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Determinants of climate-smart agricultural practices in smallholder plots: evidence from Wadla district, northeast Ethiopia

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Abstract

Purpose – This study aims to examine determinants of farmers' use of climate-smart agricultural practices, specifically improved crop varieties, intercropping, improved livestock breeds and rainwater harvesting in Wadla district, northeast Ethiopia.

Design/methodology/approach – A cross-sectional household survey was used. A structured interview schedule for respondent households and checklists for key informants and focus group discussants were used. This study used both descriptive statistics and a multivariate probit econometric model to analyze the collected data. The model was used to compute factors influencing the use of climate-smart agricultural practices in the study area.

Findings – The results revealed that households adopted selected practices. The likelihood of farmers' decisions to use improved crop varieties, intercropping, improved livestock breeds and rainwater harvesting was 85%, 52%, 69% and 59%, respectively. The joint probability of using these climate-smart agricultural practices was 23.7%. The model results confirmed that sex, level of education, livestock holding, access to credit, farm distance, market distance and training were significant factors that affected the use of climate-smart agricultural practices in the study area.

Originality/value – The present study used the most selected locally practiced interventions for climate-smart agriculture.

Keywords Climate change, Intercropping, Multivariate probit, Rain water harvesting

Paper type Research paper

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Declaration of competing interest. The authors declare that they have no competing interests.

Availability of data. Primary data for this study were available from *Wadla* District Office of Agriculture and Administration, and through directly interviewing the farm households. The secondary data were also accessed from published papers. At present, all the collected data are available with authors.

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1. Introduction

Agriculture is a cross-cutting sector in the world that transforms nations' economies and is a proven path to prosperity (FAO, 2010). No region of the world has developed a diverse and modern economy without establishing successful foundations in agriculture (FAO, 2016a). The agriculture sector needs to overcome three intertwined challenges:

1. sustainably increase agricultural productivity to meet global demand;
2. adapt to the impacts of climate change; and
3. contribute to reducing the accumulation of greenhouse gases in the atmosphere (Foresight, 2010; Beddington *et al.*, 2012; HLPE, 2012).

Similarly, the economy in African countries is mainly dependent on agriculture (World Bank, 2011; FAO, 2017). As a sector, agriculture can contribute toward major continental priorities, such as eradicating poverty and hunger, enhancing intra-Africa trade and investments, rapid industrialization, economic diversification, sustainable resource management, environmental management, creating jobs, human security and shared prosperity (AGRA, 2017). Likewise, agriculture is the life of people in sub-Saharan Africa (SSA). The adoption of innovations has attracted attention because of the fact that the basis of livelihoods for developing countries is agricultural production (Feder *et al.*, 1984). Farmers can make changes to food production and adaptive capacity through the adoption of climate-smart agricultural practices (FAO, 2018).

Currently, there is a high demand to produce food for the global population, which is expected to reach 9.1 billion people in 2050 and over 10 billion by the end of the century (Campbell *et al.*, 2014; FAO, 2017). Thus, to feed this large population, twofold agricultural production from the present level is required (FAO, 2016a). Ethiopia is one of the SSA countries dependent on agriculture for its local and national economies (Matouš *et al.*, 2013). Agriculture is the most important driver of employment creation, poverty reduction and export earnings in Ethiopia (Endashaw *et al.*, 2022).

Climate change is a threat to agricultural production systems and is one of the biggest challenges in the 21st century worldwide (FAO, 2013). Moreover, it is a serious problem for the agricultural production system in SSA in general and in Ethiopia in particular. Climate change and population pressure are persistent development bottlenecks in the country (Kindu *et al.*, 2012). Likewise, the agricultural production system in the study area faced climate change-induced problems (*Wadla* District Office of Agriculture, 2020). Agriculture is both the basis of human activity at risk from climate change and a cause of climate change. It has to be carried out without accelerating environmental problems while coping with a changing climate. Hence, climate change has fundamentally shifted the agricultural development agenda. In this respect, the governments and other stakeholders came up with the concept of climate-smart agriculture as the latest solution to reduce the interlinked problems of the agricultural production system and climate change by considering the increasing intensity of climate-related upheavals in agricultural production (James *et al.*, 2015; FAO, 2016a).

2. Climate-smart agriculture concept

The concept of climate-smart agriculture was launched in 2009. Since then, it has reformed through the interactions of different stakeholders advocating for better integration of adaptation and mitigation actions to support sustainable agricultural development for food security under climate change. Smart agriculture is an approach to understanding the basic requirements as well as the changes in the current environment because of external factors based on context information and the utilization of collected data to optimize sensors' operation or influence the operation of actuators to change the current environment (Aqeel-ur-Rehman and Zubair, 2009). Whereas climate-smart agriculture is an approach that sustainably transforms and reorients agricultural development by increasing productivity, enhancing adaptation and reducing greenhouse gases to achieve food security under the new realities of climate change (FAO, 2010). According to Kaczan *et al.* (2013), climate-smart agricultural practices are practices that help to increase adaptive capacity through efficient use of resources and creating agriculture systems that can stand up to the threats of climate change. Practices are considered as climate-smart if they maintain or achieve increments in productivity as well as at least one of the other objectives of climate-smart agriculture (adaptation and mitigation) (Hailemariam *et al.*, 2019). Climate-smart agriculture has key characteristics. It is a context-specific phenomenon that addresses climate change, integrates multiple goals, manages trade-offs and maintains ecosystem services. In addition, it consists of multiple entry points and engages women and marginalized groups (FAO, 2013; Lipper *et al.*, 2014).

