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Farmers' perceptions of climate change and variability and determinants of adaptation strategies and coping mechanism in Ethiopia

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Abstract

Climate change and variability are significantly affecting the Ethiopian agricultural sector, which serves as the backbone of the country's economy. The implementation of adaptation strategies and coping mechanisms is influenced by various factors, which are site-specific. Thus, this study aimed to explore farmers' perceptions of climate change and variability and the determinants of adaptation strategies and coping mechanisms in Ethiopia. Data were collected through face-to-face interviews with 133 farming households. The results revealed that farmers' perceptions of local indicators, such as temperature changes and rainfall patterns, underscore the diverse and impactful nature of climate variations on their experiences. The multivariate probit model output showed that the determinants of farmers' responses to climate variability, such as age, family size, educational status, sources of income, types of farming, farming experience, farm size, access to extension services, and availability of seasonal information, were significantly affected ($p < 0.01$). The impact of education, family size, farming experience, and income sources varies across various facets of agricultural practices, emphasizing the nuanced dynamics of coping mechanisms. Policymakers and agricultural practitioners seeking to develop effective strategies need to consider diverse needs and challenges faced by farmers in adapting to climate variability. Promoting education and improving access to extension services are critical components of successful adaptation strategies and coping mechanisms.

Keywords: Land management, Crop production, Animal technology, Non-farming activities

Introduction

Climate change and variability pose a significant challenge to agricultural systems worldwide, impacting crop yields, water availability, and overall farm productivity (Roy et al., 2023). Developing nations, especially those with lower incomes, witness substantial impacts across various sectors, with agriculture bearing the brunt, experiencing challenges in production and productivity (Milkessa and Amsalu, 2022). Ethiopia faces significant vulnerability to climate change and variability, primarily attributed to its reliance on rain-fed agricultural practices (Mulat, 2023). The various rural agricultural systems within the country, encompassing crop cultivation, pastoralism, and agro-pastoralism, have been identified as particularly vulnerable to climate-induced hazards in multiple ways (Metadel and Yihunie, 2020). Agriculture is the cornerstone of Ethiopia's economy, playing a crucial role in the country's socio-economic activities (Gebissa, 2021). It accounts for approximately 33.88% of the national GDP (Plecher, 2020). This heightened sensitivity underscores the pressing need for comprehensive strategies and interventions to enhance resilience and sustainability within Ethiopia's agricultural sector (Kiros et al., 2019; CIAT and BFS/USAID, 2017). Despite its economic significance, agriculture in Ethiopia is primarily subsistence-oriented and vulnerable to climatic shocks (UNDP, 2016). Recognised by the IMF (2012) as a key source of growth, the agricultural sector faces substantial challenges. In certain regions, recent weather patterns reveal a decline in rainfall, while others experience an increase, thereby influencing rain-fed agriculture in Ethiopia (Moges and Bhat, 2021).

According to Arragaw and Woldeamlak (2017), off-farm employment or non-farming mechanisms are coping mechanisms. While farming practices like crop diversification, soil conservation, planting trees, changing crop planting dates, and irrigation are the most common adaptation strategies used by smallholder farmers in the world (Tessema et al., 2013), Farming and non-farming activities become crucial choices for farmers to cope with climate variability (Mequannt et al., 2020). However, the adoption of these technologies is influenced by various factors such as age, educational status, family size, farming experience, income source, types of farming, access to credit services, agricultural extension services, and seasonal information (Eshetu et al., 2021; Dangia and Dara, 2020; Gebrehiwot et al., 2020).

Previous studies have been conducted on adaptation strategies, coping mechanisms, and determinant factors at different corners of the country employed in various regions of

Ethiopia for agricultural practices, such as the Upper Blue Nile Basin (Alemayehu et al., 2022), the Gambella Region (Yared et al., 2022; Azemir et al., 2021), Central Ethiopia (Etana et al., 2020), Eastern Tigray (Gebrehiwot et al., 2020), the Central Highlands (Arragaw and Woldeamlak, 2017), the Central Rift Valley (Belay et al., 2017), the Northern Highlands (Miheretu and Yimer, 2017), and Southern Ethiopia (Tesfaye, 2016). A more comprehensive understanding of farmers' responses, encompassing not only agricultural but also non-farming endeavours, is crucial for a holistic comprehension of adaptation strategies and coping mechanisms at both local and national levels. This is particularly pertinent in the East Belesa district, where a multifaceted exploration of the nature of these responses can provide valuable insights. The ability of individuals and communities to respond and adapt effectively varies due to the complex interplay of site-specific environmental, historical, socio-economic, and institutional factors (Below et al., 2012). Therefore, understanding the potential impact of climate variability in a specific location requires consideration of various local challenges (Keenan, 2015). This study aims to bridge the knowledge gap by investigating farmers' perceptions of climate change and variability and determinant factors related to adaptation strategies and coping mechanism technologies.

