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Original Research

Factors Determining the Adoption of Multiple Climate-Smart Agriculture by Smallholder Farmers: The Case of West Arsi Zone, Ethiopia

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Abstract

Climate-smart agriculture (CSA) is a promising solution to lessen the detrimental effects of climate change, but smallholder farmers in poor nations like Ethiopia are not fully adopting it. This study investigates variables that impact the espousal and degree of adoption of several CSA tactics, such as drought resistance, high-yielding improved cultivars, comprehensive disease, pest, and herb control, organic fertilizer, soil and water conservation, and crop diversification. Primary data were obtained from 404 smallholder farmers by employing interview schedules, focused group discussions, and key informant interviews. Descriptive statistics and econometric models were deployed in the data analysis. A study outcome revealed that 73.8% of farm households have adopted CSA practices, including drought-resistant cultivars, pest control, soil and water conservation, organic fertilizer, and crop diversification. Factors such as agro-ecology, family size, farm experience, tropical livestock units, access to credit, members of farmers group, awareness of climate change, access to training, soil fertility significantly impact farmers' adoption. The study's findings indicate that in order to enhance the adoption of CSA techniques among smallholder farmers in the West Arsi Zone and spread CSA practices throughout the nation, agricultural policymakers and CSA executioners should acknowledge the synergy between CSA methods.
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INTRODUCTION

Around the globe, the most critical problems endangering humankind are still climate change and variability (Abdallah *et al.,* 2019; Hundera *et al*., 2019; Pedersen *et al.,* 2021). Most people in underdeveloped countries depend on environmentally sensitive means of sustenance since they cannot adapt well (Asfaw *et al.,* 2021). Consequently, these nations are seriously threatened by climate change. In this regard, the fifth evaluation report of Working Group II (Edenhofer, 2015) states that poverty is already a problem in most low-income nations and is predicted to worsen owing to climate change. According to Sasson (2012), food insecurity and hunger affect millions of individuals in rural Africa. Because of its excessive dependence on rain, Africa's agricultural industry is extremely prone to the ramifications of the climate crisis (Antwi-Agyei and Stringer, 2021). The inferences of environmental issues consist of exhaustion of natural resources, insecurity of food, impairment of employment, reduced agricultural productivity, and an increase in resource usage disputes (Pedersen *et al*., 2021; Alewoye *et al.,* 2020; Etana *et al.,* 2020).

The agricultural sector's expansion across the tropics is jeopardized by severe temperatures and insufficient rainfall (Tripathi *et al.,* 2016). Oseni and Masarirambi (2011) contend that increasing agricultural pest and disease incidence, declining soil fertility, crop failure, and low productivity are also related to climate change. According to Venkateswarlu (2017), the medium-term (2010–2039) climate effect estimate predicts a 4.5%–9% decline in agricultural productivity, whereas the long-term (2070–2099) impacts are predicted to result in a 25% or larger decline. Reducing agriculture's vulnerability to climate change's repercussions is crucial to improving income and lowering poverty, as one-third of the population persists under the poverty threshold (Branca *et al.,* 2021).

Ethiopia's agricultural output has decreased due to unfavourable weather scenarios and global warming, which has also led to food insecurity (Hilemelekot *et al.,* 2021), "marginalization" (Solomon *et al.,* 2018), "poverty" (Onyutha, 2019; Seife, 2021), and intensified conflict (van Weezel, 2019). Agriculture is the cornerstone of Ethiopia's economy, accounting for 52 percent of the nation's economic output and 80 percent of overall job creation, contributing 80.2 percent of export earnings. It is, therefore, a key industry influencing incomes and availability of food (Belay *et al.,* 2021; Deressa *et al.,* 2011). The nation's agricultural industry is predominated by small-scale blended crop production and modest farm animal rearing, despite extension facilities being inadequate (Tessema and Simane, 2021). The crucial causes of Ethiopia's low agricultural output are conventional methods of farming, intense degradation of land brought on by excessive grazing and woodland clearing, inadequate institutional amenities (such as marketing, credit provisions, and extension), and harsh weather trends like drought and floods (Etana *et al.,* 2020; Tesfahunegn and Gebru, 2021).

