate its impacts.

Flooding was reported by 69.92% of respondents, representing another significant threat to agricultural systems. Floods often result in soil erosion, nutrient depletion, and damage to critical infrastructure such as roads and storage facilities. These effects not only reduce agricultural productivity but also hinder farmers' ability to transport and market their produce. Addressing flooding requires integrated land management practices, such as afforestation, terracing, and the construction of flood control systems, to minimize its destructive consequences. Snow and hailstorms were perceived as major hazards by 90.22% of respondents, particularly in mountainous or high-altitude areas of the district. These extreme weather events can cause direct physical damage to crops, leading to significant financial losses for farmers. The unpredictability of snow and hailstorms further complicates agricultural planning and risk management, necessitating the adoption of protective measures such as crop insurance, early warning systems, and resilient farming practices. Frost, reported by 67.66% of respondents, is another critical stressor, especially in higher elevations and colder climates. Frost can damage crops during vulnerable growth stages, such as flowering or early seedling development, leading to reduced yields or complete crop failure. Farmers in frost-prone areas require access to frost-resistant crop varieties, as well as techniques like mulching and row covers to protect their crops during cold spells.

Dry winds were experienced by 85.71% of respondents, contributing to soil erosion and the desiccation of crops. These winds exacerbate water loss from soils and plants, further straining already limited water resources. Combating the effects of dry winds requires the implementation of windbreaks, such as tree planting, and the adoption of soil moisture conservation practices like conservation tillage and cover cropping. Finally, widespread erosion, reported by 87.21% of respondents, is a persistent issue often triggered by heavy rainfall or flooding. Soil erosion leads to the loss of fertile topsoil, reducing land productivity and increasing the vulnerability of agricultural systems to other climate-related hazards. Addressing soil erosion demands comprehensive soil conservation strategies, including contour plowing, agroforestry, and the restoration of degraded lands.

The binary logistic regression models presented in Table 1 analyze farm-level adaptation strategies employed by farmers to mitigate the impacts of climate variability hazards. These strategies include fallowing, mulching, using farmyard manure, reducing tillage frequency, and planting Acacia species. The models assess the influence of various socio-economic and farm-specific factors, such as age, education level, farm size, farming experience, income level, type of farming, access to credit, and availability of extension services. The results indicate that these factors significantly shape farmers' adoption of adaptation strategies ($p < 0.01$). For instance, farmers with higher education levels and access to extension services are more likely to adopt innovative practices like mulching and fallowing, while those with larger farm sizes may prioritize strategies such as planting Acacia species for soil conservation. These findings highlight the critical role of education, resource availability, and institutional support in enabling farmers to adapt to climate variability.

