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Factors influencing smallholder farmers' perceptions of climate change and their adoption of climate-smart agriculture: The case of West Arsi Zone, Ethiopia

Shambel Bekele[1*], Semeneh Bessie[2] and Daniel Masersha[3]

[1]Wollega University, Department of Economics, Ethiopia

[2]Ethiopian Economic Association, Addis Ababa, Ethiopia

[3]Wollega University, Department of Business and Economics

*Corresponding author's email: selalinaenat@gmail.com; ORCID: https://orcid.org/0009-0004-6645-7123

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Abstract

This research aimed to gain an understanding of how farmers perceive and comprehend climate change, as well as how they could utilize climate-smart agriculture (CSA) techniques to cope with it. Data were collected through face-to-face interviews with 404 households in West Arsi, Ethiopia. Data was also complemented through focus group discussions and key informant interviews and analyzed by employing a Heckman probit two-stage selection model. The results disclosed that 75.2% of farmers indicated higher temperatures and 73.5% noted less precipitation distribution, indicating that most farmers (77.7%) thought the local climate was changing. Among the CSA adoption strategies that farmers attempted to practice in the study area were higher-yielding crop cultivars that can withstand drought, organic fertilizers, crop diversification, soil and water conservation, and joint control of herbs and pests. Family size, land size, total livestock units, accessibility of credit, social group membership, annual income, training accessibility, and weather and climate data significantly affected farmers' ability to adopt climate-smart agriculture. Agroecology, age, education, access to mass media, pest infestations, and interactions with non-governmental organizations were significant factors persuading farmers' perceptions regarding climate change and erraticism. Farmers in the study zone are cognizant of climate change and use adaptation mechanisms to mitigate its negative consequences on their means of subsistence. This shows that policies should be focused on enhancing the accuracy of meteorological data, supporting farmer training through extension services, and taking financial facilities into account to raise farmers' understanding and adoption of climate-smart agriculture. Development endeavors ought to include cooperation between the public and private, in addition to a common goal among all pertinent stakeholders.

Keywords: Adoption, Climate-smart agriculture, Heckman two-stage, Perceptions

Introduction

The biggest global issues that humankind is currently confronting worldwide are climate change and variability (Pedersen et al., 2021; Abdallah et al., 2019; Hundera et al., 2019). Climate change puts a huge endangerment on underdeveloped nations as the vast majority of their inhabitants depend on living that are susceptible to its effects and have inadequate capacity for adaptation (Amogne et al., 2021). For example, many low-income countries currently experience poverty, and the repercussions of climate change are anticipated to make it worse, according to the IPCC's Working Group II's Fifth Appraisal Review (IPCC, 2015). Millions of people in rural Africa suffer from food instability and hunger, and this is especially true there (Sasson, 2012). Recent research investigations found that the agricultural and food security of sub-Saharan Africa have already suffered because of climate change (von Braun, 2020).

In Ethiopia, agricultural output has decreased due to extreme weather-related incidents and climate disruption, exacerbating food scarcity (Fiker et al., 2021), marginalization (Solomon et al., 2018), impoverishment (Seife, 2021; Onyutha, 2019), and violence (van Weezel, 2019). Agriculture is the primary driver of Ethiopia's economy, accounts for 85% of overall employment, 32.5% of the nation's GDP, and 75% of foreign exchange profits (NBE, 2022). As a result, it is the main factor influencing both financial stability and food availability (Belay et al., 2021; Deressa et al., 2011). Tesfahunegn and Gebru (2021), Etana et al. (2020), and Derressa et al. (2011) argue that conventional farming, significant land loss, an inadequate level of institutional support, and harsh weather conditions like floods and drought are the primary reasons for Ethiopia's low agricultural productivity. These elements diminish and have a detrimental effect on producers' aptitude to acclimatize to climate change (Jha and Gupta, 2021).

The extent to which Ethiopian farmers are cognizant of the effects of climate change on their industry has become the subject of comprehensive research (Ketema et al., 2024; Mekuyie and Mulu, 2021; Thinda et al., 2021; Zerssa et al., 2021). Weldegebriel and Prowse (2017) stated that numerous farmers have seen the impact of climate change. For instance, Etana et al. (2021) investigated how well Ethiopia's financial and alimentary security could be increased by climate change adaptation (CCA). Farmers are more knowledgeable about climate change, according to the writers. Yet, the results lack triangulation with observable meteorological data and instead concentrate on comprehending climate change from the viewpoint of farmers. However, additional research (Ali et al., 2021; Asrat and Simane, 2017) and studies of (Etana et al., 2020; Befikadu et al*.,* 2019) have demonstrated that agriculturalists lack knowledge of climate change. According to Talanow et al. (2021), farmers' choices for implementing adaptation measures are impacted by their degree of understanding of climate change. Incorporating farmers' perspectives on the effect of climate change on their sustenance into adaptability platforms is vital. This will encourage the use of indigenous knowledge and allow for efficient solutions (Yang et al., 2024). One of the key gaps that adaptation fills locally in response to climatic stimuli is farmers' perspectives and comprehension of a changing environment (Ricart et al., 2019).

This study adds to the very scant research on climate variation insight and adoption in two ways. Initially, the study employed the two-step technique of Heckman's probit model to adjust for selection prejudice in determining decisions (Heckman, 1976). Secondly, this research delves into the variables that dictate the first stage of climate change cognizance and mitigation methods in a dynamic climate by implementing climate-smart farming methods. This research intends to investigate how farmers' viewpoints ascertain CSA espousal as an adaptation action in confronting climate variation and unpredictability in the West Arsi zone. Hence, the results of this research complement a profound comprehension of how agriculturalists' observations steered the embracing of CSA practices in the West Arsi Zone and boosted the execution of climate deed policies in Ethiopia.

Research methods

Description of the research area

The research was carried out in Oromia Regional State's West Arsi Zone. The West Arsi Zone is bordered to the north by the East Shewa Zone, to the south by the Sidama Regional State, to the west and south by the South Ethiopia Regional State, to the northeast by the Arsi Zone, to the southeast by the Guji Zone, and to the east by the Bale Zone. The elevations in this area range from 1500 to over 3300 meters. Shashemene town serves as the zone's governmental hub. It is situated 250 km from Addis Ababa, and the entire area of the zone is 12556 km². It is found in the Rift Valley section. The geographical location of West Arsi Zone is situated between 6^0 07′55′′N to 7^0 56′55′′N latitude and 38^0 06′55′′E to 39^0 43′55′′E longitude (WAZANR, 2020/2021). The zone has 12 districts, 4 urban governances, and 332 farmer associations.