The nation's agricultural industry has suffered a lot because of the effects of climate change. In light of its traditional, rain-fed method of farming and farm households' lack of capacity to adapt to adverse weather conditions and natural disasters, Ethiopian agriculture is especially exposed to climate change (Skambraks, 2014; Hirpha *et al.,* 2020). For example, Gelaw (2017) estimates that by 2050, climate change will result in Ethiopia's GDP declining by 8–10%, whereas agricultural adaptation strategies might cut losses from climate shocks by 50%. Smallholder farmers have a great deal of uncertainty in their income and productivity due to climate change (Abebe and Bekele, 2017).

Climate Smart Agriculture (CSA) is a broadly accepted and practical tactic to decrease the detrimental effects of climate change (Lipper *et al.,* 2014; FAO, 2018; Mazhar *et al.,* 2021). CSA is a holistic strategy with three instantaneous objectives: greater resilience, less greenhouse gas discharge, and enhanced yield and income (FAO, 2013; FAO, 2018a, b). To improve well-being and food security, Ethiopia has enacted an array of CSA activities (FAO, 2016; Eshete *et al.,* 2020). Examples of CSA techniques in Ethiopia encompass Amalgamated ecosystems management, making compost, optimized livestock feed initiatives, equitable land utilization, agroforestry, organic farming, unified soil fertility management, and pasture restoration (FAO, 2016; Eshete *et al.,* 2020)

The three main hypotheses that underpin the investigation, which is currently concentrated on the adoption of agricultural innovations, are the adopter perception paradigm, diffusion innovation, and economic constraints (Ngwira *et al.,* 2014; Prager & Posthumus, 2010). The economic constraint model states that even though farmers' goal to maximize yield or utility, the pace and level of implementation are opted by the unfair allocation of endowed resources (Samiee &

Rezaei-Moghaddam, 2017). The idea of diffusion of innovations elucidates how knowledge, information, and communication were used to spread agricultural technology across time (Montes de Oca Munguia *et al.,* 2021). The relative benefit, harmony, intricacy, trialability, and visibility are the five attributes of the "diffusion of innovations" concept that impact the level to which agricultural innovations are being deployed (Mlenga, 2015). Furthermore, after knowing about technology, admitting an idea, and deciding to uptake an innovative concept is deemed to be cognitive actions that go through processes including convincing, making decisions, execution, and validation (Meijer *et al.,* 2015; Ntshangase *et al.,* 2018).

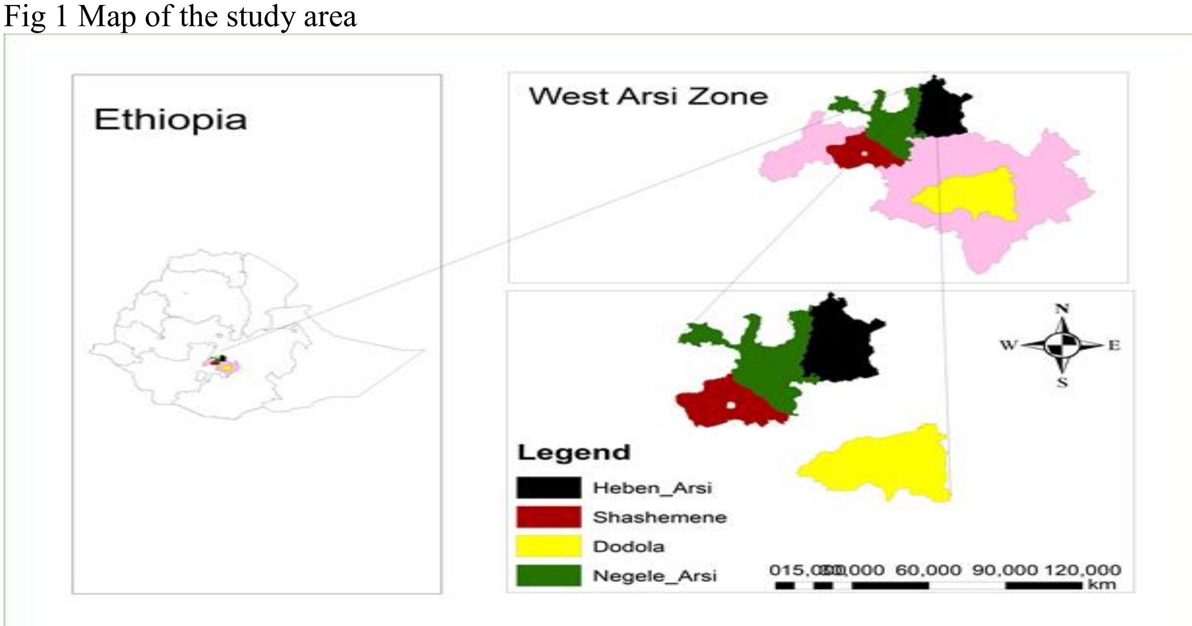
Smallholder farmers are consumers who typically have idiosyncratic choices for certain features of technologies, and their need for a given innovation is profoundly influenced by how they perceive its features (Adesina & Jojo, 1995). Therefore, one of the present investigation's benefits is modelling multiple CSA adoptions while accounting for their interrelation, which is one of the contributions of the current work. The second contribution of this article is to explore the magnitude of CSA adoption by employing an ordered choice model. Therefore, the purpose of this study was to ascertain the variables affecting smallholder farmers' uptake of multiple climate-smart agriculture practices and the extent of adoption.