Figure 2

Climate variability related hazard in East Belesa district, Ethiopia

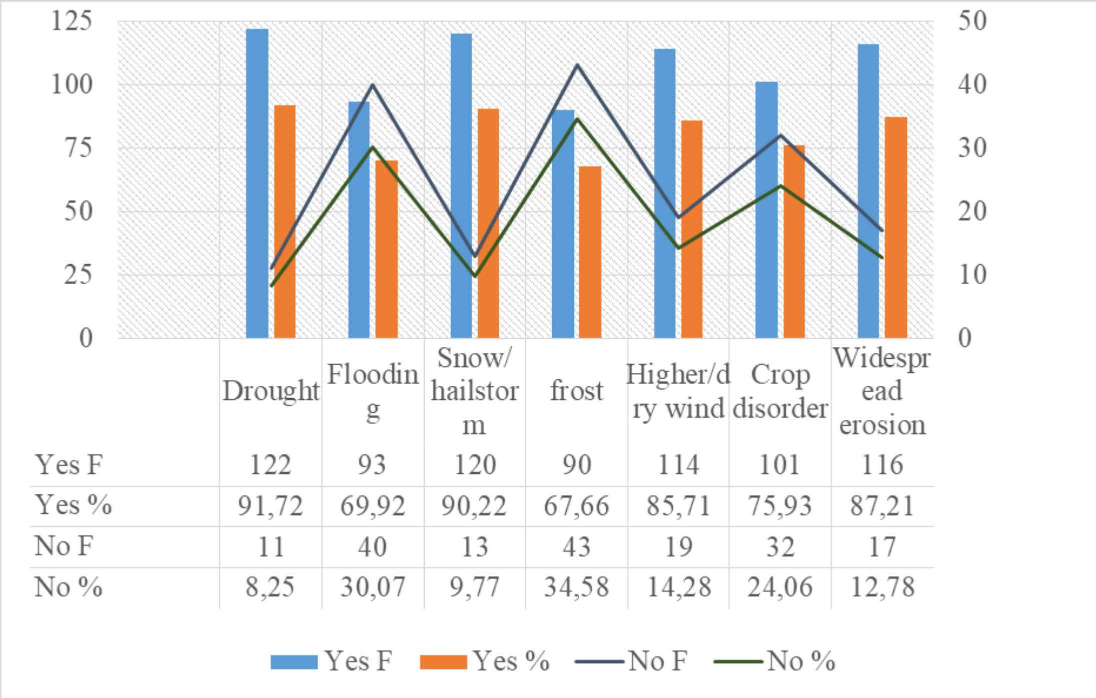


Table 1

Binary logistic models of farm-level climate variability hazard adaptation strategies in East Belesa district, Ethiopia

Independent Variable	Fallowing			Mulching			Farm Yard manure			Reduce tillage frequency			Planting Acacia Species		
	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Age	.108	.001	1.03	-.030	.617	.780	.361	.002	1.265	-.127	.005	.774	.689	.005	1.719
Education	-.036	.001	.866	.166	.001	1.847	.385	.005	1.832	.167	.673	1.161	.811	.001	1.526
Farm size	.215	.005	1.239	.062	.850	1.371	-.282	.101	.864	.246	.002	1.590	-.090	.634	.843
Farm experience	.319	.003	1.7527	.625	.141	1.430	-.020	.933	.981	.082	.775	1.197	-.721	.020	.486
Source of income	.043	.004	1.230	.054	.005	1.155	.131	.001	1.032	.062	.235	2.152	.834	.908	2.004
Kind of farming	.073	.864	3.928	-.746	.246	.564	.075	.821	1.078	-.031	.954	.779	.914	.053	2.495
Credit	-.541	.168	.678	.863	.097	2.124	0.426	.005	.731	-.110	.073	.330	1.769	.007	1.215
Extension	.231	.001	1.302	.980	.001	2.335	.214	.001	1.82	.852	.001	1.212	.475	.001	1.530

Similarly, Table 2 presents the results of binary logistic regression models examining farm-level coping mechanisms used by farmers to address climate variability hazards. These mechanisms include changing planting dates, sowing drought-resistant seeds, intercropping, and leaving land for grazing. The analysis identifies key determinants influencing the adoption of these strategies, such as education, farm size, farming experience, age, source of income, type of farming, access to credit, and extension services ($p < 0.01$). For example, farmers with access to credit and extension services are more likely to adopt drought-resistant seeds and intercropping, as these resources provide the necessary knowledge and financial support for such practices. Additionally, older farmers with extensive experience may prefer traditional coping mechanisms like changing planting dates, while younger, more educated farmers may opt for innovative approaches such as intercropping. These results underscore the importance of tailored support systems that consider the diverse socio-economic backgrounds of farmers.