2.1 Climate-smart agricultural practices in Ethiopia

In Ethiopia, climate-smart agriculture has been introduced and practiced for over a decade, initiated by the government and NGOs such as Farm Africa, SOS Sahel, Self Help Africa, Climate Change Forum, CARE, SG2000 and World Vision (FAO, 2016b). Therefore, promoting climate-smart agricultural practices among farmers through empowerment and capacity building has been enhanced as the development means to sustain agricultural activities in SSA, including Ethiopia (Branca *et al.*, 2013). Previous studies revealed different results on climate-smart agriculture as demographic, economic, institutional and physical factors have influenced agricultural practices (Malefiya, 2017; Amare and Abebe, 2018; Adera and Pauline, 2018; Wekesa, 2018; Zeinu, 2019; Tekeste, 2021). Moreover, Ethiopia has promoted several climate-smart agricultural practices in different parts of the country, including *Wadla* district. Nevertheless, farm households could not improve agricultural productivity (MoANR, 2015). The aforementioned researchers have not yet studied climate-smart agricultural practices, particularly on improved crop varieties, animal breeds, rainwater harvesting and intercropping using seemingly unrelated multivariate probit models among smallholders in northeast Ethiopia of *Wadla* district (FAO, 2016b). Therefore, the objective of this study was to investigate factors that influence climate-smart agricultural practices in the study area.

Farming decisions are complex, dynamic and contextual. Humans in general and farmers' behavior in particular are directly linked to utility maximization or rational choice theory. The utility maximization theory is the basis for adaptation in the decision-making process for agricultural practices (Sanga *et al.*, 2021). The choices of utility depend on randomness of human behavior and the interaction of dependent and explanatory variables (Ghazali, 1982; Greene, 2008). The assumption is that farmers adopt improved practices when their perceived utility exceeds the old practices (Paulos and Belay, 2017).

Hence, farmers have different cultures, resource endowments, preferences and decisions on the use of climate-smart agricultural practices (Loevinsohn *et al.*, 2013). They have been used in various combinations of farming practices to mitigate climate change hazards, generate income, attain food security and reduce poverty. This implies decisions to use multiple farming practices are inherently multivariate, and attempting univariate computation would exclude useful economic information about the interdependence and concurrent use of climate-smart agricultural practices (Aryal *et al.*, 2017). When farmers use multiple interventions in their farming systems, they prefer and take into account diversified forms of interdependencies among agricultural practices. Disregarding such interdependencies might lead to inconsistent policy recommendations (Beyene *et al.*, 2017). Therefore, in this paper, the theory of utility maximization is used to elucidate whether the likelihood of farmers' decisions on multiple climate-smart agricultural practices is greater in isolation or in combinations. As a result, farmers can use multiple climate-smart agricultural practices either in isolation or in combination if the expected values obtained from the intervened practices are greater than the traditional business practiced as usual.

3. Methodology

3.1 Description of the study area

Wadla district is located in the North *Wollo* zone of the *Amhara* region of Northeast Ethiopia. Its geographical coordinates are between 11°50′N latitude and 38°50′E longitude. The district is situated at a distance of 644 km from Addis Ababa and 252 km from Bahir Dar, the regional city (Figure 1). The total area covered by the district was 661.5 km^2, which includes 23 rural and 2 urban *kebeles* (the lowest administrative unit in the country). The size of the population of the district was 135,208 of which 67,110 were males and 68,098 were females. The agroecological zone of the study district is categorized into three agro-climatic zones, namely, highland "Dega," mid-highland "Woina Dega" and lowland "Kolla" (*Wadla* District Office of Agriculture, 2020).

The rainfall distribution of the study area is bimodal, or has two rainy seasons. These are spring (from March to May) and summer (from June to August). The mean annual rainfall was 1,498 mm, and the mean annual temperature was 27°C. The altitude of the district ranges from 700 to 3,200 m.a.s.l. During the study period, the total area of the district was 66,148.24 ha, of which 31.4% was cultivated, 10.75% was forest, 1.6% was communal, 26.25% was grazed, 20% was residential, 4% had developed infrastructure and 6% of the lands was allocated for valleys, gorges and water bodies. The soil type of the study area includes brown, red and black (*Wadla* District Office of Agriculture, 2020). The main livelihood strategy of the people in the district was agriculture. Farmers are engaged in both

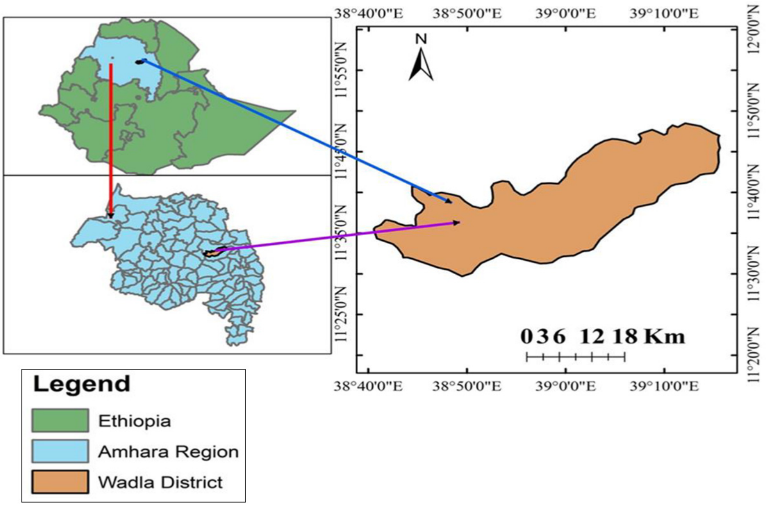

Figure 1.
Map of study area

Source: Author's work 2020/2021

crop and livestock production. The dominant crops produced in the district were wheat, barley, peas, beans, lentils, chickpeas, grass peas, tef and maize. The main livestock types reared in the district were cow, ox, goat, sheep, horse, donkey, mule and poultry. Moreover, some households practiced modern and traditional beekeeping. Agriculture remained the dominant strategy of traditional practices in the district and was exposed to climatic risks (*Wadla* District Office of Agriculture, 2020).