RESEARCH METHODOLOGY

Description of the Study Area

The research was carried out in the West Arsi Administrative Zone, Oromia Regional State. There are twenty zones in the Oromia National Regional Government, one of which is the West Arsi zone. This zone, which is a portion of the Oromia Regional Government, is bordered to the north and south by three national regions; to the northeast and southeast by Arsi; to the southeast by Guji; and to the majority of the zone's extent by Bale; the zones' elevations range from 1500 to over 3300 meters. Shashemene town is the administrative centre of the zone. it is found 250km from Finfinnee, and the entire area of the Zone is 12556 km2. It is found in the Rift Valley Section. The Astronomical location of the West Arsi zone lies between 6012'29" to 7042'55" latitude and 38004'04" to 39046'08" longitude (WAZANR, 2020/2021).

Fig 1 Map of the study area



Sampling methodology and estimating sample size

A multistage sampling tactic was used to effectively reach the household level within the West Arsi zone. The foundation for well-informed decision-making was laid during the first selection step, which was drawn from key statistical data sources and existing literature. The West Arsi zone was identified as one of the zones impacted by changing climates (Abate, 2009), and practicing climate-smart agriculture was selected purposefully. In the second phase, with the guidance of the Bureau of Agriculture and Natural Resources (BOANR) offices, the zone, four districts out of the twelve that are prone to fluctuations in climate and engage in climate-smart agriculture, were explicitly chosen. These four districts make up 33.3 percent of all the rural districts in the zone. After the districts were deliberately nominated in the third phase, purposive sampling was employed to choose two kebeles (a total of eight kebeles) from each district. Only accessible villages engaged in climate-smart farming were considered. The sampling frame (an entire village household list) was retrieved in cooperation with Kebeles officials and development personnel of the respective Kebeles, and random sampling was applied to draw sample respondents. Due to the vast geographic coverage and size of the population, a thorough census would entail a substantial investment of time and money. As a result, the sample size was established by applying the relevant sampling algorithm, as stated by Kothari (2004), while accounting for the population of the study area. The sample size was decided according to Kothari (2004), considering the characteristics of the population, level of precision, and study design. This approach enables a margin of error and is calculated under a 95% confidence interval. The Kothari formula is as follows:

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

This formula was used to get the total sample size of respondents. Finally, the probability proportional to sample size (PPS) method was employed to draw the representative sample of farm households from each selected study Kebeles. According to this, there was a 10% contingency increase in the sample size, and 404 households were incorporated in the study. As shown in Table 1 below, the sample houses were designated from Arsi Negele (82 sample houses), Dodola (86 sample houses), Heban Arsi (98 sample houses), and Shashemene (137 sample houses) based on relative household sizes

Table 1
Sample households

S.N	Districts	kebeles	Total households	Percentage share	Sample HH
1	Arsi Negele		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