Table 2

Binary logistic models of farm-level climate variability hazard coping mechanism in East Belesa district, Ethiopia

Independent Variable	**Change planting date**			**Sow drought resistance seed**			**Inter cropping**			**Leave land for grazing**		
	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)	B	Sig.	Exp(B)
Age	-.024	.745	.886	.625	.005	1.195	.742	.004	1.359	-.056	.007	.846
Education	1.222	.005	2.321	.112	.001	1.002	-.372	.333	.689	.768	.001	1.464
Farm size	.649	.001	1.762	-.218	.191	.804	-.164	.446	.849	-.295	.017	.744
Farm experience	1.107	.657	2.122	.723	.001	1.385	-.680	.258	.819	.211	.129	1.137
Source of income	-.201	.162	.704	.455	.009	1.665	.335	.004	1.235	.028	.661	1.218
Kind of farming	1.877	.003	1.156	.441	.532	1.639	1.433	.001	2.358	.757	.001	1.669
Credit	-.353	.776	.882	.201	.003	1.312	-1.358	.131	.257	.984	.001	2.195
Extension	6.223	.001	2.101	1.084	.001	2.438	1.038	.312	1.454	.283	.001	2.353

Furthermore, Table 3 explores off-farm coping mechanisms that farmers employ to manage the impacts of climate variability hazards. These mechanisms include remittances, migration, trade, and house rent. Among these, remittances emerge as a particularly significant strategy, influenced by factors such as age, education level, and farm size ($p < 0.01$). For instance, younger farmers with smaller landholdings may rely more on remittances and migration as alternative income sources, while those with larger farms may diversify into trade or renting out property. These off-farm strategies provide a vital safety net for farmers facing reduced agricultural productivity due to climate variability.

Table 3

Binary logistic models of farm-level climate variability hazard off-farm coping mechanism in East Belesa district, Ethiopia

Independent Variable	Remittance			Migration			Trade			House rent		
	B	Sig.	Exp (B)	B	Sig.	Exp (B)	B	Sig.	Exp (B)	B	Sig.	Exp (B)
Age	.814	.005	2.814	-.432	.001	.862	-.006	.861	.924	-.347	.001	.954
Education	-.684	.007	1.605	-.378	.273	.685	-.535	.017	.586	.647	.008	2.954
Farm size	.383	.006	1.488	-.111	.020	.518	.401	.030	1.818	-.335	.006	.995
Farm experience	.023	.932	1.023	-.695	.158	.499	-.210	.006	.611	-1.41	.002	.320
Source of income	-.039	.239	.740	.051	.165	1.052	.032	.005	1.323	.017	.702	1.017
Kind of farming	-.136	.565	0.623	.771	.141	2.185	.273	.416	1.314	.699	.204	1.821
Credit	-.867	.005	2.153	.882	.223	2.311	.758	.107	2.135	.138	.004	1.471
Extension	-.923	.001	.846	.760	.639	1.769	.333	.626	1.395	.345	.763	1.233

Discussion

Climate variability hazards, including drought, flooding, hailstorms, frost, snow, and dry winds, are becoming more frequent and severe, largely driven by human-induced climate change (Jain, 2022). Historically, such weather extremes were part of natural climate cycles. However, global warming has amplified their intensity and frequency, disrupting traditional weather patterns across many regions of the world (Zscheischler *et al.*, 2028). Droughts are now lasting longer and affecting larger areas, while floods are more intense, causing widespread destruction of infrastructure and agricultural land. Hailstorms and frost events, once relatively rare, are becoming more common, damaging crops and reducing yields. The shifting nature of these climate events poses a serious threat to ecosystems and livelihoods, particularly in regions heavily dependent on rain-fed agriculture. This escalating trend shows the critical need for proactive and robust adaptation strategies to mitigate the adverse impacts of climate variability. In the agricultural sector, improving land management practices and adopting innovative techniques are key steps toward building climate resilience. Strategies such as conservation agriculture, agroforestry, integrated water resource management, and the use of climate-smart technologies can help farmers adapt to changing weather conditions, reduce vulnerability, and maintain food production (Anderson *et al.*, 2020). Strengthening these approaches will be essential for ensuring long-term food security in a world facing unprecedented climate challenges.