3.2 Data and methods

3.2.1 Sampling techniques and sample size determination. Quantitative and qualitative research approaches were used using a cross-sectional survey. Three-stage sampling techniques were carried out to select respondent households. In the first stage, the study district was selected purposefully based on its potential for the selected climate-smart agriculture practices. In the second stage, four study *kebeles* were selected through a simple random sampling technique using the lottery method. In the third stage, respondent farmers were selected through systematic random sampling from the sample frame of the study. The sample size was determined using a formula adapted in Israel (2003):

$$n = \frac{N}{1 + N(e^2)} \tag{1}$$

where n is the sample size, N is the total households in the sampling frame and e is the level of precision (8%). Respondent households were selected from the study *kebeles*. The sizes of households were 1,675 in *Hamusit*, 1,470 in *Timtmat*, 1,150 in *Qurqursolela* and 1,300 in *Gashena kebeles*. Thus, a total of 200 sample respondents were selected. The sample size for each sampled *kebele* was proportional to the total number of their respective households, as shown in Table 1.

3.2.2 Data type, sources and methods of data collection. To get adequate information, both quantitative and qualitative data types were collected from primary and secondary sources. The secondary data were collected from published literature such as books, journal articles, statistical and office reports, while the primary data were collected from surveyed households supplemented by key informants, focus group discussants and field observations.

3.2.3 Method of data analysis. Both descriptive statistics and an econometric model were used for data analysis. A multivariate Probit model was used to analyze factors influencing farmers' use of climate-smart agricultural practices. Estimation of the univariate probit model for the use of each climate-smart agricultural practices by farmers would lead to the unexpected problem of simultaneity (Greene, 2008). To account for this problem, the multivariate probit model was used to show the interdependence among dependent variables (Degye *et al.*, 2013; Arinloye, 2015; Taye *et al.*, 2018). The multivariate probit model

Sample *kebeles*	No. of households	Proportion of samples
Hamusit	1,675	60
Timtmat	1,470	53
Qurqursolela	1,150	41
Gashena	1,300	46
Total	5,595	200

Source: Author's work 2020/2021

Table 1. Sample size distribution

is a generalization of the probit model, which is used to estimate several correlated binary outcomes jointly and is appropriate for prediction when the dependent variables are discrete (Chib and Greenberg, 1998). The use of one type of climate-smart agricultural practices would be dependent on the selection of another because farmers make decisions that have interdependencies and suggest the need to estimate them simultaneously. It is more advantageous because it estimates the probability of each joint practice. It also shows the associations among the dependent variables and helps to estimate several but correlated binary outcomes jointly. To account for the expected simultaneity problem, a seemingly unrelated multivariate probit simulation model was specified as follows:

$$\begin{cases} IMCROPVj = X_1{}'\beta_1 + \varepsilon^A \\ INTCROPj = X_2{}'\beta_2 + \varepsilon^B \\ IMPRLIVBj = X_3{}'\beta_3 + \varepsilon^C \\ RAINWHj = X_4{}'\beta_4 + \varepsilon^D \end{cases} \tag{2}$$

$$\begin{pmatrix} \varepsilon^A \\ \varepsilon^B \\ \varepsilon^C \\ \varepsilon^D \end{pmatrix} \cdots\cdots N \left[\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix} \begin{pmatrix} 1 & \rho_{12} & \rho_{13} & \rho_{14} \\ \rho_{21} & 1 & \rho_{22} & \rho_{24} \\ \rho_{31} & \rho_{32} & 1 & \rho_{34} \\ \rho_{41} & \rho_{42} & \rho_{43} & 1 \end{pmatrix} \right] \tag{3}$$

$$\begin{aligned} &E\left({}^{\varepsilon}/_{X}\right) = 0 \\ &Var\left({}^{\varepsilon}/_{X}\right) = 1 \\ &Cov\left({}^{\varepsilon}/_{X}\right) = \rho \end{aligned} \tag{4}$$

where IMCROPVj, INTCROPj, IMPRLIVBj and RAINWHj are binary variables with value 1 when farmer *j* uses IMCROPVj, INTCROPj, IMPRLIVBj and RAINWHj, respectively, and 0 otherwise; X_1 to X_4 are vectors of independent variables determining the use of climate-smart agriculture practices; β_1 to β_4 are vectors of simulated maximum likelihood parameters to be estimated; ε^A to $\varepsilon^D$are correlated disturbances in a multivariate probit model; andρ's are tetrachoric correlations between endogenous variables.