Materials and methods

Description of study area

The study was conducted in East Belesa district, North Gondar Administrative Zone, Amhara Region, Ethiopia. Geographically, it 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).

Topography, climate and soils

The altitude range of the district is 1200–2000 metres above sea level. Topographically, the district is characterised by flat/plain, mountainous, and rugged features, which constitute 55%, 40%, and 5%, respectively (EBD-OARD, 2018). According to the agricultural office of the district, black or “Walka” (Vertisol) soil type dominates about 45 percent of the flat/plain topography areas. The red soil (Litosols), which is locally known as "Keyatie", covers 38.5 percent. The serebola, or mixed soil type, covers 16.5 percent of the soil type found in mountains and nearby areas. The annual rainfall in the district ranges from 651 to 965 mm per year, and it is highly variable. The majority (>90%) of the people in the district, especially who reside in Kola/lowland agro-climatic zones live in poverty because of the very low productivity as well as recurrent drought occurred in the district (Amene et al., 2022). Most of this rain was received from mid-June to early September. The mean annual temperature ranges from 14.4–33.6 °C. Soil erosion, land degradation, deforestation, increased rainfall variability, and low soil fertility are commonly mentioned environmental problems (EBD-OARD, 2018).

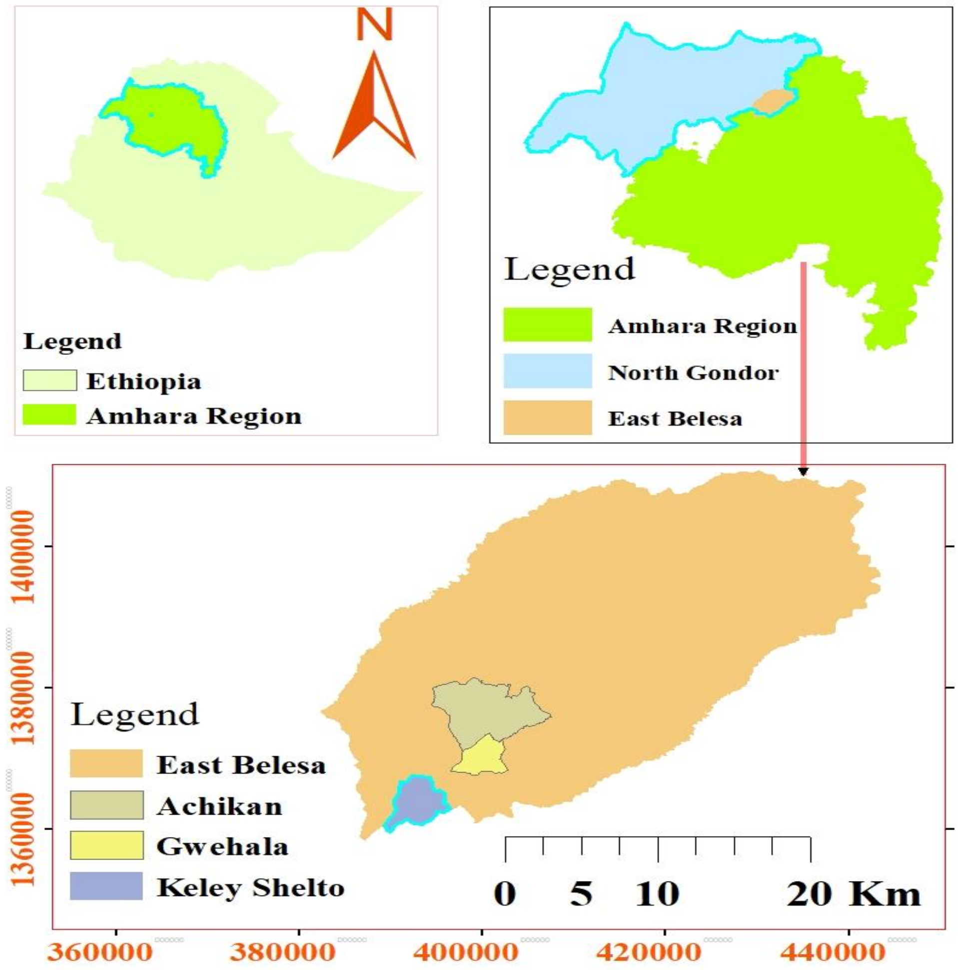

Figure 1. Map of the study area

Farming systems

The farming system of the district is predominantly characterized by crop-livestock mixed farming. This integrated approach to farming is essential for sustaining livelihoods and ensuring food security in the region. Small-scale agriculture is at the core of this farming system, reflecting diverse socio-economic and biophysical settings within the community (Amene et al., 2022). These variations are evident not only across different geographical