The adoption of various agricultural adaptation strategies is influenced by a combination of socio-economic factors, access to resources, and traditional knowledge. These strategies play a critical role in enhancing resilience to climate variability and improving sustainable land management practices. Fallowing, a traditional practice where land is left uncultivated to allow soil recovery, is more commonly adopted by older and more experienced farmers. These farmers often draw on generations of traditional soil management knowledge, recognizing the long-term benefits of fallowing for soil health and fertility (Taye and Megento, 2017). Additionally, larger landholders are more likely to adopt fallowing due to their greater flexibility in land use. With more land available, they can afford to leave portions uncultivated without significantly influencing their overall productivity (Subedi *et al.*, 2022). This practice highlights the importance of integrating traditional knowledge with modern agricultural systems to promote sustainable land management.

Mulching, a technique used to conserve soil moisture and regulate temperature, is heavily influenced by education, income levels, and access to extension services. Educated farmers are more likely to understand the scientific principles behind mulching and its benefits for crop production. Similarly, farmers with higher incomes can afford the materials needed for effective mulching. Access to extension services further encourages adoption, as these services provide technical guidance and demonstrate the practical application of mulching in field conditions (Turyahabwe *et al.*, 2022). This underscores the critical role of education and institutional support in promoting climate-resilient agricultural practices.

The use of farmyard manure, a key strategy for improving soil fertility, is associated with factors such as age, education, and access to credit. Older farmers, with their wealth of experience, tend to appreciate the long-term benefits of organic fertilizers like manure. Educated farmers are also more likely to adopt this practice, as they understand its role in enhancing soil structure and nutrient content. Access to credit enables farmers to invest in the resources needed to collect, store, and apply manure effectively (Sharna *et al.*, 2024). This practice exemplifies the synergy between traditional knowledge and modern agricultural inputs in building sustainable farming systems

Reducing tillage frequency, a practice aimed at minimizing soil disturbance and erosion, is more prevalent among larger farms and farmers with access to extension services. Larger farms often have the resources and equipment needed to implement reduced tillage practices effectively. Extension services play a crucial role in encouraging farmers to adopt this sustainable land management practice by providing training and demonstrating its benefits, such as improved soil health and reduced labor costs (Legesse *et al.*, 2021).

The adoption of Acacia species in agroforestry systems is influenced by age, education, and access to extension services. Older farmers, with their deep understanding of local ecosystems, recognize the multiple benefits of Acacia species, including soil fertility improvement, nitrogen fixation, and water retention in semi-arid regions. Educated farmers and those with access to extension services are more likely to adopt this strategy, as they are better informed about its ecological and economic advantages (Miheretu and Yimer, 2018). This practice highlights the importance of agroforestry in enhancing climate resilience and sustainable land use.

Education and extension services play a pivotal role in enhancing farmers' ability to adapt to climate variability. Educated farmers are more likely to adjust planting dates based on climate knowledge and forecasts, demonstrating their capacity to respond to changing weather patterns (Ali *et al.*, 2020). Extension services provide critical support by disseminating information about improved practices and technologies, such as drought-resistant seeds and intercropping techniques. These services bridge the gap between traditional knowledge and modern innovations, enabling farmers to adopt more resilient and sustainable practices (Dessalegn *et al.*, 2022).

The adoption of drought-resistant seeds is influenced by age, farming experience, and access to extension services. Older and more experienced farmers, who have witnessed the impacts of drought firsthand, are more likely to recognize the benefits of these seeds in mitigating crop losses. Extension services further support adoption by providing information about improved seed varieties and their suitability for local conditions (Baloyi, 2023). This strategy is particularly important in drought-prone regions, where it can significantly enhance food security and livelihoods.

Intercropping, the practice of growing multiple crops together, is closely linked to diversified farming systems and alternative income sources. Farmers engaged in mixed farming are more likely to adopt intercropping, as it enhances crop resilience and spreads income risk across different crops. This practice also improves soil health and reduces pest infestations, making it a valuable strategy for sustainable agriculture (Sivaraman *et al.*, 2023).

Leaving land for grazing is a practice more common among younger farmers and is positively influenced by education and access to credit. Educated farmers are better equipped to manage grazing lands sustainably, while access to credit enables them to invest in livestock and grazing infrastructure. This practice not only supports livestock production but also improves soil health through natural fertilization and reduced erosion (Asante *et al.*, 2018).