In the tetravariant case, there are 16 joint probabilities corresponding to possible combinations of successes (a value of 1) and failures (a value of 0). If one focuses on the probability that every outcome is a success, the probabilities that enter the likelihood function for the use of climate-smart agricultural practices are explained as follows:

$$\begin{aligned} &\Pr(IMCROPVj = 1, INTCROPj = 1, IMPRLIVBj = 1, RAINWHj = 1) \\ &= \phi_3\left(\beta_1{}'X_1, \beta'_2X_2, \beta'_3X_3, \beta_4{}'X_4, \rho\right) \\ &= \Pr\left(\varepsilon^A \leq \beta X_1, \varepsilon^B \leq \beta X_2, \varepsilon^C \leq \beta X_3, \varepsilon^D \leq \beta X_4\right) \end{aligned} \tag{5}$$

where ϕ_3 is the multivariate normal density function. The Chi^2 test showed that separate estimation of the use of improved crop varieties, intercropping, improved livestock breeds and rainwater harvesting practices is biased, and that the decision to use the four practices is also interdependent with household decisions. The livelihoods of farm households were mainly dependent on these selected climate-smart agricultural practices, which were implemented on the plots of smallholder farmers. The joint probabilities of success or failure of using the four types of climate-smart agriculture practices suggested that households were likely to use the four climate-smart agricultural practices jointly.

3.3 Hypothesized variables

3.3.1 Dependent variables. In this study, the major climate-smart agricultural practices, namely, improved crop varieties (IMCRPV), intercropping (INTCROP), improved livestock breeds (IMPLIVB) and rainwater harvesting (RAINWH) practices were selected. These climate-smart agricultural practices are the major practices selected purposively during preliminary field assessments.

3.3.1.1 IMCROPV. Improved crop varieties are the use of those that are drought-tolerant, disease-resistant and early maturing to avoid crop loss from shorter growing seasons or unreliable rains. It improves productivity and can reduce the risk of failure. In the study area, promoted climate-smart improved crop varieties were wheat, maize and barley. The type and unit of this variable is a dummy variable measured in terms of practiced or not practiced to the endorsed climate smart improved crops. Use of improved crop varieties is assigned 1 for “yes” and “zero” otherwise.

3.3.1.2 INTCROP. Intercropping is the concurrent cultivation of more than one crop on the same plot of land. This practice is important for better growth and production of crops through the efficient utilization of natural resources such as land, sunlight, water and nutrients. It contributed to nitrogen fixation, improved water retention and reduced crop failures to drought, pests and diseases. This variable was measured in terms of the application or non-application of more than one crop species on the same plot of land. One is assigned for the application of intercropping, “yes,” and “zero” otherwise.

3.3.1.3 IMPLIVB. Improved livestock breeding is the practice by which farmers rear improved livestock breeds that could give better production under the situation of climate change to tolerate and adapt climatic hazards that affect them. The use of environment-friendly and productive breeds is very crucial for farmers to reduce the climate hazardous impact on livestock and increase production. It was measured in terms of improved livestock management. It was assigned 1 for the response “yes” if a household reared improved livestock breeds, and zero otherwise.

3.3.1.4 RAINWH. Rainwater harvesting is a practice used for collecting and storing rainwater from rooftops and the land surface (surface runoff) using jars, locally made containers or underground check dams. The rainwater harvesting practice used by smallholders enables them to store water for irrigation. These water stocks are expected to curb the negative effects of rainfall variability and enhance yields. The unit of this variable was the activity of both storing water and preparing the structure for water harvesting or not. There are two reasons that yields can be enhanced using rainwater harvesting. First, farmers prepared structures for water harvesting activity and can use the harvested water to fill the moisture shortage gap when rainfall shocks occur. For instance, farmers used the harvested water for the growth of crops before maturity. Second, farmers used water harvesting structures to produce high-value crops because it reduced weather risk. Households that used rainwater harvesting were assigned as 1 and zero otherwise.

3.3.2 Independent variables. Factors that influence the outcome variable are referred to as independent variables. In this study, the hypothesized independent variables that were expected to affect the use of improved crop varieties, intercropping, improved livestock breeds and rainwater harvesting practices are shown in Table 2 and described briefly.

Table 2. Descriptions and units of measurements for hypothesized variables

Acronym	Description of variables	Measurement	Type of variable	Expected sign
Dependent variables			Dummy	
IMCROPV	Improved crop variety	1 = yes, 0 = no		
INTCROP	Intercropping	1 = yes, 0 = no		
IMPLIVB	Improved livestock breed	1 = yes, 0 = no		
RAINWH	Rain water harvesting	1 = yes, 0 = no		
Independent variables				
SEX	Sex of the household head	1 = male, 0 = female	Dummy	+
AGE	Age of the household head	Measured in years	Continuous	+/−
LASIZE	Size of labor	Measured in adult equivalent	Continuous	+
EDUC	Educational level of the household head	0 = Illiterate 1 = Can read and write 2 = Primary school 3 = Secondary school 4 = TVET/University and above	Discrete	+
EXTEN	Access to extension service	1 = Yes if the household has access to extension services, 0 otherwise	Dummy	+
TRAIN	Access to training	1 = Yes if the household heads have access to training, and 0 otherwise	Dummy	+
LAND	Land size	Measured in hectares	Continuous	+
LIVSIZE	Livestock size	Measured in TLU	Continuous	+
FDIST	Distance from the farmers' home to the farm	Measured in minutes	Continuous	−
MKTDIST	Distance from home to the nearest market	Measured in minutes	Continuous	−
CREDIT	Access to credit	1 = Yes if household has access to credit, 0= otherwise	Dummy	+

Sources: Adopted and modified from Malefiya (2017), Amare and Abebe (2018), Adera and Pauline (2018), Wekesa (2018), Zeinu (2019) and Tekeste (2021)

3.3.2.1 SEX. It was hypothesized that usually women face overload of housework more than men. Hence, women might not have enough time to get information from extension services about climate-smart agricultural practices and to choose the practice for their production. Male-headed households might have better access to information than female-headed households, which helps the farmer choose climate-smart agricultural practices as important for their production. A study by Tekeste (2021) showed that male-headed households are more likely to access technologies and climate change related information than female-headed households. Therefore, maleness was hypothesized to affect the use of climate-smart agricultural practices positively.