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areas but also within the various farming systems present in the district. Multiple farming systems coexist within the district, each shaped by a complex interplay of socio-economic and biophysical factors, including land availability, soil fertility, climate conditions, market access, and cultural practices. As a result, farmers adopt different strategies and techniques to optimize agricultural production based on their specific circumstances (EBD-OARD, 2018).

Sampling design and sampling size determination

This study employed both probability (random sampling) and non-probability sampling (purposive sampling technique). Purposive sampling was utilized to select sample district and *kebeles* (the lower administration level of the country), while random sampling was employed to select sample households. East Belesa district comprises 30 rural kebeles classified into one agro-ecological zone, namely Kola. Three kebeles were chosen for this study: Keley Shelto, Gwehala, and Achikan. To determine the sample size for data collection and observation, household heads were used as the sampling frame, and the standard population survey formula was applied to calculate the number of household heads to be included in the study. The documents available at sample *kebeles* served as sampling frames, and the sample size was determined proportionally to the total number of household heads, as presented in Table 1.

Table 1. Sampling size and proportional distribution of kebele and households

No	Kebele	Total HHs per Kebele	Proportional Sampled HHs
1	Kalaysholt	1680	58
2	Gwehala	1200	41
3	Achikan	980	34
4	Total	3860	133

Note: HHs= Households

In the case of a finite population, the Cochran (1977) formula was employed. The sample size was calculated as:

$$n = \frac{Z^2pq}{d^2} \text{............... ....Equation (1)}$$

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 % (for this survey)

q = 1-p

d = level of statistical significance (0.05)

$$q = 1\text{-}0.95 = 0.5 = \frac{(1.96)2x0.9x0.1}{(0.05)2} = 138$$

Hence, the desired sample size (Fn) was

$$Fn = \frac{n}{1+\frac{n}{N}} \text{............... ....Equation (2)}$$

Where, Fn = desired sample size n = Z^2pq/d^2

N = sample frame of the three study *Kebele* (total No. of HHs, i.e. =3860)

Fn =138/ [(1+ (138/3860)] = 133

Consequently, a survey sample consisting of 133 households was selected. The process of selecting these households employed a simple random sampling technique, ensuring each household had an equal opportunity for selection. Initially, the first unit of the sample was chosen at random, followed by the systematic selection of subsequent units.

In a population comprising N units from which n units are to be selected, the sampling interval (R) is calculated as R = N/n. The first number is then chosen randomly from the remainder of this sampling interval (R) to the previously selected number, and this interval is maintained for each kebele. Throughout this process, the list of households within each kebele was utilized to randomly select households. The description of explanatory variables used in the data analysis presented in Table 2.

Table 2. Description of explanatory variables used in the data analysis

No	Description Variable	Abbreviation	Level of independent Variables	Direction of Relation (sign)
1	Age of the household head	AGEHH	Continuous	±
2	Educational status of the household head	EDUSHH	Continuous	+
3	Household family size	FAMHH	Continuous	+
4	Households farm size in hectare	HMHH	Continuous	±
5	Farming experience of the household head	FAREHH	Continuous	±
6	Households source of income	SIHH	Continuous	±
7	Kinds of farming practice	KFP	Continuous	±
8	Access to credit service	ACSHH	Dummy	+
9	Access to agricultural extension	AAEHH	Dummy	+
10	Access to seasonal information	ACIHH	Continuous	+

Descriptive and econometric data analysis

The data obtained from closed-ended questionnaires were analyzed quantitatively by using descriptive data analysis statistical technique using SPSS version 22.0, while the qualitative data gathered using a semi-structured interview were transcribed, coded, sorted, and analyzed through thematic analysis techniques.