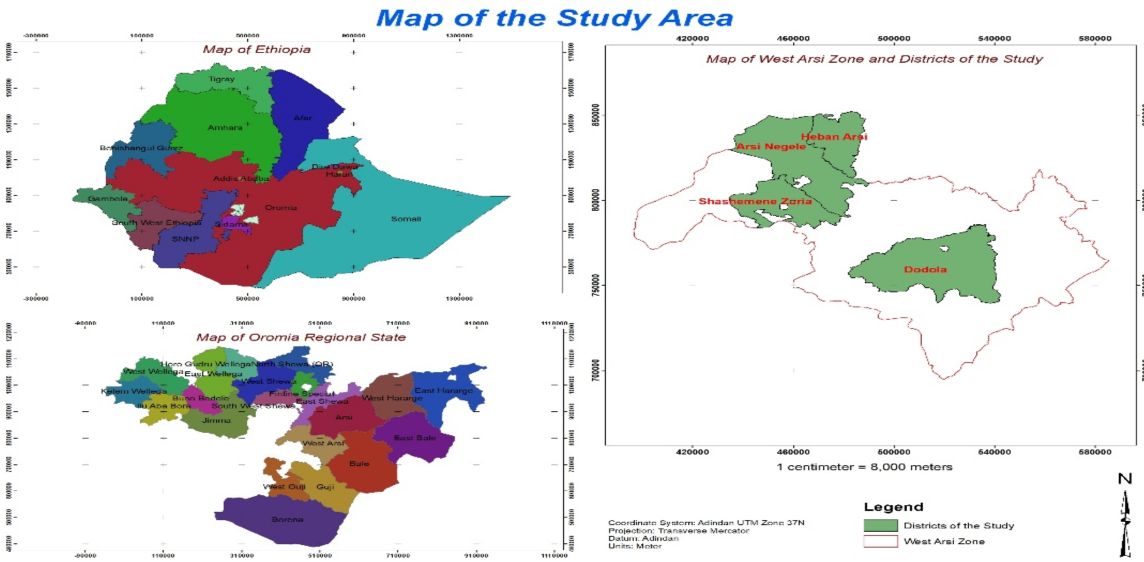

Figure1. Map of the research area

Source of data and data collection method

The study was based on cross-sectional household-level information obtained from sample respondents in the West Arsi zone. Both primary and secondary sources of data were used in this research. The primary information was gathered between November 2022 and July 2023 from a sample of smallholder farmers in the Arsi Negele, Dodola, Heban Arsi, and Shashemene districts. The intriguing factors were determined based on the literature and the accessibility of the data, and the information was gathered using questionnaires. Focus group discussions and key informant interviews (KII) were conducted in each village to gather detailed data on farmers' understanding and perceptions of precipitation and temperature trends over the past 20 years, climate hazards, apparent impacts of climate fluctuations, and climate-smart agriculture adaptation actions to weather change. The validity of the checklist and questionnaire was confirmed through pre-testing before the official data collection.

Sampling methods and sample size determination

A multistage random sampling was employed to arrive at the household level. Literature and the most important statistical information sources were used as a framework for the initial selection phase. The West Arsi zone was purposefully selected because it is among the zones affected by climate change and is practicing CSA (Abate, 2009). In the second phase, with the guidance of the Bureau of Agriculture and Natural Resources (BOANR) offices' experts, four districts out of the twelve susceptible to changing atmospheric conditions and engaging in climate-smart agriculture were explicitly chosen. These four districts make up 33.3 percent of all the rural districts in the zone (WAZAO, 2021). In the third stage, after the districts were purposively sampled, two kebeles (overall eight kebeles) were selected by purposeful sampling from each district. Only accessible villages engaged in climate-smart agriculture were selected. The sampling frame (complete village household lists) was obtained in consultation with the kebeles' governors of the different kebeles and development workers of the corresponding kebeles. Due to the vast geographic coverage and size of the population, a thorough census would entail a pertinent investment of time and money. Thus, the sample size was established by employing the relevant sampling formula, as stated by Kothari (2004), while accounting for the study area's population size. The sampling size was determined based on Kothari (2004), taking into consideration the characteristics of the population, degree of precision, and type of study. This procedure permits a margin of error and is anticipated under the 95% confidence interval. The Kothari formula is as follows:

$$n = \frac{Z^2 PqN}{e^2\ (N-1)+Z^2 pq} \quad (1)$$

The equation above was employed to get the entire sample size of households. The proportional sampling method was applied to ascertain the precise number of participants from each kebele. According to this, a 10% contingency increase was added to the sample size, and a total of 404 households were considered in the investigation. As shown in Table 1 appearing hereunder, the 82, 86, 98, and 137 sample households were nominated from Arsi Negele, Dodola, Heban Arsi, and Shashemene, respectively.

Table 1. Sample districts

S. N	Districts	Kebeles	Total households	Percentage share	Sample households
1	Arsi Negelle		1672		82
		Turge	738	44%	36
		Qalo Tulu	934	56%	46
2	Dodola		1761		86
		Kata Baranda	781	44%	38
		Baka	980	56%	48
3	Heban Arsi		1979		98
		Degaga	848	47%	42
		Shopa	1131	56%	56
4	Shashemene		2798		138
		Turfe watara	2042	73%	101
		Watara Shagule	756	27%	37
			8269		404

Source: Own survey data; data on the size of farmers for each district in Column 4 is obtained from WAZAO (2022).

Data analysis

The gathered data was inputted, encoded, cleaned, and scrutinized using STATA software version 15. The study utilized descriptive statistics to examine socioeconomic features, institutional characteristics, and farmers' cognizance of climate variability and its related effects. To investigate the variables that impact farmers' outlooks and decisions to adopt CSAs, we used the Heckman choice model. Farmers' perspectives of weather change, comprising fluctuations in precipitation and temperature, as well as their adoption decisions, are the contingent component employed in the selection model.