Table 1 Continues,

Watara Shagule	756	27%	37
	8269		**404**

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

Econometric framework

Farmers' adoption of CSA is interrelated (Teklewold *et al.,* 2019; Kurgat *et al.,* 2020; Usman *et al.,* 2021). The association is due to the technical synergy or interchangeability of CSA execution (Wainainaa *et al*., 2016; Bedeke *et al.,* 2019). When the execution of the CSA has this interconnection, applying multivariate probit (MVP) leads to neutral and effective assumptions (Wainainaa *et al.,* 2016; Greene, 2018). The MVP model is established based on the randomized utility theory (RUT). Let U_0 represent the anticipated advantages of a farmer from non-adoption, and let U_j symbolize the anticipated rewards obtained from implementing the j^{th} CSA activity. As stated by the RUT, a farmer i decides to uptake j^{th} CSA activities if the anticipated advantage from embracing exceeds the advantage obtained from non-adoption (Leonardi, 1981; Leonardi and Tadel, 1984; Kreps, 1990; Horowitz *et al.,* 1994; Newbold, 2005; Andersson and Ubøe, 2010). Suppose U^*_{ij} conveys the anticipated advantage. The farmer agrees to uptake CSA execution j if the prerequisites in Eq. (2) are realized:

$$U_{ij}^{*} = U_j^{*} - U_0 > 0 \qquad (2)$$

U^*_{ij} is a latent parameter that is thought to be a linear function of the agro-ecological aspects, peculiarities of the land, institutional aspects, and socioeconomic makeup of the household, where each of them is portrayed by a vector X_{ij}, and the error term (ε_{ij}).

$$U_{ij}^{*} = X'_{ij}\beta_j + \varepsilon_{ij} \qquad (3)$$

Where j = D, P, O, S, C

D= drought-resistant high-yielding improved cultivar; P= integrative surveillance for weeds, diseases, and pests; S= soil and water conservation; O= Organic fertilizer applications; and C= crop diversification.

The observed binary results pertain to every CSA adoption decision stipulated in Eq. (4) accordingly:

$$U_{ij} = \begin{cases} 1 \; if U_{ij} > 0 \\ 0 \; otherwise \end{cases} \qquad (4)$$

If CSA practice adoptions are correlated, it is more realistic to assume that the error terms in Eq. (3) are jointly follow a multivariate normal distribution with zero conditional mean and variance normalized to unity. That is, $\varepsilon_{ij} \sim$ MNP (0, Ω″) where Ω is the symmetric covariance matrix which is given by Eq. (5)

$$\Omega = \begin{bmatrix} 1 & \rho_{12}\rho_{13} & \rho_{15} \\ \vdots & \ddots & \vdots \\ \rho_{51} & \rho_{52}\rho_{53}\cdots & 1 \end{bmatrix} \qquad (5)$$

Where, ρ stands for the unobserved relationship among the random variables of the error terms pertaining to any two of the espousal algorithms to be anticipated in the model. The association among the probabilistic aspects of the various adaptation techniques used is reflected by the off-diagonal variables in Equation (5). Researchers argue that CSA procedures are reliant on adoption if the computed off-diagonal correlation indices are collectively significant.

This study also aims to evaluate the factors that determine the degree of adoption of CSA practice. The number of CSA techniques embraced by farm households serves as a good indicator of the magnitude of adoption (Ojoko *et al*., 2017; Oladimeji *et al*., 2020; Usman *et* *al.*, 2021). A farmer may decide to start none, one, two, or more CSA endeavors. Adoption is thus a parameter that can be considered as ordinal, with subsequent categories of ordered consequences. The adoption of CSA practices by farm households in our research area takes on six distinct values ($y_i = 0, 1,2,3, \dots ,5$) which are naturally ordered.

In keeping with Davidson and MacKinnon (1999); Verbeek (2004); Cameron and Trivendi, (2009), and Greene (2018), we make an inference that a latent variable y_i is produced by a latent element y^*_i, where y^*_i is stated in Eq. (6) below:

$$y_i^* = x_i'\beta + \varepsilon_i \quad (6)$$

It is presumed that ε_i is to be normally distributed with a normalized average and variance of zero and one, respectively. The association between the latent factor and the observed result is elucidated in Eq. (7), outlined below:

$$\begin{cases} 0 \; if \; y_i^* \le 0 \\ 1 \; if \; 0 < y_i^* \le \mu_1 \\ 2 \; if \; \mu_1 < y_i^* \le \mu_2 \\ . \\ . \\ . \\ m \; if \; \mu_{m-1} \le y_i^* \end{cases} \quad (7)$$

The μ‘s are cut points to be computed with β. For m-alternative ordered categories, we generally define:

$$y_i = j \; if \; \mu_{j-1} < y_i^* \le \mu_j, j = 1,2,3, \dots, m$$
$$where \; \mu_0 = -\infty \; and \; \mu_m = \infty$$

According to Cameron and Trivendi (2009), the likelihood of observing result j is provided by Eq. (8):

$$P(y_i = j) = \Phi(\mu_j - x_i^*\beta) - \Phi(\mu_{j-1} - x_i^*\beta) \quad (8)$$

Where Φ is the cumulative normal distribution function of ε_i

MVP estimates in five sets of variables are anticipated, one for the embracing of each mutually interconnected CSA practice. The Wald test rejected the null hypothesis that all regression coefficients are instantly equal to zero.