Multivariate Probit Model (MPM) was employed to identify determinant factors affecting the choice of specific coping and adaptation mechanisms in related to land management, animal production, and crop production etc… adopted by the sample households in the study area. The empirical model indicated or specified by Green et al. (2012). J was different coping and adaptation mechanisms, we can extend this to a multivariate probit model. For each mechanism *j* (where *j* =1, 2… *J*), the model for the latent variable Y_{ij}^{*} can be written as:

$$Y_{ij}^{*} = \beta_{oj} + \sum_{k=1}^{10} \beta_{kj} X_{ik} + \epsilon_{ij} \text{ …………… ……………………………Equation (3)}$$

Results and discussion

Farmers' perception of climate change and variability trends

Based on the responses of the respondents, 78.2% of farmers acknowledged changing temperature trends. The majority of households (63.9%) affirmed changes in rainfall amounts (Table 3). Overall, these findings underscore farmers' widespread recognition of climate-related changes, emphasising concerns about temperature trends, climate variability, and shifts in rainfall. Understanding farmers' perceptions of how rainfall fluctuates and changes is crucial in anticipating the impacts of changing climate patterns (Simelton et al., 2013). The study of farmers' perceptions of climate variability was recognised by Mequannt et al. (2020) and Befikadu et al. (2019).

Table 3. Farmers' perceptions to climate change and variability

Parameters	Frequency in number (n=133)				Responses in %			
	Yes very muc h	Yes	No there is no	I don't know	Yes very much	Yes	No there is no	I don't know
Change in temperature	104	26	1	2	78.2	19.5	0.8	1.6
Change in rainfall	40	85	5	3	30.1	63.9	3.8	2.3
Climate variability	47	79	1	6	35.3	59.4	0.8	4.5

Farmers perceptions of indicators for trend of temperature changes

The majority of farmers (91 %) reported continuous heat incidence, and 83.5% perceived an increase in temperature (Table 4). The data indicates a strong consensus among farmers regarding the observed climate variability, particularly in terms of frequent temperature changes and sustained periods of heat. A significant majority of farmers have reported an increase in temperature. These findings underscore the diverse and intricate nature of local climate variations, as perceived by the agricultural community. The present studies align with Mkonda and He (2017) findings, where farmers expressed confidence in various observations regarding the mean annual temperature, indicating perceptions of increase, fluctuation, decrease, or no change.

Table 4. Farmer’s perception of indicators for trend of temperature changes

No	Local indicator climate variability	Farmer’s perception (n = 133)			
		Yes		No	
		Frequency	%	Frequency	%
1	Change the temperature frequently	124	93.2	9	6.8
2	Continuously Heat	121	91	12	9
3	Increase temperature	111	83.5	22	16.5
4	Decreasing temperature	37	27.8	96	72.2

Farmer’s perception of indicators for trend of rainfall change

The respondents perceived local climate variability indicators and farmers' perceptions, with a specific focus on rain fall changes: delayed onset of rainfall, increased frequency of droughts (91.7%), early termination of rainfall (88.1%), delayed termination of rainfall (32.4%), and high rainfall concentration (70.7%) (Table 5). These findings underscore the diverse and impactful nature of local climate variations on farmers' experiences, particularly highlighting concerns related to rainfall patterns and their timing. The high percentage of respondents reporting these observations suggests a shared awareness of climate-related challenges within the farming community. The findings align with the flingings of Befikadu et al. (2019), Asrat and Simane (2018), and Tesfahunegn et al. (2016).

Table 5. Farmer’s perception of local indicators trends of rainfall

Local indicator climate variability	Farmer’s perception (n = 133)			
	Yes		No	
	Frequency	%	Frequency	%
Rain comes lately	122	91.7	11	8.3
Increase droughts frequency	122	91.7	11	8.3
Rain goes early	118	88.1	15	11.3
Rain is a permanent phenomenon	114	85.7	19	14.3
Decreasing rainfall	109	81.2	24	18
Highly rain at the same time	94	70.7	39	29.3
Rain comes early	49	36.1	84	63.2
Rain goes lately	43	32.4	90	62.7
Increasing rainfall	31	24.3	102	76.7

Farmer's perception in local indicator of climate variability

The most prominent perception, reported by 90.2% of farmers, is the shortage of time for seed germination. This suggests a shared concern about the timing of agricultural activities. Additionally, 88.7% of farmers express worries about increasing soil erosion or widespread soil erosion, indicating the impact of environmental changes on soil stability. Farmers also note variations in extreme winds (84.2%), the loss of plant species (81.2%), and changes in dry winds (79.9%) (Table 6). These observations highlight the farmers' keen awareness of alterations in weather patterns and their potential consequences for crop cultivation. A significant proportion of farmers (74.4%) report emerging human health problems not seen previously, indicating potential linkages between climate variability and public health. The study also captures the farmers' perspectives on uncommon occurrences, such as plant diseases (rust) in local areas, new local animal diseases, and the occurrence and disappearance of new species of animals. These findings emphasize the complex interplay between climate variability and the ecosystem. The findings confirmed that farmers conveyed their observations about changes in temperature and rainfall through various expressions (West et al., 2021; Mkonda and He, 2017; Le Dang et al., 2014).