Producers' perspectives on climate variation were identified before the factors determining their adoption behaviour were examined. The next step will be to thoroughly investigate how well farmers are making adjustments to the consequences of climate disruption (Deressa et al., 2010, 2009; Gbetibouo, 2009; Maddison, 2007). A particular model to be used diverges from investigator to investigator, contingent upon the kind of variables they are intrigued by incorporating, the range they seek to address with the socio-economic and farm features, the institutional and agroclimatic hurdles they confront, and other obstacles that the scholars come across. The most popular models for this type of analysis, notwithstanding notable exceptions, are the logit and probit models (Deressa et al., 2010; Maddison, 2007). There are two phases involved in adapting to climate change: first, recognizing that the climate is changing, and second, planning to implement CSA adoptions as a means to adapt (Deressa et al*.,* 2011; Morton, 2007). Two-step maximum likelihood procedures may be employed to address this choice scepticism (Heckman, 1976). Heckman's choice model ruminates on farmers' views regarding climate change in two stages: the first is the choice model, and the second is the result model. The fundamental premise of Heckman's probit choice model is the existence of a causal relationship, which is represented by the latent equation given by (Eq. 2):

$$y_j = \beta xj + \mu_{1j} \tag{2}$$

where y_j represents the latent parameter, or the willingness to espouse climate change actions, x is a crucial vector of descriptive elements that influence mitigation actions, β is the estimated variable, and μ_{1j} is the error term. Essentially, the binary result provided by the probit model is seen in this instance, and it is as follows (Eq.3)

$y_j^{probit} = (yj > 0)$ (3)

The observation of the reliant variable is contingent upon the observation of j in the choice equation (Eq. 4).

$y_j^{select} = (zj\delta + u2j > 0)$ (4)

$\mu 1 \sim N(0,1)$
$\mu 2 \sim N(0,1)$
$\text{Corr}(\mu 1, \mu 2) = \rho$

Where y_j^{select} is assuming the farmers noticed climate change or not, z is the vector of independent factors that impact how farmers view of climate change, δ is the variable extrapolation, and u_1 and u_2 are the error terms, which are normally dispersed with mean zero and variance one. In this instance, the choice model (Eqn. 2), which is the initial phase of Heckman's two-stage model, displays producers' viewpoint on climate change. The subsequent phase, the resulting model (Eqn. 2), depicts how farmers adopt approaches that address climate change and are dependent on how farmers comprehend climate change. When the error terms are interrelated from the choice and result model or when $\rho \neq 0$, the typical probit model was employed in Eqn. (4) provides skewed estimates. Therefore, the Heckman probit choice model was employed to investigate farmers' mindset of climate change and their adoption tactics in the West Arsi zone. The outcome variable is contingent upon whether or not farmers have adopted CSA techniques as an affirmation of the ramifications of the environment. One set of factors that depend on the selection equation involves farmers' insights into climate change. Explanatory variables that are believed to influence farmers' cognizance of climate variability and espousal of CSA activities were identified by analysing the literature on climate change, along with available data.

Table 2: Description of parameters

Category and meaning	Parameters name	Attribute of parameter	Expected sign
Dependent variable			
Farmers' perception of climate change	Perception	Dummy: 1 for perceived; 0 otherwise	
CSA Adoptions	Adoption	Dummy: 1 for adopters; 0 otherwise	
Explanatory Variables			
Household Characteristics			
Sex of household head	SEX	Dummy	+/-
Age of household head in years	AGE	Continuous	+/-
Family size	FAMSZE	Continuous	+
Age above eighteen	AGABVEIGN	Continuous	+
Education of household head in years	EDULEVL	Continuous	+
Farming experience in years	FAEXP	Continuous	+
Off-farm income	OFINCM	Continuous	+
Annual income	ANINCM	Continuous	+
Market access			
Distance to market in kilometers	DISMKT	Continuous	-
Social capital and information access			
Membership in farm groups	MFG	Dummy	+
Institutional characteristics			
Frequency of extension contacts	FEXC	Continuous	+
Access to credit	ACRDT	Dummy	+
Access to mass media	ACMIDA	Dummy	+
Access to weather information	AWINF	Dummy	+
Duration of training	DURTNG	Continuous	+
Access to market information	MARKINFO	Dummy	+
Access to irrigation	AIRGN	Dummy	-
Contacts with NGOs	NGOCONT	Dummy	+

Farm characteristics			
Agroecology	AGRECO	Dummy	+/-
Land Size (Land) in hectares	LADSZE	Continuous	+
Total livestock	TLU	Continuous	+
Land quality (Soil fertility)	SOLFERT	Dummy	+/-
Pest infestation	PESTINSFTN	Dummy	+

Source: Author's Computation (2023)

Results and discussion

Socio-demographic context

According to the socioeconomic and demographic data gathered from 404 farm households all around the districts, there were 93.1% male heads of families and 6.9% female heads of households. Men possess greater prospective than women to engage in physically labor-intensive agricultural tasks outside since most of them demand it (Tsige et al., 2020). According to Teshome et al. (2021), 94% of the observations in their study on eastern Ethiopia came from families headed by men. However, as shown by Kristjanson et al. (2017), women in sub-Saharan Africa are in a worse position, have fewer resources, and are less likely than men to adopt specific climate change mitigation measures. The marital state of the household appears to be another factor that affects one's capacity to complete a job. As to the study results, 91.6% of the participants were married and lived together, while 4% were widowed and 2.7% were separated. The percentage of single people is 1.7%. This suggests that the marriage situation in the area is stable. In their study, Haque et al. (2023) explore how marital relationships can significantly influence farmers' perspectives and responses to climate change

Table 3. Households' demographic attributes.

Socio-economic variables	Percentage of respondents	
	Frequency	Percent
Sex of household		
Male	376	93.1
Female	28	6.9
Marital status of households		
Married	370	91.6
Single	7	1.7
Widow	16	2.7
Divorced	11	4

Source: Authors' calculation based on survey data (2023)

The respondents' household sizes ranged from one to thirteen members per home. The respondents' average family size was 6.7, which is around 47.8% greater than the national average of 5.8 people (CSA, 2020). Having a larger family is predominantly vital because of the labor-intensive characteristics of agricultural operations and the fact that many family members contribute to the job of intensive agriculture. The average experience of smallholder farmers in the research area was 19.2 years. The implication is that farmers' comprehension of climate change and their choice to execute an adjustment technique are influenced by the duration of time they have been involved in farming. Moreover, a greater degree of farming expertise leads farmers to use adaptation tactics that strengthen their ability to adapt since they can recognize environmental changes. The results of the study agreed with Mwungu et al. (2018) and Nyang'au et al. (2021), who state that farmers with greater farming expertise have better opportunities to use efficient adaptation tactics that increase their resistance to climate change.

Education is one of the most vital assets that farmers must use to react to both internal and external shocks in their living and working environments. Understanding and interpreting agricultural information that is presented to them from any source is essential. A knowledgeable farmer only needs to respond to the knowledge that a development agent imparts to them. Only 0.5% of the households attended tertiary education, while 161 (39.9%) of the household heads completed elementary school. The results of the study corroborate the verdict of Nyasimi et al. (2017), who noticed that greater levels of education boost smallholders' agricultural output and fortify their adaptability to climate change.