3.3.2.2 AGE. The older a farmer, the more experienced he/she in farming and the more exposed to past and present climatic conditions. In contrast, young farmers might have long plans to carry out farm investments in technologies whose benefits are realized over time. According to Adera and Pauline (2018), elder farmers implement climate-smart agricultural practices because they are more experienced in farming and past and present climatic conditions. However, Hailemariam *et al.* (2019) reported that an increase in the age of the household head reduces the possibility to choose and use climate-smart agricultural practices because as a farmer becomes older, he/she tends to minimize activities that demand much of their labor and management activities than younger farmers.

3.3.2.3 LASIZE. Labor size is the total number of workers in a household during the study period. In this study, if the majority of the household members include a more active labor force, the household can have adequate labor and the probability of using climate-smart agricultural practices might increase. Some authors found that the presence of a large active labor force in the household leads to the implementation of climate-smart agricultural practices (Adera and Pauline, 2018; Zeinu, 2019 and Tekeste, 2021), while the presence of a less active labor force in the household did not enforce the use of more climate-smart agricultural practices.

3.3.2.4 EDUC. The educational level for elementary school, secondary school and higher teaching institutions was grade 1 to 8, grade 9–12 and above grade 12. An educated farmer tends to be better at recognizing the need to take risks associated with climate change hazards and hence he/she might be inclined to choose and use climate-smart agricultural practices. This is because literate farmers seek knowledge from extension agents and other institutions about climate-smart agricultural practices. According to Farid *et al.* (2015), educated farmers have better exposure to new technologies and innovations and are more receptive to new ideas. Thus, it was hypothesized that educated farmers might be more willing to use climate-smart agricultural practices.

3.3.2.5 EXTEN. Access to extension refers to services delivered to farmers about climate-smart agricultural practices by development agent(s). Extension service plays a great role in raising awareness about climate-smart agriculture practices and the possibility of using those practices. It implies that farmers with more access to information and technical support related to climate-smart agricultural practices might be aware of the impacts of climate change and have already applied climate-smart agricultural practices. Matouš *et al.* (2013) stated that available information on resource-conserving agriculture can directly lead to an increase in farmers' investments in such agricultural practice.

3.3.2.6 TRAIN. Training indicates whether the household head participated in training related to climate-smart agriculture in the study year. When farmers get training about climate-smart agricultural practices, they can be more aware of the use of climate-smart agricultural practices than non-trained farmers. Zeinu (2019) reported that training farmers in climate-smart agricultural practices increased the probability of their use.

3.3.2.7 LAND. It is the total land size of a household. Large land sizes allow farmers to diversify their crop and livestock options and help them to spread the risks of losses associated with climate change (Farid *et al.*, 2015). Muraoka *et al.* (2018) also found that the more households have access to land, the more they grow their food and provide the necessary inputs and resources to reverse climate change by applying different climate-smart agricultural practices.

3.3.2.8 LIVSIZE. Livestock is considered as a source of income, food, draught power and an asset indicating the wealth status of the household, which may increase the availability of capital and the ability of farmers to invest in climate-smart agricultural practices. The size of livestock is an indicator of economic security. If a farmer has a large number of livestock, he/she is not threatened by practicing climate-smart agricultural practices because he/she has full confidence to take a risk with climate change on their crop production by substituting his/her income gained from the livestock (Amole and Ayantunde, 2016).

3.3.2.9 FDIST. Farm distance is the average distance between a household's home and farmlands. If there is a long distance from home to the farm, a farmer may not have interest in using climate-smart agricultural practices. Wekesa *et al.* (2018) reported that farmers who live far from their farmlands face difficulties using climate-smart agricultural practices.

3.3.2.10 MKTDIST. Market distance is the distance from the farmer's home to the nearest local market center. If the farmers' homes are far from the market center, they may not have access to transport facilities. Thus, they lose better support from concerned bodies that might increase the use of climate-smart agricultural practices. Malefiya (2017) and Zeinu (2019) noted that the nearest homes of farmers to the local market get lots of opportunities as compared with the far ones.

3.3.2.11 CREDIT. Access to credit was accounted for in terms of cash or assets from formal or informal institutions for applying climate-smart agricultural practices. Access to credit would enhance the financial capacity of a farmer to purchase the inputs, thereby implementing climate-smart agricultural practices. According to Malefiya (2017), farmers' access to credit simplifies cash constraints and allows them to purchase agricultural inputs such as improved seed, fertilizer, chemicals, livestock feed and farm equipment. Iftikhar and Mahmood (2017) stated that households that obtained finance from either formal or informal credit sources could fulfill economic obligations. It is very important to choose and apply agricultural practices.

4. Results and discussion

4.1 Household characteristics

Both quantitative and qualitative data were collected from respondents and analyzed using descriptive statistics that are shown in Table 3. The results disclosed that the majority (92%) of households were headed by men. More than half of the respondents were illiterate. Proportionally, 37.0% of respondents could read and write. Only one-tenth of the respondents attended elementary, secondary and tertiary schools. Nearly 82%, 34% and 59% of households could not access credit, extension and training services, respectively. In the study area, the average age of the sample household heads was 53.8 years. The average labor size was 5.3 adult equivalents. Labor availability directly or indirectly influences the use of climate-smart agricultural practices (Table 4).