RESULTS AND DISCUSSION

We used cross-tabulation and Chi-squared tests to determine the relationship between every distinct predictor component and the adoption of multiple CSAPs. As shown in Table 2, seven factors, such as access to extension, access to credit, engagement with farmer associations, access to weather data, disaster exposure, contact with NGOs, and market access, had a significant association with the application of disease-resistant, high-yielding, improved cultivars. These findings suggest that enhancing farmers' access to these resources could potentially increase the adoption rates of disease-resistant, high-yielding, improved cultivars. Furthermore, the results highlight the importance of planned interventions that address the particular demands of farmers in diverse contexts to promote sustainable agricultural practices. Integrated disease, pest, and weed management was significantly influenced by access to extension, access to credit, affiliation in farmer cooperatives, availability of climate information, disaster exposure, contact with NGOs, and market access. These factors collectively create an enabling environment for farmers to implement integrated disease, pest, and weed management practices that can lead to higher productivity and resilience against climate variability.

Soil and water conservation techniques were significantly impacted by the sex of the sample household, access to extension, access to credit, membership in farmer cooperatives, access to weather information, disaster exposure, contact with NGOs, and market access. These variables play a vital role in deciding the success of soil and water conservation techniques. Organic fertilizer application was significantly influenced by access to extension, access to credit, engagement with farmer cooperatives, availability of weather information, disaster exposure, contact with NGOs, and market access at 1% significance level. These elements not only enhance the farmers' ability to implement organic fertilizer application but also foster resilience against environmental challenges. The adoption of crop diversification was significantly affected by the sex of the sample household, access to extension, access to credit, affiliation in farmer cooperatives, access to weather data, disaster exposure, contact with NGOs, and market access at 1% significance level. These factors collectively empower farmers to allocate their land for different crops and make informed decisions that can mitigate risks associated with climate variability.

The results in Table 3 revealed that among the ten continuous independent variables, five parameters showed a mean difference that was statistically significant between adopters and non-adopters of multiple CSAPs. Farm size showed significant mean differences between adopters and non-adopters of drought-resistant, high-yielding, improved cultivars at a 1% significance level, whereas contact with the development agents and training duration showed significant mean differences among adopters and non-adopters of drought-resistant, high-yielding, improved cultivars at a 5% significance level, respectively. Similarly, at 10% significance levels, annual income revealed substantial mean differences between adopters and non-adopters of drought-resistant, high-yielding, improved cultivars. The mean test analysis indicated that there is a significant mean difference between adopters and non-adopters of integrated disease, pest, and weed management in terms of mean land size, annual income, contact with the development agents, and training duration at the 1% significance levels, respectively. In terms of total livestock units, there is also a significant mean difference between those who have adopted integrated disease, pest, and weed management and those who have not, at a significance level of 10%.

Likewise, the data analysis confirmed that there is a significant variation in terms of land size and contact with the development agent between adopters and non-adopters of soil and water conservation at 1% and 1%, respectively. Farm size, annual income, and contact with the development agents showed significant mean differences among adopters and non-adopters of organic fertilizer practices at 1%, 5%, and 1% significance levels, respectively. Likewise, annual income, contact with the development agents, and training duration showed that there is a significant mean difference between adopters and non-adopters of crop diversification at 1% significance levels, respectively

Table 2

Descriptive statistics for discrete choice variables

Variables description		*Drought-tolerant high-yielding cultivar*			*Integrated disease, pest, and weed management*			*Soil and water conservation*		
		Adopter (%)	*Non adopter (%)*	*X^2 -value*	*Adopter (%)*	*Non adopter (%)*	*X^2 -value*	*Adopter (%)*	*Non adopter (%)*	*X^2 -value*
				2.703			*1.811*			*5.029***
Sex	*Male*	*94.6*	*90.3*		*94.4*	*90.8*		*95*	*91.2*	
	Female	*5.4*	*9.72*		*5.6*	*9.2*		*5*	*8.8*	
Access to extension				*151.968****			*172.743****			*137.363****
	Yes	*91.2*	*67.4*		*93.6*	*68*		*97.4*	*44.2*	
	No	*8.8*	*32.6*		*6.4*	*32*		*2.6*	*55.8*	
Access to credit				*125.372****			*132.262****			*108.492****
	Yes	*77.7*	*20.1*		*79.3*	*20.9*		*83*	*32*	