Institutional features

For extension receivers, the average number of visits every season was roughly 4.2. Climate-smart agriculture techniques and the way people perceive climate change are influenced, either favorably or adversely, by the availability of extension services. Regarding their agricultural endeavors, over 57.2% of survey participants have access to loans. The result is corroborated by the findings of Mutunga et al. (2018) and Belay et al. (2017), who distinguished that the availability of finance may influence the decision to adopt climate-smart agriculture methods, including soil conservation and irrigation, that call for large capital investments. Being a part of social groups allows farmers to exchange information about the climate, new techniques, crop varieties, and other necessary information to strengthen climate-smart agriculture practices. This understanding of climate disaster and the embracing of CSA tacit are positively correlated. About 30.2% of the respondents in the sample did not belong to any social group, while 69.8% of them were members of one. The outcome agrees with the conclusions stated by Stefanovic et al. (2017).

A total of 57% of the households in the sample had access to several sources of weather and climate data. Access to climate information augments farmers' insight into the changes in precipitation and temperature, and this updates their reaction measures. The study is supported by Amir et al. (2020) and Mutunga et al. (2018); if farmers have access to weather forecast information, they can make informed decisions about which crops to plant. In this study, about 82.2% of the participants reported having access to a market, with an average distance of 12.3 km to the adjacent marketplace. The results complement those of Maddison (2007), who suggested that proximity to the market can facilitate information sharing and exchange between producers and other stakeholders, thereby enhancing adoption.

Table 4. institutional attributes of the households in the sample

Institutional attributes	Percentage of participants			
	Yes	%	No	%
Access to market	332	82.2	72	17.8
Access to credit	231	57.2	173	42.8
Access to weather & climate information	232	57.4	172	42.6
Members of farmer cooperatives	282	69.8	122	30.2

Source: Authors' computation based on survey data (2023)

Farmer's perspective on climate change

Knowing farmers' perspectives on the matter is important for choosing the most practical CSA approach to increase resilience to acclimatize to climate change (Gandure et al., 2013). It is believed that people who are noticing changes in the climate are adopting one or more CSA activities to mitigate the negative consequences of climate change. Identifying the different adaptation tactics employed in the research area necessitates an assessment of farmers' attitudes toward climate unpredictability and change. By contrasting the present weather with that of twenty to thirty years back, farmers were able to identify several indicators of climate change. Many respondents (76.7%) agreed that, to the best of their knowledge, the climate has changed over the past two decades. Likewise, 75.2% of farmers reported a temperature rise, and 73.5% of the farmers reported less rainfall. A farmer who participated in KII mentioned that over the previous five to ten years, the pattern of precipitation changed, becoming irregular and having short seasons with either early or late commencement. In the meantime, longer dearth and dry spells have become more common. The results corroborate the findings of three research conclusions (Teshome et al., 2021; Hundera et al*.,* 2019; Concha, 2018), which showed that many producers were aware that the climate was changing. According to the KII from Degaga and Watera Shagule Kebele, who have resided in the vicinity for about 40 and 45 years, respectively. Twenty years prior, the intensity of precipitation followed a reasonably regular rhythm and was satisfactory for cultivation. The length and frequency of rainy seasons, or what Oromfia speakers would refer to as "*arfasa*" (little rainy season) and "*gena*" (crop cultivation time), have, however, decreased over the past ten years and have followed unpredictable rainfall patterns.

Climate change and the unpredictable distribution of rainfall were seen by smallholder farmers as the main difficulties to their livelihood systems. About 77.7% of farmers claimed that crop yields had dropped because of global warming. These results are consistent with the findings of Omoyo et al. (2015), who revealed that irregular rainfall, late beginnings, and untimely ends of the rainy period caused moisture stress and withering in crops, lowering their yield in eastern Kenya. About 20 years ago, the planting, cultivation, and harvesting times, as well as the rainy seasons, were predictable, as the farmers in the FGDs confidently explained. Respondents also mentioned a decrease in farmland productivity (75.7%) and loss of household income (74.5%) as additional repercussions of climate change. The other effect of climate change indicated by 74.26 % was the increased cost of farm inputs. This is probably due to heavy precipitation that triggered deterioration of the soil's nutrients because the land is stripped of its vegetation cover, and farmers eliminate plant matter from the land for contending reasons, such as building houses, a source of propane for cooking, animal feed, etc. This is also likely linked to a boom in fertilizer usage as a sign of deteriorating soil fertility. Approximately 73% of smallholder farmers stated that climate change has culminated in a rise in pests and diseases. This could be attributed to the ideal conditions that temperature and rainfall variations create for the spread of diseases and pests. This verdict is reinforced by the inference of Naveenkumar et al. (2018), which shows that the diversity and adaptability of agriculture to diseases and pests were impacted by climate change and accounted for a substantial percentage of maize yield losses. Araro et al. (2019) results, which support this finding, showed that 52.2% of the households in Southern Ethiopia reported lower crop yield and decreased land productivity.

CSA practices adopted by farmers.

There is a growing concern about the effect of global warming on crop productivity, such as seed loss, delayed germination of ripening crops, delayed desiccation of crops, spoiling of harvested products, dearth, deluge, soil loss, insect threats, and diseases. Consequently, farmers who were impacted by climate change have embraced various CSA measures (Abayineh and Belay, 2017; Sertse et al., 2021). Integrated pest and herb management, crop rotation, improved crop varieties (high-yielding crops), crop diversification, SWC, agroforestry systems (woody perennial crops), and organic fertilizer supplementation to mineral fertilizer are the most popular CSA practice strategies used by agriculturalists in the study area. The results of the research showed that producers in the study area use more than eight CSA strategies (Figure 2).