The reliance on remittances as a coping mechanism varies significantly among farmers based on factors such as age, education level, and farm size. Older farmers, for instance, tend to depend more on remittances as a source of income (Veljanoska, 2022). This could be attributed to their reduced capacity to engage in physically demanding agricultural activities or their limited access to alternative income sources. In contrast, farmers with higher levels of education are less reliant on remittances, as they are more likely to explore and engage in alternative income-generating activities (Redehegn *et al.*, 2019). Education equips farmers with the knowledge and skills to diversify their income streams, reducing their dependence on external financial support.

Farm size also plays a crucial role in shaping farmers' reliance on remittances. Interestingly, larger farm sizes are positively associated with remittance dependence, indicating that even farmers with more land may still require external financial assistance (Wafula *et al.*, 2016). This could be due to the higher costs associated with managing larger farms, such as purchasing inputs, hiring labor, or dealing with climate-related challenges, which may strain their financial resources.

Migration, as a coping strategy, shows a negative association with both age and farm size. Younger farmers, who are often in search of better economic opportunities and may face fewer family obligations, are more likely to migrate (May *et al.*, 2019). This aligns with the idea that migration serves as a survival strategy for youth, particularly in the face of agricultural difficulties exacerbated by climate stress. On the other hand, farmers with larger landholdings are less inclined to migrate, as they may have more at stake in terms of their agricultural investments and may prefer to stay and manage their farms.

Trade is another important coping mechanism, influenced by education and farm size. Less educated farmers are more likely to engage in small-scale trade, which requires minimal capital and expertise. In contrast, larger farms, which often produce surplus yields, facilitate larger trading activities (Duguma, 2022). This suggests that farm size not only affects the scale of agricultural production but also the scale of trade activities that farmers can undertake.

House rent as a coping strategy is strongly associated with age, education, and access to credit. Younger farmers are less likely to rent out houses, possibly due to their limited property ownership or their focus on other income-generating activities. More educated farmers, however, are more likely to engage in house renting, as they may have a better understanding of property management and the potential income it can generate (Holme, 2022). Access to credit also plays a pivotal role in enabling off-farm activities such as trade and house renting, as it provides the necessary financial resources to invest in these ventures (Ullah *et al.*, 2022).

Conclusion

The data demonstrates that climate-related environmental stressors, including drought, flooding, snow/hailstorms, frost, dry winds, crop disorders, and widespread erosion, significantly impact agricultural productivity and food security. These challenges are likely to intensify with ongoing climate change, necessitating urgent adaptation measures. The findings underscore the critical role of socio-economic factors and institutional support in helping farmers adapt to climate variability. Education, extension services, and credit access are key drivers of adaptive capacity, enhancing the likelihood of adopting sustainable farming practices. While traditional strategies like fallowing and planting Acacia species remain common among older farmers, educated farmers tend to favor modern techniques such as mulching and reduced tillage.

Off-farm coping strategies, including remittances and migration, are influenced by factors such as age and farm size, with younger farmers more likely to migrate. These results emphasize the need for targeted interventions that combine both traditional and modern knowledge, alongside improved access to financial and technical resources, to enhance climate resilience in farming communities. An integrated approach recognizing the interconnectedness of farming and non-farming activities is essential for effective coping mechanism.

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References

Ali U, Wang J, Ullah A, Tan Y, Nurgazina Z & ZA Khan. (2020). Determinants of farmers' choice adaptation strategies to climate change: Evidence from Khyber Pakhtunkhwa Pakistan. *Pakistan Journal of Agricultural Sciences*.57: 941-951.

Amene D, Alemu A, Birhanu T, Gebremariam T, Hagos T & N Holvoet. (2022). Gender and climate change: perception, vulnerability and agriculture-related adaptation preferences among male and female-headed households in Northwest Ethiopia.

Anderson R, Bayer PE & D Edwards. (2020). Climate change and the need for agricultural adaptation. *Current opinion in plant biology*. 56: 197-202.