Households in the study area owned a range of livestock types with an average size of 5.2 tropical livestock unit (TLU). The qualitative data obtained through key informants revealed that the main sources of feed for livestock were grazing land, hay, local alcohol (*Atela*) residue and crop residues such as the straw of barley, wheat and legume crops. The average land size of the sample households was 6.2 ha. The average walking time from the

Household characteristics	Frequency	%
Sex of the household heads		
Male	184	92.0
Female	16	8.0
Educational level of household heads		
Illiterate	105	52.5
Read and write	74	37.0
Elementary school	17	8.5
Secondary school	2	1.0
TVET/university	2	1.0
Access to credit		
Yes	35	17.5
No	165	82.5
Extension service		
Yes	132	66.0
No	68	34.0
Participated in training on climate-smart agriculture practices		
Yes	82	41.0
No	118	59.0

Source: Author's work 2020/2021

Table 3. Descriptive results for discrete variables

Household characteristics	Measurement	Min	Max	Mean	SD
Age of the household head	Year	23	83	53.8	12.5
Size of labor	Adult equivalent	1	10	5.3	1.7
Livestock size	TLU	0	20	5.2	3.5
Total land size	Hectare	0	22	6.2	3.8
Distance from home to farm	Minute	2	120	12.2	21.4
Distance from home to market	Minute	5	240	46.2	48.0

Source: Author's work 2020/2021

Table 4. Descriptive results for continuous variable

homestead's home to their farmlands and the nearest local market was 12.2 and 46.2 min, respectively. It implies the nearest market was at a greater distance compared with the average distance between homes and farmlands (Table 4).

4.2 Factors that influenced farmer's use of climate-smart agricultural practices

To analyze climate-smart agricultural practices, independent variables were drawn from social, economic, institutional and physical factors. The multivariate probit model was used to investigate determinants of the use of climate-smart agricultural practices. The results of the model are presented in Table 5, and the model fitted the data reasonably well. The Wald test was used to test the model fitness, the results of which are as follows: Chi^2 (44) = 102.95, Prob > Chi^2 = 0.000, and significant at the 1% level. It indicated that the subset of coefficients in the model was jointly significant and the explanatory power of the factors included in the model was agreeable. The likelihood ratio test of the null hypothesis of independence between the use of climate-smart agricultural practices (rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0) was significant at 5%. Therefore, the null hypothesis that all the δ (Rho) values are jointly equal to 0 is rejected, indicating the goodness-of-fit of

Table 5. Multivariate probit model results on the use of climate-smart agriculture practices

	IMCROPV		INTCROP		IMPLIVB		RAINWH	
Variables	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
SEX	0.993**	0.408	0.461	0.287	−0.565	0.351	0.811***	0.294
AGE	−0.006	0.019	0.011	0.012	0.008	0.014	−0.006	0.012
LASIZE	−0.104	0.155	−0.020	0.090	0.045	0.100	0.008	0.091
EDUC	0.572	0.381	−0.176	0.203	0.425*	0.240	0.083	0.212
EXTEN	−0.183	0.498	0.393	0.246	0.212	0.288	0.342	0.253
TRAIN	0.525*	0.316	−0.003	0.194	0.672***	0.226	0.164	0.198
LANDSIZE	0.028	0.082	0.015	0.057	0.062	0.065	0.071	0.061
LIVSIZE	0.374**	0.188	−0.197**	0.085	−0.073	0.094	−0.157*	0.085
FDIST	−0.034**	0.015	−0.016**	0.007	−0.001	0.009	−0.010	0.009
MKTDIST	−0.015	0.013	0.008	0.006	−0.035***	0.011	−0.007	0.009
CREDIT	1.731***	0.391	0.157	0.199	1.167***	0.234	0.467**	0.207
Predicted probability	0.85		0.52		0.69		0.59	
Rho21				(0.299) 0.312				
Rho31				(0.028**) 0.46				
Rho41				(0.300) 0.311				
Rho32				(0.134) *** 0.144				
Rho42				(0.057***) 0.166				
Rho43				(0.981) 0.981				
Number of simulations (draws) = 5								
Wald Chi^2 (44)						102.95***		
Likelihood ratio test of independence						rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0, chi2(6) = 13.9145**		
Joint probability (success)						0.237		
Joint probability (failure)						0.039		

Note: ***, ** and * is for 1, 5 and 10% probability level, respectively
Source: Model results

the model or implying that the decisions to use selected climate-smart agricultural practices were interdependent. The δ values (δ_{ij}) indicate the degree of correlation between climate-smart agricultural practices.

The simulated maximum likelihood estimation results suggested that δ = 31 (there was a positive correlation between the use of improved livestock breeds and improved crop variety and it was significant at 5% significance level). This finding revealed that farmers who practiced improved livestock breeds were more likely to practice improved crop varieties. In δ = 42, there was a positive correlation between rainwater harvesting and inter-cropping at 10% significant level. This result led to the assumption that farmers who practiced rainwater harvesting were more likely to practice intercropping and vice versa. The model results showed that the probability that farmers practice improved crop varieties, intercropping, improved livestock breeds and rainwater harvesting were 85%, 52%, 69% and 59%, respectively. The likelihood of practicing intercropping was relatively low (52%) as compared to the probability of practicing improved crop variety, improved livestock breeds and rainwater harvesting. This implies that farmers were not interested in using intercropping compared with others because that might take more time and demand high labor and skill at the time of sowing.

The likelihood of households jointly using the four climate-smart agricultural practices was 23.7%, which implies the likelihood of practicing all selected climate-smart agricultural practices at the same time is minimal. This can be justified either by the fact that simultaneous use of all climate-smart agricultural practices was unaffordable for farmers or by the fact that all climate-smart agricultural practices were not simultaneously practiced in the study areas. However, the joint probability of not using all climate-smart agricultural practices was 3.9%. This finding is also contradicted by the findings of Degye *et al.* (2013), who studied food security and agricultural technology interaction in Ethiopia.