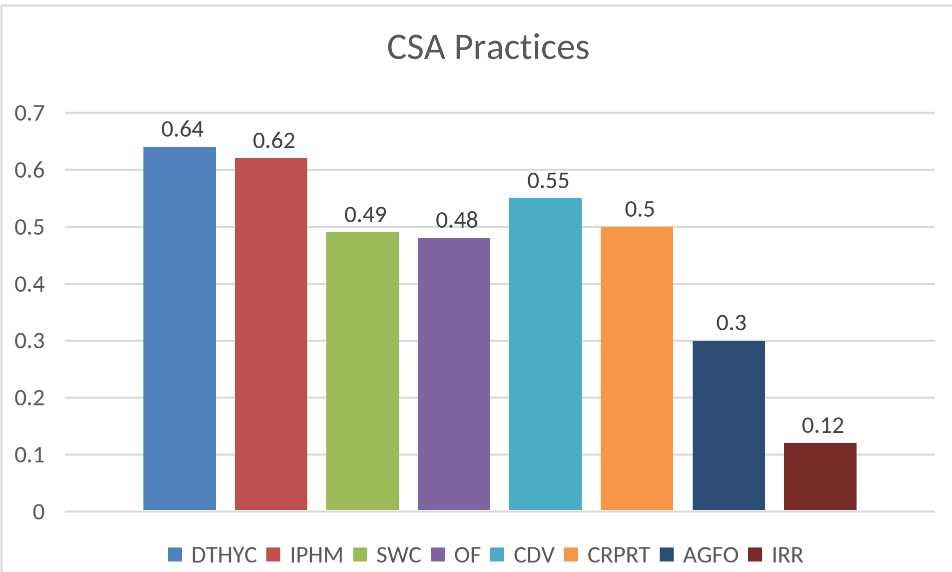

Figure 2. Various climate-smart agriculture techniques are being applied by farmers in the research area as mitigation measures.

Adopting crop cultivars that are more productive and tolerant to hurdles such as drought, heat, insects, and diseases is essential. These cultivars aid in sustaining yield stability despite climate change. In the study area, 64% of the sampled smallholder farmers implemented improved crop varieties, specifically high-yielding crops, as part of their CSA techniques. The use of upgraded crop cultivars significantly enhances crop output by improving adaptive and resilient capacity and mitigating adverse consequences (Habte et al., 2018). Integrated pest and herb control fosters climate-smart pest management, which amalgamates monitoring, prevention, and control measures to mitigate crop losses, complement ecosystem benefits, and strengthen resilience to climate change. The survey results reveal that roughly 62% of the surveyed participants implemented integrated pest and herb management (IPHM) to address various insect and pest infestations on crops. The application of IPHM as an adaptation and mitigation approach aids in lessening the amounts of agrochemicals used, which have negative impacts on climate change (Zenebe et al.,2021).

Crop diversification maintains yields, enhances the availability of food, and reduces the risk of total crop failure. Crop diversification is employed by approximately 55 percent of the farmers in the sample as a strategy for mitigating and adapting to climate change. Crop diversity minimizes the impact of climate change triggered by reliance on single-crop production, along with promoting healthy soil management, interrupting the disease cycle, and reducing weed populations (Ali et al., 2023). Rotating diverse crops in the same field over seasons helps balance nutrient removal, control pests and weeds, avert soil erosion, and enhance soil richness. This practice is a cornerstone of CSA, improves soil wellness and resilience to climate fluctuation, while reducing the need for chemical inputs. The study's outcome shows that nearly 50% of the participants implemented crop rotation.

Soil and water conservation measures such as mulching, minimum tillage, permanent planting basins, and water harvesting. These practices enhance soil moisture holding, boost soil humus, minimize erosion, and enhance water use efficiency, all of which are indispensable for resilience in rainfed and drought-prone systems. About 49% of the respondents implemented soil and water conservation in the study areas. Combining organic (e.g., compost, manure) and mineral fertilizers optimizes nutrient availability, boosts productivity, and improves agronomic efficiency. The findings of the study revealed that roughly 48% of participants administered organic fertilizer. Furthermore, to mitigate the crop production risks due to inadequate precipitation, nearly 12% of surveyed households used small-scale irrigation alternatives.

Factors impacting farmers' perspectives on climate change and adoption of CSAs

This study determines the variables affecting the tendency to perceive and the determination to adapt to the changing climate. To achieve this, the Heckman probit model with selection, or the sample selection model, was applied. The Heckman probit choice model was employed, and the model has undergone verification for its pertinence over the standard probit model (i.e., a probit model does not account for selection). The outcome confirmed that the sample selection issue was noticed and contingent on the error term in both the result and choice model, arguing for the application of the Hackman choice probit model, with rho quite distinct from zero (Wald X^2 =

595.82, with $p < 0.000$), and this designates that it has robust descriptive power. The outcome showed that most independent parameters in both the result and choice model and their marginal estimates arrive at $p < 0.05$, indicating statistical significance.

Researchers have studied the views of farmers and tactics for adaptation with a unit change in an explanatory parameter by employing marginal outcomes, which measure the anticipated change in likelihood. The selection model determines the likelihood that farmers will acknowledge climate change and attempt to lessen its negative consequences. The outcome variable's dichotomous dependent variable represents farmers' embracing climate-smart agricultural techniques, while the selection equation's dichotomous dependent variable reflects farmers' views regarding climate change. The outcomes of the selection model, which explores influential variables on cognizance of the climate, and the outcome model, which examines factors driving farmers' decisions about embracing climate-smart agriculture, are displayed in Table 5. The outputs of the outcome model, which examines the factors inducing producers' verdicts to espouse climate-smart agriculture, showed that certain independent factors were positively and significantly associated with the likelihood of adopting climate-smart agriculture. These variables include family size, possession of livestock, land size, credit availability, social membership, annual income, availability of weather data, and training obtained. For each extra active family in the house, which means family members above 18 and below 64 in the house, there is a 1.6% increase in the possibility that farmers are going to adopt climate-smart agriculture actions. This finding supports the conclusion of Ojoko et al. (2017), who claimed that large families provide a significant workforce for effectively embracing novel farming methods in the farm parcel.

A decision by smallholders to implement climate-smart agricultural techniques was positively influenced by the aggregate count of livestock at a 1% significance level. It is anticipated that for every unit increase in TLU, the espousal of climate-smart agriculture will rise by 2.0%. It is believed that having this degree of power would make households more likely to decide to make use of climate-smart agricultural techniques. As intended, it has a notable impact on the choice to implement climate-smart agriculture. One explanation is that livestock supplies a significant portion of the traction, and dung is required to keep the soil healthy. The possibility that farmers will make additional funds to invest in the supplies and tools required for climate-smart agriculture innovations rises with the size of their herd. Similar findings from earlier research have been reported (Zakari et al., 2019). The decision to undertake climate-smart agriculture practices was positively and significantly impacted, at the 1% level, by the availability of credit. It was demonstrated that farmers with access to financing options are more financially capable of covering all of the expenses related to the CSA innovations they choose to use. In agreement with this finding, several researchers revealed that loan availability has a positive and significant effect on adopting climate-smart farming techniques (Tamiru, 2020; CIAT and BFS/USAID, 2017; Mesay et al*.,* 2013). Contrary to this finding, Aryal et al. (2017) found that the embracing of climate-smart farming techniques is significantly and negatively impacted by loan availability.