Asante BO, Villano RA, Patrick IW & GE Battese. (2018). Determinants of farm diversification in integrated crop–livestock farming systems in Ghana. *Renewable Agriculture and Food Systems*. 33: 131-149.

Asfaw A, Simane B, Hassen A & A Bantider. (2017). Determinants of non-farm livelihood diversification: evidence from rainfed-dependent smallholder farmers in northcentral Ethiopia (Woleka sub-basin). *Development Studies Research*. 4: 22-36.

Baloyi S. (2023). Determinants of Maize Seed Selection for Climate Change Adaptation among Emerging Farmers in Mopani District, Limpopo Province, South Africa (Doctoral dissertation).

Bedeke SB. (2023). Climate change vulnerability and adaptation of crop producers in sub-Saharan Africa: A review on concepts, approaches and methods. *Environment, Development and Sustainability*. 25: 1017-1051.

Below TB, Mutabazi KD, Kirschke D, Franke C, Sieber S, Siebert R & K Tscherning. (2012). Can farmers' adaptation to climate change be explained by socio-economic household-level variables?. *Global environmental change*. 22: 223-235.

Cochran WG. (1977). *Sampling Techniques*, 2nd Ed., New York: John Wiley and Sons, Inc.

Dessalegn B, Asnake W, Tigabie A & QB Le. (2022). Challenges to adoption of improved legume varieties: a gendered perspective. *Sustainability*. 14: 2150.

Duguma B. (2022). Farmers' perceptions of major challenges to smallholder dairy farming in selected towns of Jimma Zone, Oromia Regional State, Ethiopia: Possible influences, impacts, coping strategies and support required. *Heliyon*. 8: e09581

Enyew FB, & SB Wassie. (2024). Rainfall trends and spatiotemporal patterns of meteorological drought in Menna watershed, northwestern Ethiopia. *Heliyon*. 10.

Food and Agriculture Organization (FAO). (2020). The State of Food Security and Nutrition in the World FAO.

Gizachew L & A Shimelis. (2014). Analysis and mapping of climate change risk and vulnerability in Central Rift Valley of Ethiopia. *African Crop Science Journal*. 22: 807-818.

Hadgu G, Tesfaye K & G Mamo. (2015). Analysis of climate change in Northern Ethiopia: implications for agricultural production. *Theoretical and applied climatology*. 121: 733-747.

Hasegawa T, Fujimori S, Havlík P, Valin H, Bodirsky BL, Doelman JC & P Witzke. (2018). Risk of increased food insecurity under stringent global climate change mitigation policy. *Nature climate change*. 8: 699-703.

Holme JJ. (2022). Growing up as rents rise: How housing affordability impacts children. *Review of Educational Research*. 9: 953-995.

Jain M. (2022). Increasing atmospheric extreme events and role of disaster risk management: Dimensions and approaches. In *Extremes in Atmospheric Processes and Phenomenon: Assessment, Impacts and Mitigation* (pp. 303-328). Singapore: Springer Nature Singapore.

Keenan RJ. (2015). Climate change impacts and adaptation in forest management: a review. *Annals of forest science*. 72: 145-167.

Ketema N, Mintesnot A, Abraham M & A Selomon. (2024). Farmers' perceptions of climate change and variability and determinants of adaptation strategies and coping mechanism in Ethiopia. *Journal of Science and Inclusive Development*. 6: 43-66

Kumar P, Tokas J, Kumar N, Lal M & HR Singal. (2018). Climate change consequences and its impact on agriculture and food security. *International Journal of chemical studies.* 6: 124-133.

Leck H, Conway D, Bradshaw M & J Rees. (2015). Tracing the water–energy–food nexus: Description, theory and practice. *Geography Compass*. 9: 445-460.

Legesse W, Haji J, Ketema M & B Emana. (2021). Determinants of adoption of sustainable land management practice choices among smallholder farmers in Abay Basin of Oromia, Ethiopia. *J. Dev. Agric. Econ*. 13: 1-9.