Table 6. Farmer's perception in local indicator of climate variability

Local indicator climate variability	Farmers perception (n=133)			
	Yes		No	
	Frequency	%	Frequency	%
Shortage of time for seed germination	120	90.2	13	9.8
Increasing soil erosion/wide spread soil erosion	118	88.7	15	11.3
Existing extreme winds differently	112	84.2	21	15.8
Loss of a few species plant	108	81.2	25	18.8
Existing dry wind differently	106	79.9	27	20.3
Growing of new crop varieties	103	77.4	30	22.6
Emerging human health problem which is not seen previously	99	74.4	33	24.8
A plant disease (rust) is created uncommonly in local area	96	72.2	37	27.8
Local animal diseases occurred which is not seen previously	88	65.9	44	33.1
New species of animals occurred and disappeared	81	60.9	52	38.1
Increasing land slide	74	55.6	59	44.4

Determinates of farmers' responses to adaptation strategies

Land management

Educational status emerges as a positive and significant factor (P<0.05) impacting forest management and soil water conservation. Family size is identified as a negative and significant factor (P<0.05) affecting tree planting around fields, while farm size is positively and significantly associated (P<0.05) with tree planting and area closure activities. This emphasizes the importance of farm size in implementing strategies such as planting trees and providing alternative grazing land, showcasing the multifaceted nature of land management practices. The dual role of the source of income is noteworthy, negatively impacting tree planting (P<0.05) but positively influencing soil and water conservation (P<0.05). The type of farming also plays a significant role, positively affecting various land management technologies: soil water conservation (P<0.01), area closure (P<0.1), and planting trees and compost (P<0.05) while negatively influencing forest management (P<0.05). Agricultural extension services exhibit a varied impact, positively influencing forest management (P<0.05) but negatively affecting compost and soil water conservation (P<0.05). Access to seasonal information is found to have a negative and significant effect on farmyard manure (P<0.01) (Table 7), suggesting that despite information access, certain agricultural practices, such as manure usage, might not be effectively adopted.

The study highlights the intricate nature of adaptive strategies, the imperative for tailored approaches that acknowledge the diverse array of factors influencing farmers' responses to climate variability in the examined region. Asrat and Simane (2018) research reveals the pivotal role played by agroforestry practices, soil conservation methods, and irrigation techniques as crucial mechanisms in addressing climate variability within their specific locale. The study posits that education and increased farming experience augment farmers' capacity to obtain and utilize information, enhancing awareness of potential benefits and fostering willingness to engage in local natural resource management, conservation activities (Amare and Simane, 2017). Similarly, age is reported to have both positive and negative effects on farming activities (Baharu, 2016). Moreover, Miheretu and Yimer (2018) findings suggest that educated household heads exhibit a higher likelihood of adopting soil conservation practices as adaptive measures to climate variability. Contrary to this, Abid et al. (2015) argue that access to farm credit is positively correlated with changing crop variety and increased irrigation but negatively linked to altering crop type, adjusting planting dates, planting shade trees, and soil conservation. Additionally, family size, as noted by Amare and Simane (2017), positively influences farmers to adopt labor-intensive adaptation measures such as soil and water conservation. Gebrehiwot et al. (2020) highlights the positive and statistically significant impact of extension services on smallholder farmers' participation in soil and water conservation and tree planting. Askal and Mesert (2022) emphasize the positive relationship between forest management, education, access to training, and experience-sharing. These findings are in line with previous studies by Gujarati (2019) and Girma and Zegeye (2017), providing a comprehensive understanding of the multifaceted factors influencing farmers' adaptive responses to climate variability.

Animal production technology

Various factors play a crucial role in influencing farmers' adaptation strategies to climate variability in relation to animal production. Age emerges as a noteworthy factor, with a positive and significant impact ($P<0.01$) observed in the utilization of grazing land. Conversely, age is associated with a negative and significant effect ($P<0.05$) on the preparation of forage and homes for animals. Farm size also plays a pivotal role, exhibiting positive and significant effects ($P<0.05$) on practices such as preparing forage and employing the cut-and-carry method ($P<0.01$) while simultaneously showing a negative and significant impact on the use of common grazing land in rotation (Table 8).