The results of the model indicated that some explanatory variables influenced the probability of using climate-smart agricultural practices as expected. Sex, training, livestock holding, farm distance and access to credit were independent variables that influenced improved crop varieties significantly at different probability levels. Livestock and farm distance significantly influenced intercropping. Training, market distance and access to credit significantly affected the use of improved livestock breeds, while the educational level of the household head influenced the use of improved livestock breeds. Sex, livestock holding and access to credit services also significantly affected the use of rainwater harvesting activities in the study area.

4.2.1 SEX. It affected the use of improved crop varieties and rainwater harvesting positively and significantly at 5% and 1%, respectively. Being male, the probability of using improved crop varieties increases by 0.99, and the use of rainwater harvesting increases by 0.81. Hence, the result was similar to the prior expectation. The positive sign indicates that male-headed households could use improved crop varieties and rainwater harvesting compared with their counterparts. The probable reason might be that women are more loaded with home activities compared with men. Hence, women had inadequate time to get extension services and other relevant information regarding the importance of climate-smart agricultural practices. Thus, male-headed households had better access to information than female-headed ones. This result is similar to previous findings (Abrham *et al.*, 2017; Zeinu, 2019; Meseret *et al.*, 2020; Tekeste, 2021). In contrast to this result, Amare and Abebe (2018) and CIAT and BFS/USAID (2017) found that the sex of the households had no influence on the use and non-use of climate-smart agricultural practices between male and female-headed households.

4.2.2 EDUC. The educational level of household heads increases farmers' ability to get and use information to improve their decisions on the use of climate-smart agricultural practices. The result indicated that the educational level of the household head affected the use of improved livestock breeds positively and significantly at 10%. Hence, this finding is similar to the prior expectation. As the education level of the household-head increases by one year of schooling, the probability of the use of improved livestock breeds increases by 0.43. The possible explanation is that educated farmers had better knowledge of the risk associated with climate change and hence tended to use environmentally friendly and productive livestock breeds to lessen the effect of climate change hazards. This result is in agreement with several previous findings that, as the education level of a farmer increases, the use of improved livestock breeds also increases (Farid *et al.*, 2015; Amin *et al.*, 2015; Amole and Ayantunde, 2016). As per their explanation, educated farmers have a better possibility of rearing improved livestock breeds and can gain high yields. Nevertheless, FAO (2016a) illustrated that illiterate farmers could use better-improved livestock production as they gained training and extension services than literate farmers.

4.2.3 TRAIN. Training affected the use of improved crop varieties and improved livestock breeds positively by 10% and 1% significant levels, respectively. The survey results showed that households participated in training related to climate-smart agricultural practices, with the probability of practicing improved crop varieties and improved livestock breeds being 0.53 and 0.67, respectively. It indicated that when farmers have access to training regarding improved crop varieties and improved livestock breeds, the probability of practicing climate-smart agricultural activities also increases. Hence, this result is in line with the earlier expectation. Farmers engaged in climate-smart agricultural practices with new ideas and knowledge have better access to training that helps them practice well. Studies conducted by Mesay *et al.* (2013) and FAO (2017) indicated that participating in training about climate-smart agricultural practices affects their use positively. In contrast to this result, Bikila *et al.* (2019) reported that training is not fully efficient for households to use climate-smart agricultural practices because it may not address all the knowledge and skills for farmers that lead to climate-smart agriculture as a good practice.

4.2.4 LIVSIZE. Livestock holding affected the use of improved crop varieties, intercropping and rainwater harvesting positively at 5%, 5% and 10% significance levels, respectively. Livestock had a positive correlation with improved crop varieties, while it had a negative correlation with intercropping and rainwater harvesting. As the livestock holding increases by one TLU, the probability of using improved crop varieties increases by 0.37. On the other hand, as livestock holding increases by one TLU, the use of intercropping and rainwater harvesting decreases by 0.20 and 0.16, respectively. Hence, the result is in line with the prior expectation of the use of improved crop varieties, while it contradicts the use of intercropping and rainwater harvesting. The positive correlation implied by improved crop varieties indicated that as the number of livestock holdings increases, the capacity of farmers to practice improved crop varieties also increases, whereas, the negative sign indicated that as the number of livestock holdings increases, the ability of farmers to practice intercropping and rainwater harvesting decreases.

Increasing the livestock size is important to increase the availability of capital and the ability of farmers to use improved crop varieties, intercropping and rainwater harvesting activities to reverse climate change hazards. The money earned from livestock sales is vital for practicing improved crop varieties, intercropping and rainwater harvesting. Agreeing with this result, Zeinu (2019) and Tekeste (2021) found that the livestock size of the households determines the practices and non-practices of climate-smart agricultural practices such as improved crop varieties, intercropping and, most importantly, rainwater harvesting. In contradiction to the relationship between livestock size and rainwater harvesting, CTA (2018) reported that when the livestock size of farmers increases and they earn money by selling them, they can use rainwater harvesting by purchasing the materials that demand rainwater harvesting activities. If livestock size declines, the use of rainwater harvesting also drops. In addition, contrary to this result, previous findings revealed that the large livestock size discourages farmers from practicing improved crop varieties and intercropping because of the income they get from livestock sales, which covers all incomes and is attractive (Mesay *et al.*, 2013); Amare and Abebe, 2018).