May D, Arancibia S, Behrendt K & J Adams. (2019). Preventing young farmers from leaving the farm: Investigating the effectiveness of the young farmer payment using a behavioural approach. *Land use policy*. 82: 317-327.

Mera GA. (2018). Drought and its impacts in Ethiopia. *Weather and climate extremes*. 2018; 22: 24-35.

Miheretu BA & AA Yimer. (2018). Land use/land cover changes and their environmental implications in the Gel ana sub watershed of Northern highla nds of Ethiopia. *Environmental Systems Research*. 6: 1-12.

Niang I, Ruppel OC, Abdrabo MA, Essel A, Lennard C, Padgham J & P Urquhart. (2014). Africa. Climate change 2014: impacts, adaptation, and vulnerability. Part B: regional aspects. Contribution of working Group II to the fifth assessment report of the intergovernmental panel on climate change. 1199-1266.

Omirin OJ & C Okpara. (2018). Off-farm activities as income strategies among rural women in Ido Local Government Area, Ibadan, Nigeria. *Afr. J. Psychol. Stud. Soc*. 21: 224-239

Redehegn MA, Sun D, Eshete AM & CN Gichuki. (2019). Development impacts of migration and remittances on migrant-sending communities: Evidence from Ethiopia. *PLoS One*. 14: e0210034.

Sharna SC, Maraseni T & AM Radanielson. (2024). Determinants of organic soil fertilization methods use over time and in the face of climate vulnerability. *Soil and Tillage Research*. 240: 106066.

Sivaraman K, Thankamani CK & V Srinivasan. (20 23). Crop Diversification: Cropping/S ystem Approach for Enhancing Farmers' Income. In *Handbook of Spices in India: 75 Years of Research and Development*. Singapore: Springer Nature Singapore.3847-3926

Subedi YR, Kristiansen P & O Cacho. (2022). Reutilising abandoned cropland in the Hill agroecological region of Nepal: Options and farmers' preferences. *Land Use Policy*. 117: 106082.

Taye A & TL Megento. (2017). The role of indigenous knowledge and practice on water and soil conservation management in Albuko Woreda, Ethiopia. *International Journal of*

Bonorowo Wetlands. 7: 95-107.

Turyahabwe R, Wambede NM, Asaba J, Mulabbi A & LG Turyabanawe. (2022). Factors affecting the adoption of soil and water conservation practices by small-holder farmers in Muyembe Sub-County, Eastern Uganda. *Ghana Journal of Geography*. 14: 24-49.

Ullah A, Mahmood N, Zeb A & H Kächele. (2020). Factors determining farmers' access to and sources of credit: evidence from the rain-fed zone of Pakistan. *Agriculture*. 10: 586.

Veljanoska S. (2022). Do remittances promote fertilizer use? The case of Ugandan farmers. *American Journal of Agricultural Economics*. 104: 273-293.

Wafula WN, Korir KN, Ojulong H F, Siambi M & JP Gweyi-Onyango. (2016). Finger millet (*Eleusine coracana* L.) grain yield and yield components as influenced by phosphorus application and variety in Western Kenya. *Tropical Plant Research*. 3: 673-680.

Waqas MA, Wang X, Zafar SA, Noor MA, Hussain HA, Azher Nawaz M & M Farooq. (2021). Thermal stresses in maize: effects and management strategies. *Plants*. 10 *:* 293.

World Meteorological Organization (WMO). (2020). State of the Climate in Africa 2019.

World Food Programme (WFP). Hunger map 20 21. Avaliable from https://www.wfp.org/hunger-map *Accessed October 2024.*

Zhao C, Liu B, Piao S, Wang X, Lobell DB, Huang Y & S Asseng. (2017). Temperature increase reduces global yields of major crops in four independent estimates. *Proceedings of the National Academy of sciences*. 114: 9326-9331.

Zscheischler J, Westra S, Van Den Hurk BJ, Seneviratne SI, Ward PJ, Pitman A & X Zhang. (2018). Future climate risk from compound events. *Nature climate change*. 8: 469-477.