Furthermore, the source of income and types of farming significantly influence the preparation of homes for animals and the adoption of cut-and-carry practices, with a significant, positive impact ($P<0.01$). However, these factors also exhibit a negative and significant effect ($P<0.01$) on the preparation of forage for animals, signalling the intricate trade-offs farmers face in adapting to climate variability. In addition, access to seasonal information is identified as a critical determinant, with a negative and significant impact ($P<0.01$) on the use of common grazing land in rotation (Table 8). This stresses the importance of timely and accurate information in shaping farmers' decisions related to animal production practices. In summary, the study unveils the nuanced interplay of demographic and contextual factors in shaping farmers' adaptive strategies to climate variability in animal production. Understanding these influences is vital for developing targeted interventions and support mechanisms to enhance resilience in the face of changing climatic conditions.

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Table 7. MPM of farm-level technologies related to land management

Independent variables	Farmyard manure		Forest management		Compost		Planting a tree around the field		Area closure		SWC	
	B(S)	Exp(B)	B(S)	Exp(B)	B(S)	Exp(B)	B(S)	Exp(B)	B(S)	Exp (B)	B(S)	Exp(B)
Age	.042	1.043	-.033	967	-.080***	.928	.036	1.037	-.042	.959	.063	1.065
Educational status	-.601	.549	.561**	1.752	-.012	.988	-.038	.962	.350	1.418	.857**	2.356
Family size(FAM)	.361	1.435	-.140	870	.046	1.047	-.264**	.962	-.106	.900	-.004	.957
Farming size(HMH)	-.351	.704	.207	1.230	.170	1.185	.436**	.768	.388***	1.473	-.246	.782
Farming experience (FARE)	.085	1.088	.008	1.008	-.011	989	-.020	980	-.009	.991	.010	.990
Source of income (SI)	-.153	.859	-.192	.825	-.192	.825	-.653**	.521	-.147	864	.613**	1.845
Kinds of farming(KFP)	-.523	.953	-1.304**	.271	.813**	2.256	.541***	1.718	1.198*	3.314	.614***	1.848
Access to credit service(ACS)	.128	1.136	.143	1.154	.964	2.621	.135	1.718	-.001	.999	.648	1.912
Access to agricultural extension(AAE)	-4.440*	.012	2.068**	7.908	-1.398**	.247	-.455	.634	.154	1.166	-1.716**	.180
Access to seasonal information(ASI)	-2.709***	.067	-.194	.824	-.534	.586	-.579	.560	.335	1.398	-.930***	.394

*B(S) = Nonstandard beta, Exp (β)=odds ratio, ***, **, * Significant at 1%, 5% and 10%, respectively.*

In Ethiopia, strategic approaches, such as the formation of mixed-species herds, the utilization of expansively available grasses throughout different seasons, the segregation of animals into distinct herds, and adaptability to seasonal variations in pasture productivity play crucial roles (Melese, 2019). Livestock production holds significance as it serves as intermediate food, provides draught power, contributes to wealth status, and serves as a sustainable cash source throughout the year. Enhancing animal husbandry in rural settings requires a comprehensive understanding of the production system and its operations (Yisehak et al., 2013). The results are consistent with those of Amare and Simane (2017), indicating that a larger family size positively influences farmers to adopt labor-intensive adaptation measures, like livestock rearing. The positive relationship between farm size and preparing forage for animals may be attributed to larger farms, where farmers allocate land for grazing purposes. Moreover, farmers with larger farm sizes take proactive measures, such as preparing private grasslands, obtaining crop residues, and storing them for future drought periods, to overcome feed shortages (Bashe et al., 2018).

Crop production technologies

Educational status emerges as a crucial determinant, showcasing a positive and significant impact on the adoption of advanced seed varieties ($P<0.01$) and the improvement in fertilizer usage ($P<0.05$). This emphasizes the pivotal role of education in facilitating the uptake of modern agricultural practices. Family unit size is found to positively and significantly affect ($P<0.05$) the proper utilization of irrigation methods, indicating that larger family units may be better equipped to implement and manage such water-intensive technologies. However, farm size exhibits a negative and significant impact ($P<0.05$) on the adoption of advanced seed varieties, suggesting potential challenges for larger farms in integrating such technologies. Farming experience emerges as a positive and significant factor ($P<0.01$) (Table 9) in the adoption of improved high-yielding species seeds, highlighting the importance of accumulated knowledge and expertise in influencing farmers' choices in seed selection and cultivation practices.

Income source is identified as a significant influencer, with positive and significant effects ($P<0.05$) observed in the adoption of various adaptive strategies, including planting early maturing crops, utilizing advanced seed varieties, incorporating improved high-yielding species seeds, and enhancing fertilizer usage. This underscores the financial aspect as a critical determinant of farmers' ability to adopt and sustain advanced agricultural practices.