4.2.5 FDIST. Farm distance affected the use of improved crop varieties and intercropping negatively at a 5% significance level. Thus, this result was in line with the prior expectation. As the distance between farmlands increases by one walking minute, the use of improved crop varieties and intercropping decreases by 0.03 and 0.02, respectively. The negative sign indicated that as the distance between household homes and farmlands increases, the ability of farmers to use improved crop varieties and intercropping decreases. The earlier findings, which were reported by CIAT and BFS/USAID (2017), were in agreement with this result. Adera and Pauline (2018) also reported that farm distance affects the use of climate-smart agricultural practices negatively. If there is a long distance from home to the farm, farmers may not be interested in managing their farming practices. Hence, the longer walking distance between farmlands and households' residences reduces the use of improved crop varieties and intercropping by farmers. On the contrary, Mango *et al.* (2018) stated that if farmers' easily accessed better infrastructural facilities, it would demand the use of climate-smart agricultural practices, as farm distance is not a key factor.

4.2.6 MKTDIST. Market distance affected the use of improved livestock breeds negatively at a 1% significance level. Thus, this result was similar to the prior expectation. As the distance from the household's home to the nearest local market increases by one walking minute, the use of improved livestock breeds decreases by 0.04. The negative correlation indicated that as the distance from the household home to the nearest local market increases, the farmers' ability to use improved livestock breeds decreases. Agreeing with this result, Malefiya (2017) and Zeinu (2019) reported that if the farmers' homes are far from the market center, they cannot access the facilities and they demand better support from the concerned bodies, which might increase the use of climate-smart agricultural practices. The authors of previous findings noted that in the homes of farmers found nearest to the local market, households get a lot of opportunities compared with those at far distances. Hence, the distance from the households' home to the nearest local market affects negatively the use of improved livestock breeds that are environmentally friendly and productive ones.

4.2.7 CREDIT. Access to credit affected the use of improved crop varieties, and improved livestock breeds and rainwater harvesting practices positively and significantly at 1%, 1% and 5% probability levels, respectively. As households get credit services, the use of improved crop varieties, improved livestock breeds and rainwater harvesting increases by 1.73, 1.17 and 0.47, respectively. The correlation between credit and selected climate-smart agricultural practices was in agreement with the prior hypothesis. The positive sign indicated that a household that has used credit services could use improved crop varieties, improved livestock breeds and rainwater harvesting practices. In agreement with this result, some researchers found that access to credit has a positive and significant effect on the use of climate-smart agricultural practices (Mesay *et al.*, 2013; CIAT and BFS/USAID, 2017; Tamiru, 2020). Inconsistent with this result, Aryal *et al.* (2017) stated that credit access has a negative and significant effect in the use of climate-smart agricultural practices. As they identified in their study, the credit taken for agricultural purposes is often used for other social purposes instead of investing on climate-smart agricultural practices.

5. Conclusion and policy implications

Ethiopian economy is characterized by low productivity in general and low yield per unit area in particular because of climate change hazards. Less motivation to use climate-smart agricultural practices among farmers is one of the key persistent challenges. Farmers could not use and promote climate-smart agricultural practices efficiently for a decade. The use of climate-smart agricultural practices was affected by several factors. The multivariate Probit model explained interdependent relationships between various climate-smart agricultural practices used by farmers. The dependent variables were jointly significant and interdependent, while the independent variables included in the model were agreeable. The empirical results showed that sex, educational level, training, livestock holding, distance and access to credit were the key determinants that affected the use of selected climate-smart agricultural practices.

Improved crop varieties and livestock breeds had better probabilities of implementation compared with intercropping and rainwater harvesting. Among the identified climate-smart agricultural practices, improved livestock breeds and crop varieties were influenced by four to five factors compared with intercropping and rainwater harvesting practices. There is a low probability of jointly accomplishing the selected practices. Male-headed households had a better likelihood of practicing improved crop varieties and rainwater harvesting practices. Therefore, to increase the probability of the use of improved crop varieties and rainwater harvesting by female farmers, it is imperative to identify hindrances to women's involvement in climate-smart agricultural practices. Training was one of the key factors that influenced improved crop and livestock production systems. Hence, the regional and local governments should strengthen formal and informal trainings by facilitating all necessary materials in the study area such as the farmer training centers. The size of livestock affected improved crop varieties as crop residues were used for livestock and livestock manure was used to improve the fertility status of the soil. Institutional variables accessed by farms and markets in the vicinity of farmers' villages enabled the enhancement of crop and livestock production management practices, respectively.

Access to credit is also one of the key determinants that can positively influence crop production, livestock husbandry and rainwater harvesting practices. As households get credit services, the use of improved crop varieties, improved livestock breeds and rainwater harvesting also increases. Therefore, lending institutions need to sustainably finance farm households to facilitate the use of climate-smart agricultural practices, and benefit from better agricultural products. However, to enhance the use of intercropping and rainwater harvesting, raising farmers' awareness of climate-smart agriculture through extension or any other means is essential, which enables them to earn money from livestock sales and lead to practicing intercropping and rainwater harvesting profoundly.

Moreover, successful implementation of climate-smart agricultural practices can improve quality of life for smallholders and contribute a body of knowledge for policymakers, researchers, development practitioners, local officials and other initiatives [1] such as NGOs, international organizations, programs and projects ought to strengthen gender inclusion activities, credit institutions and access to training so that adaptive capacity and awareness of farm households on climate-smart agricultural practices can be improved. Establishing market centers near households' residences also enables them to access agricultural outputs in general and livestock products in particular.

Note

1. NGOs include Farm Africa, SOS, Climate Change Forum, CARE and World Vision; International organizations such as FAO and World Bank; programs such as Sustainable Land Management and Productive Safety Net, while projects include SG 2000 and others.

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