Households that have participated in social associations have information related to farming, which is expected to prompt the CSA espousal positively at 1% significance level. Participating in a social organization raises the chance that farmers are going to employ CSA strategies by 34.9%. Participating in social events is seen as beneficial for developing the social assets of society, which are essential for exchanging agricultural knowledge and having robust social connections. This, in turn, contributes to CSA espousal (Abegunde et al*.,* 2020). Moreover, as shown by Zougmore et al*. (*2021), members of social groups have a 10.6% higher chance of adopting CSAs than farmers who have not joined social organizations. Training accessibility had a favorable impact on the choice to embrace climate-smart agriculture at the 1% significance level. Engaging in training increases the chance of farmers adopting CSA by 17.3%. The findings indicate that farmers who received training used various climate-smart agriculture techniques more effectively than farmers without it. This is because farmers are more likely to utilize CSA technology if they receive great methodological support and training from development personnel. A recent study reported a similar finding (Franco, 2020; Mango et al., 2018).

Results associated with farm size were contradictory to prior expectations. The size of the farm negatively impacts the espousal of climate-smart agriculture. As the farm size increases, the adoption of climate-smart agriculture decreases by 15.8%. This suggests that larger farms may face more challenges in implementing innovative practices, possibly due to variables like management complexity or limited resources. Smaller landholders may adopt CSA more intensively as a survival strategy or a means to improve productivity on limited land. Larger farms may rely more on conventional practices or mechanization that are less compatible with the CSA method. The results are comparable to those of Petros et al. (2023), who revealed that farm size had a detrimental impact on the uptake of CSA.

The decision to adopt climate-smart farming techniques was significantly impacted by the accessibility of meteorological information at 1% significance level. There is a 7.8% rise in farmers' propensity to employ CSA tactics when climate data is accurate. Farmers who have control over meteorological data are better equipped to comprehend fluctuations in temperature and rainfall. This may be because farmers who have a repository of accurate data about present and projected temperatures and precipitation will be able to choose superior cultivars that are early ripening and resilient to drought, disease, and pests. Additionally, when they have precise knowledge about the climate and weather, they can make better decisions regarding the adaptation approach that will lift their resilience. As previously noted, the result aligns with relevant research conclusions (Franco, 2020; Machingura et al., 2018).

Table 5: Outcome of Heckman two-stage sample selection model (n = 404)

Explanatory variables	Outcome model (Adoption of climate-smart agriculture)		Selection model (Perception of climate change)	
	Regression	Marginal effect	Regression	Marginal effect
	Coefficient	Coefficient	Coefficient	Coefficient
AGRECO	0.001(0.036)	0.001	0.483(0.179)	0.121***
SEX	-0.028(0.058)	-0.028	0.109(0.381)	0.027
AGE	-0.0002(0.004)	-0.000	0.556(0.024)	0.014***
MARSTA			0.005(0.170)	0.001
FAMSZE	0.016(0.009)	0.016*	0.068 (0.055)	0.017
EDULEVL	0.004(0.004)	0.004	0.059(0.025)	0.014***
FAEXP	-0.001(0.003)	-0.001	-0.020(0.023)	0.005
LADSZE	-0.1588(0.06)	-0.1588***		
TLU	0.020(0.009)	0.020 ***		
ACCRDT	0.256(0.036)	0.256 ***		
FEXC	-0.002(0.007)	-0.002		
MFG	0.349(0.069)	0.349***		
PARTDOM	-0.004(0.026)	-0.004		
MARKINFO			-0.234(0.409)	-0.059)
ACMIDA			0.429(0.189)	0.108***
ANINCM	1.85e-06(9.22e-07)	1.85e-06**		

OFINCM	-2.36e-06(1.65e-06)	2.36e-06		
DURTNG	0.173(0.052)	0.173***	0.460(0.208)	0.116**
DSTMKTK	-0.007(0.005)	-0.007		
AIRGN	0.0008(0.042)	0.001		
SOILFER	0.008(0.029)	0.008		
PESTINSFTN	0.069(0.071)	0.069	1.165(0.405)	0.294***
AWINF	0.078(0.036)	0.078***	0.108(0.212)	0.027
NGOCON			-0.631(0.382)	-0.159*
Constant	0.094(0.199)		-3.387(0.896) ***	
Total observation	404			
Selected	314			
Non selected	90			
Wald chi-square	595.82(P<0.001)			

***, ** and * indicate significance levels at 1%, 5% and 10%, respectively

Numbers in parentheses represent standard error

The findings of the choice model, which examine the variables impacting farmers' views on climate variation, show that farmers' attitudes are positively impacted by agroecology, their age, level of schooling, access to mass media, duration of training received, pest infestation, interaction with non-governmental organizations, and access to meteorological information. Similar results became apparent in Asrat and Simane (2017) and Deressa et al. (2011), who investigated the perks of climate-smart agricultural methods for adaptation as well as farmers' viewpoints and reactions to climate change in Ethiopia's Nile basin. The variables that have been explored as influencing agriculturalists' views on climate change and their mitigation techniques are closely allied to Ethiopia's government development initiatives aimed at alleviating poverty and strengthening smallholder farmers' ability to cope (Ampaire et al., 2020; Filho et al., 2018; and Hameso, 2018).

Conclusion

The findings of the research concluded that respondents witnessed a decline in rainfall and a temperature rise. Farmers cited drought, rising insect and disease incidences, declining richness of soils, and decreasing crop outputs as among the primary challenges to cultivating an array of crops. Thus, they were able to acclimatize to climate change through the engagement of more abiotic and biotic stress-tolerant crop types, crop diversification, integrated pest management, the application of fertilizers supplemented with organic fertilizers, and the implementation of soil and water conservation tactics. Agroecology, age, education level, credit availability, pest infestation, and mass media availability were the main factors that determined farmers' attitudes towards a changing environment positively, while affiliation with a non-governmental organization negatively affected perception of climate change. Family size, total livestock units, land size, access to credit, membership of farmers' cooperatives, annual income, training opportunities, and access to meteorological data were the main variables positively impacting the adoption of climate-smart agriculture. The results suggest that farmers are now cognizant of the effects of climate change and have been making efforts to counteract it by implementing a variety of tactics to keep up agricultural yield. However, their efforts are being hampered by institutional, socioeconomic, and agroecological constraints. Hence, a policy to improve the agricultural production of rural communities against a changing climate should be the main priority for agricultural policymakers to enhance subsistence farmers’ capability to acclimatize and develop resilience to climate change in the study area.