Table 8. MPM of farm-level technologies in related to related to animal production

Independent variables	Preparing improved forages for animals		Prepare improved homes for animals		Cut and carry		Protecting common grazing lands		Use common grazing lands in rotation	
	B(S)	Exp(B)	B(S)	Exp(B)	B(S)	Exp(B)	B(S)	Exp(B)	B(S)	Exp(B)
Age	-.126**	.882	-.126**	.882	.061	.941	-.030	.970	.052***	1.054
Educational status	-.406	.667	-.406	.667	.135	1.145	-.281	.755	.310	1.364
Family size	.120	1.132	.124	1.132	-.031	.969	-.087	.917	.140	1.150
Farming size	1.098**	2.999	1.098*	2.999	.493**	1.637	-.250	.779	.-.305***	.337
Farming experience	.053	1.054	.053	1.054	.002	.998	.036	1.037	-.018	.982
Source of income	-.630***	.533	-.630***	.533	-.613***	.542	-.140	.870	.120	1.128
Kinds of farming	-.737***	.478	.856***	2.354	.685***	1.984	.183	.1.201	-.369	.692
Access to credit service	-.057	.944	-.866	.421	-.120	.887	-.648	.523	.479	1.614
Access to agricultural extension	.186	1.204	-.270	.763	-.535	.586	.216	1.241	.284	1.329
Access to seasonal information	-.861	.423	.892	2.439	.265	1.303	-.551	.576	-1.386**	.250

*B(S) = Nonstandard beta, Exp (β)=odds ratio, ***, **, * Significant at 1%, 5% and 10%, respectively.*

The type of farming is crucial, showing a positive and significant impact (P<0.01) on the utilization of composts for crop production. However, the improvement in fertilizer usage is negatively and significantly affected (P<0.01), indicating diverse approaches to soil enrichment among different farming practices. Access to credit and agricultural extension services proves to be a positive and significant factor (P<0.01) (Table 9) influencing specific adaptive strategies, such as planting early-maturing crops and using improved high-yielding species seeds. These findings highlight the pivotal role of support systems and resources in enhancing farmers' resilience to climate variability.

Amare and Simane (2017) revealed that a larger family size positively influences farmers to adopt labor-intensive adaptation measures, such as irrigation, which becomes crucial during peak periods of production when labor availability is a critical issue. Additionally, Gebrehiwot et al. (2020) demonstrated that extension services have a positive and statistically significant impact on the participation of smallholder farmers in adopting improved crop varieties. Furthermore, factors such as education, wealth, access to credit, family size, and engagement with extension services directly influence the demand and utilization of improved seed varieties (Afework and Lemma, 2015).

Determinates of farmer's responses to coping mechanism measure

Non-farming activities

Educational background emerges as a significant factor, demonstrating a positive and noteworthy impact on petty trading (P<0.01). This suggests that individuals with a higher level of education may adopt more effective adaptation strategies in non-farming sectors. Family size is identified as a factor influencing certain activities, such as selling firewood and coal, as well as engaging in daily labor, showing a positive and significant impact (P<0.05) (Table 10). This implies that larger family sizes may lead individuals to pursue these specific economic activities in response to climate variability. This nuanced relationship underscores the diverse ways in which family dynamics influence adaptive strategies.

The source of income emerges as a pivotal factor, with a positive and significant impact (P<0.05) on selling firewood and coal, daily labor, and petty trading. This emphasizes the interconnectedness of income sources and highlights the diverse economic activities individuals adopt in response to climate variability. Additionally, the types of farming and access to seasonal information exhibit a negative and significant impact (P<0.01) on petty trading (Table 10). This suggests that specific agricultural practices and access to timely information may influence individuals' engagement in non-farming endeavors.

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Table 9. MPM of farm-level crop production technologies

Independent variables	Planting early maturing crops		Use advanced seed varieties		Use improved high-yielding species seeds		Improving usage of fertilizers		Using composts for product crops		Proper use of irrigation	
	B(S)	Exp(B)	B(S)	Exp(B)	B(S)	Exp(B)	B(S)	Exp(B)	B(S)	Exp(B)	B(S)	Exp(B)
Age	.005	1.005	.024	1.025	.005	1.005	.063	1.065	-.009	.991	-.032	.969
Educational status	.019	1.019	.221	1.247	.019***	1.019	.857**	2.356	-.122	.885	.176	1.192
Family size	.173	1.189	.035	1.247	.173	1.189	-.044	957	.106	1.112	.197**	1.217
Farming size	-.254	.775	-.379**	.684	-.254	.775	-.246	782	.195	1.215	-.066	.936
Farming experience	.029	1.030	.014	1.014	.029***	1.030	-.010	.990	-.012	.988	-.005	.995
Source of income	.723**	2.060	.553**	1.739	.723**	2.060	.613**	1.845	-.134	.875	-.070	.933
Kinds of farming	-.435	.647	-.194	.823	-.435	.647	-.737***	.478	1.740***	5.699	.085	1.088
Access to credit service	1.066**	2.903	.271*	1.311	1.066**	2.903	-.057	.944	-.542	.518	-.779***	.459
Access to agricultural extension	1.031***	2.805	-.298	742	1.031***	2.805	.186	1.204	.108	1.114	.557	1.745
Access to seasonal information	-.139	.870	.004	1.005	-.139	.870	-.861	.423	.455	1.576	-.172	.842

*B(S) = Nonstandard beta, Exp (β)=odds ratio, ***, **, * Significant at 1%, 5% and 10%, respectively.*

The findings of the current study shed light on the complex dynamics individuals navigate as they adapt to the challenges posed by climate variability in both farming and non-farming spheres.

Table 10. MPM of non-farming activities

Independent variables	selling of firewood and coal		daily labor		petty trading	
	B(S)	Exp(B)	B(S)	Exp(B)	B(S)	Exp(B)
Age	-.016	.984	-.013	.987	.052	1.054
Educational status	.117	1.124	-.039	.961	.452***	1.572
Family size	.188**	1.207	.272**	.961	-.113	.893
Farming size	.119	1.127	-.004	.996	.099	1.104
Farming experience	-.011	990	-.028	.972	-.071**	.931
Source of income	.574**	1.775	.559**	1.070	.706**	2.026
Kinds of farming	-.111	895	-.402	.669	-.575***	.563
Access to credit service	.505	1.658	-.239	.787	.527	1.693
Access to agricultural extension	-.357	.700	.593	1.809	-.490	.612
Access to seasonal information	-.494	.610	-.194	.824	-1.037***	.355

*B(S) = Nonstandard beta, Exp (β)=odds ratio, ***, **, * Significant at 1%, 5% and 10%, respectively.*

In Ethiopia, non-farm activities exhibit a pro-cyclical relationship with agricultural operations, with 34% of households participating in such activities at the national level (Neglo et al., 2021). Education serves as a key indicator of diversifying livelihoods towards non-farm employment and self-employment (Fuje, 2017). Furthermore, the size of a family plays a significant role in stimulating activities aimed at diversifying non-agricultural income. Larger households tend to allocate additional labor resources to non-farm entrepreneurship, presenting an opportunity for engagement in both agricultural and non-agricultural pursuits (Nagler and Naude, 2014). The presence of an extra adult member in a household expands the available labor force, enabling participation in various economic activities (Ashebir and Negussie, 2016). Notably, the relatively higher consumption needs of larger families suggest that engaging in off-farm activities may serve as a strategic approach for household heads to enhance their financial capacity, ensuring the fulfilment of essential family needs. This aligns with findings from other studies, including those by Wondim (2019), Mohammedawel (2015), Derajew and Rao. (2016).

Conclusion

The study reveals a high level of awareness among farmers regarding climate change and variability. Farmers' perceptions of local indicators, such as changes in temperature and rainfall patterns, underscore the diverse and impactful nature of climate change on their experiences. The study identifies various socio-economic and environmental factors influencing farmers' adaptation strategies and coping mechanisms, emphasizing the complexity of these responses. Different factors influence coping mechanisms in land management, animal production, and crop production, emphasizing the need for tailored approaches. The study explores non-farming activities as part of farmers' coping mechanisms, revealing the importance of education, family dynamics, income sources, and access to information in shaping these activities. The findings shed light on the complex dynamics individuals navigate as they adapt to the challenges posed by climate variability in both farming and non-farming provinces. Policymakers need to design coping mechanisms and support programmes that consider the diverse factors influencing farmers' responses to climate variability to enhance farmers' resilience. Promoting education and improving access to extension services are critical components of successful coping mechanisms. These factors positively influence farmers' awareness and ability to adopt effective climate-related measures. Providing financial support and access to credit services can enhance farmers' capacity to implement adaptive measures, especially in the context of changing climate patterns affecting agricultural practices. There is also a need a need to adopt an integrated approach that recognizes the interconnectedness of various aspects of farming and non-farming activities.

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Data availability statement

All datasets generated and/or analysed during the current study are incorporated within this article.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.”

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