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References

Abayineh Amare, Belay Simane. 2017. Assessment of household food security in the face of climate change and variability in the upper Blue Nile of Ethiopia. J Agric Sci Technol B. 7: 285–300.

Abdallah AH, Ayamga M, Awuni JA. 2019. Impact of agricultural credit on farm income under the Savanna and Transitional zones of Ghana. Agric. Finance Rev. 79 (1): 60–84.

Abegunde VO, Sibanda M, Obi A. 2020. Determinants of the adoption of climate-smart agricultural practices by small-scale farming households in King Cetshwayo District Municipality, South Africa. Sustainability 12 (1): 195.

Ali H, Menza M., Hagos, F. et al. 2023. Impact of climate-smart agriculture adoption on food security and multidimensional poverty of rural farm households in the Central Rift Valley of Ethiopia. Agric & Food Secur. 11: 62.

Ali S, Ying L, Nazir A, Ishaq M, Shah T, Ye X, Ilyas A, Tariq A. 2021. Rural farmers' perception and coping strategies towards climate change and their determinants: evidence from Khyber Pakhtunkhwa province, Pakistan. J Clean Prod. 291: 125250.

Amir S, Saqib Z, Khan MI, Ali A, Khan MA, Bokhari SA, Zaman ul Haq. 2020). Determinants of farmers' adaptation to climate change in rain-fed agriculture of Pakistan. Arab J Geosci. 13 (19).

Amogne Asfaw, Amare Bantider, Belay Simane, Ali Hassen. 2021. Smallholder farmers' livelihood vulnerability to climate change-induced hazards: agroecology-based comparative analysis in North central Ethiopia (Woleka Sub-basin). Heliyon 7 (4), e06761.

Araro K, Legesse SA, Meshesha DT. 2019. Climate change and variability impacts on rural livelihoods and adaptation strategies in southern Ethiopia. Earth Sys. Environ. 4: 15–26

Asrat P, Simane B. 2017. Adaptation benefits of climate-smart agricultural practices in the Blue Nile Basin: empirical evidence from North-West Ethiopia. In: Leal Filho, W., Belay, S., Kalangu, J., Menas, W., Munishi, P., Musiyiwa, K. (eds) Climate Change Adaptation in Africa. Climate Change Management. Springer, Cham.

Belay DW, Asfaw Z, Lulekal E, Kassa B. 2021. Farmers' management of potato (*Solanum tuberosum* L.) late blight (*Phytophtora infestans* (Mont.) de Bary) and sprouting in Shashemene and West Shewa districts, Ethiopia. Cogent Food & Agriculture. *7*(1).

Belay A, Recha JW, Woldeamanuel T. et al. 2017. Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. Agric & Food Secur. 6: 24.

Concha CD. 2018. Farmer perceptions and climate change adaptation in the West Africa Sudan Savannah: Reality check in Dassari, Benin, and Dano, Burkina Faso. J Clim. 6(2):19.

Deressa TT, Hassan RM, Ringler C. 2011. Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. J Agric Sci. 149 (1): 23–31

Deressa T., Rashid M. Hassan, Claudia Ringler, Tekie Alemu, Mahmud Yesuf. 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Glob Environ Change. 19(2):248-255.

Befikadu Esayas, Belay Simane, Ermias Teferi, Victor Ongoma, Nigussie Tefera. 2019. Climate variability and farmers' perception in southern Ethiopia. Adv Meteorol. Article ID 7341465.

Etana D, van Wesenbeeck CFA, de Cock Buning T. 2020. Socio-cultural aspects of farmers' perception of the risk of climate change and variability in Central Ethiopia. Clim Dev. 13(2):139–151.

Fiker Hilemelekot, Desalegn Yayeh Ayal, Kassahun Ture, Tadesse Terefe. 2021. Climate change and variability adaptation strategies and their implications for household food Security: the case of Basona Worena District, North Shewa zone, Ethiopia. Clim Serv. 24: 100269.

Franco JC. 2020. Integrated Pest Management: Sustainable approach to crop protection; Springer: Berlin/Heidelberg, Germany.

Gandure S, Walker S, Botha J J. 2013. Farmers' perceptions of adaptation to climate change and water stress in a South African rural community. Environ Dev**.** 5:39–53.

Habte Werede M, Smith JU, Boke Ambaye S. 2018. Integrated soil fertility management for sustainable teff (*Eragrostistef*) production in Halaba, Southern Ethiopia. Cogent Food Agric. 4(1).

Haque AS, Kumar L, Bhullar N. 2023. Gendered perceptions of climate change and agricultural adaptation practices: a systematic review. Clim Dev. 15(10): 885–902

Heckman JJ. 1976. The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models. Ann Econ Soc Meas. 5: 475–492.

Hundera H, Mpandeli S, Bantider A. 2019. Smallholder farmers' awareness and perceptions of climate change in Adama district, central rift valley of Ethiopia. Weather Clim Extrem. 26: 100230.

Jha CK, Gupta V. 2021. Do better agricultural extension and climate information sources enhance adaptive capacity? A micro-level assessment of farm households in rural India. Ecofeminism Clim Chang. 2 (2): 83–102.

IPCC (Intergovernmental Panel on Climate Change). 2015. Climate Change 2014: Mitigation of Climate Change: Working Group III Contribution to the IPCC Fifth Assessment Report. Cambridge University Press.

Ketema Nebere, Mintesnot Azene, Abraham Mebrat, Selomon Afework. 2024. Farmers' perceptions of climate change and variability and determinants of adaptation strategies and coping mechanism in Ethiopia. J Sci Incl Dev. 6(2): 43–66.

Kothari CR. 2004. Research methodology: Methods and techniques, 2nd Revised Edition, New Age International Publishers, New Delhi, India

Kristjanson P, Bryan E, Bernier Q, Twyman J, Meinzen Dick R, Kieran C, Ringler C, Jost C, Doss C. 2017. Addressing gender in agricultural research for development in the face of a changing climate: where are we and where should we be going? Int J Agric Sustain. 482–500.

Maddison D. 2007. The perception of and adaptation to climate change in Africa. Policy Research working paper; no. WPS 4308 Washington, DC: World Bank.

Mango N, Makate C, Tamene L, Mponela P, Ndengu G. 2018. Adoption of small-scale irrigation farming as a climate-smart agriculture practice and its influence on household income in the Chinyanja Triangle, Southern Africa. Land. 7: 49.

Mekuyie M, Mulu D. (2021). Perception of impacts of climate variability on pastoralists and their adaptation/coping strategies in Fentale district of Oromia region, Ethiopia. Environ. Sys. Res. 10:4.

Mutunga Evelyn J, Ndungu Charles K, Muendo P. 2018. Factors influencing smallholder farmers' adaptation to climate variability in Kitui County, Kenya. Int J Environ Sci Nat Res. 8(5): 555746.

Mwungu CM, Mwongera C, Shikuku K, Acosta M, Laderach P. 2018. Determinants of adoption of climate-smart agriculture technologies at farm plot level: an Assessment from Southern Tanzania. In: Filho, Walter Leal (editors) Handbook of Climate Change Resilience. Springer.

NBE (National Bank of Ethiopia). 2022. National Bank of Ethiopia. Annual Report. Addis Ababa.

Njeru E, Grey S, Kilawe E. 2016. Eastern Africa climate-smart agriculture. Scoping Study: Ethiopia, Kenya and Uganda. FAO, Addis Ababa, Ethiopia.

Nyang'au JO, Mohamed JH, Mango N, Makate C, Wangeci AN. 2021. Smallholder farmers' perception of climate change and adoption of climate smart agriculture practices in Masaba South Sub-county, Kisii, Kenya. Heliyon 7 (4), e06789.

Nyasimi M, Kimeli P, Sayula G, Radeny M, Kinyangi J, Mungai C. 2017. Adoption and dissemination pathways for climate-smart agriculture technologies and practices for climate-resilient livelihoods in Lushoto, Northeast Tanzania. Clim. 5 (3): 63

Ojoko EA, Akinwunmi JA, Yusuf SA, Oni OA. 2017. Factors influencing the level of use of climate-smart agricultural practices (CSAPs) in Sokoto state, Nigeria J Agric Sci. 62 (3): 315–327.

Omoyo NN, Wakhungu J, Oteng'i S. 2015. Effects of climate variability on maize yield in the arid and semi-arid lands of lower eastern Kenya. Agric Food Secur. 4: 8

Onyutha C. 2019. African food insecurity in a changing climate: the roles of science and policy. Food Energy Sec. 8 (1): e00160.

Pedersen JST, Santos FD, van Vuuren D, Gupta J, Coelho RE, Aparício BA, Swart R. 2021. An assessment of the performance of scenarios against historical global emissions for IPCC reports. Global Environ Change 66: 102199

Petros C, Chizumba S, Million S, Samuel F. 2023. Factors influencing climate-smart agriculture practices adoption and crop productivity among smallholder farmers in Nyimba District, Zambia. https://doi.org/10.21203/rs.3.rs-3604497/v1

Ricart S, Olcina J, Rico AM. 2019. Evaluating public attitudes and farmers' beliefs towards climate change adaptation: awareness, perception, and populism at European level. Land 8 (1): 4.

Sasson A. 2012. Food security for Africa: an urgent global challenge. Agric. Food Secur. 1 (1): 1–16

Sertse SF, Khan NA, Shah AA, Liu Y, Naqvi SAA. 2021. Farm households' perceptions and adaptation strategies to climate change risks and their determinants: evidence from Raya Azebo district, Ethiopia. Int J Disaster Risk Reduc. 60: 102255

Solomon N, Birhane E, Gordon C, Haile M, Taheri F, Azadi H, Scheffran J. 2018. Environmental impacts and causes of conflict in the Horn of Africa: a review. Earth Sci Rev. 177: 284–290.

Stefanovic, J. O., Yang, H., Zhou, Y., Kamali, B., & Ogalleh, S. A. (2017). Adaption to climate change: a case study of two agricultural systems from Kenya. Clim. Dev.11(4): 319–337.

Katharina Talanow, Emmeline N. Topp, Jacqueline Loos, Berta Martín-López. 2021. Farmers' perceptions of climate change and adaptation strategies in South Africa's Western Cape, J Rural Stud. 81:203-219.

Tesfahunegn GB, Gebru TA. 2021. Climate change effects on agricultural production: insights for adaptation strategy from the context of smallholder farmers in Dura catchment, northern Ethiopia. Geojournal 86 (1): 417–430.

Teshome H, Tesfaye K, Dechassa N, Tana T, Huber M. 2021. Smallholder farmers' perceptions of climate change and adaptation practices for maize production in Eastern Ethiopia. Sustainability 13: 9622

Thinda K, Ogundeji A, Belle J, Ojo T. 2021. Determinants of relevant constraints inhibiting farmers' adoption of climate change adaptation strategies in South Africa. J Asian Afr Stud. 56 (3): 610–627.

Tsige M, Synnevåg G, Aune JB. 2020. Gendered constraints for adopting climate- smart agriculture amongst smallholder Ethiopian women farmers. Scientific African 7: e00250

van Weezel S. 2019. On climate and conflict: precipitation decline and communal conflict in Ethiopia and Kenya. J Peace Res. 56 (4): 514–528.

von Braun J. 2020. Climate change risks for agriculture, health, and nutrition. In: Health of People, Health of Planet and Our Responsibility. Springer, Cham.

Weldegebriel ZB, Prowse M. 2017. Climate variability and livelihood diversification in northern Ethiopia: a case study of Lasta and Beyeda districts. Geogr J. 183 (1): 84–96

Yang M, Xing F, Liu X, Chen Z, Wen Y. 2024. The impact of livelihood resilience and climate change perception on farmers' climate change adaptation behaviour decision. For Econ Rev. 6 (1).

Zakari S, Ouédraogo M, Abasse T, Zougmoré R. 2019. Farmer's prioritization and adoption of climate-smart agriculture technologies and practices. J Agric Environ Sci. 8: 176–185

Zenebe Mekonnen, Marta Kidemu, Habtamu Abebe, Mihiret Semere, Marta Gebreyesus, Adefris Worku, Musse Tesfaye, Abraham Chernet. 2021. Traditional knowledge and institutions for sustainable climate change adaptation in Ethiopia. Curr. Res. Environ Sustain. 3:100080.

Zerssa G, Feyssa D, Kim DG, Eichler-Löbermann B. 2021. Challenges of smallholder farming in Ethiopia and opportunities by adopting climate-smart agriculture. Agriculture 11: 192.

Zougmore RB, Laderach P, Campbell BM. 2021. Transforming food systems in Africa under climate change pressure: role of climate-smart agriculture. Sustainability 13 (8): 4305.