Table 2 Continues,

	No	*22.3*	*79.9*		*20.7*	*79.1*		*17*	*68*	
Members of farmer cooperatives				*146.605****			*160.998****			*130.960****
	Yes	*90.4*	*32.6*		*92.4*	*32.7*		*96.4*	*44.2*	
	No	*9.6*	*67.3*		*7.6*	*67.3*		*3.6*	*55.8*	
Participate in a field demonstration				*2.286*			*3.617**			*1.317*
	Yes	*41.5*	*49.3*		*40.6*	*50.3*		*41*	*32.5*	
	No	*58.5*	*50.7*		*59.4*	*49.7*		*59*	*61.5*	
Access to weather information				*104.647****			*139.123****			*217.655****
	Yes	*76.2*	*23.6*		*80.1*	*20.3*		*94*	*21.8*	
	No	*23.8*	*76.4*		*18.9*	*79.7*		*6*	*80.2*	
Disaster exposure				*14.283****			*32.632****			
	Yes	*79.2*	*61.8*		*82.7*	*56.7*		*87.3*	*52.9*	*40.610****
	No	*20.8*	*38.2*		*17.3*	*43.3*		*12.7*	*47.1*	
Contact with NGO				*112.327****			*124.238****			
	Yes	*86.2*	*34.7*		*88*	*34.6*		*91*	*44.7*	
	No	*13.7*	*65.3*		*12*	*65.4*		*9*	*55.3*	
Access to market				*141.426****			*160.899****			*134.632****
	Yes	*89.6*	*32.6*		*88.8*	*66*		*96.4*	*43*	
	No	*10.4*	*67.4*		*11.2*	*34*		*3.6*	*57*	

*Source: Authors' calculation based on the survey dataset (2023), ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively*

Table 2

Descriptive statistics for discrete choice variables continued

Variables description		Organic fertilizer			Crop diversification		
		Adopter (%)	Non adopter (%)	X^2 -value	Adopter (%)	Non adopter (%)	X^2 - value
				1.081			6.466***
Sex	Male	94.4	91.8		96	89.5	
	Female	5.6	8.2		4	10.5	
Access to extension				107.119***			125.846***
	Yes	94.4	47.3		93.3	42	
	No	5.6	52.7		6.7	58	
Access to credit				242.142***			116.974***
	Yes	96.4	19.8		80.7	42.7	
	No	3.6	80.2		19.3	57.3	
Members of farmer cooperatives				97.260***			115.605***
	Yes	92.9	47.8		91.9	42.5	
	No	8.1	52.2		8.1	57.5	
Participate in a field demonstration				2.131			3.899
	Yes	40.6	47.8		39.9	49.7	
	No	59.4	52.2		60.1	50.3	
Access to weather information				96.783***			94.092***
	Yes	82.2	33.8		78.9	30.9	

Table 2 Continues,

	No	17.8	66.2		21.1	69.1	
Disaster exposure				13.118***			20.661***
	Yes	81.2	65.2		82	61.9	
	No	18.8	34.8		18	38.1	
Contact with NGO				97.697***			91.875***
	Yes	91.4	45.4		87.9	43.1	
	No	8.6	54.6		12.1	56.9	
Access to market				96.270***			119.737***
	Yes	92.6	47.3		91.9	41.3	
	No	7.6	52.7		8.1	59.7	

Source: Authors' calculation based on the survey dataset (2023), ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively

Table 3

Descriptive statistics for continuous variables.

Variables description	Drought-tolerant high-yielding improved cultivar		Integrated disease, pest, and weed management		Soil and water conservation		Organic fertilizer		Crop diversification	
	Adopter	Non adopter	Adopter	Non adopter	Adopter	Non adopter	Adopter	Non adopter	Adopter	Non adopter
Age	41.43 (7.38)	41.35 (8.12)	41.91 (7.88)	40.58 (7.20)	41.63 (7.34)	41.18 (7.94)	41.65 (7.77)	41.17 (7.53)	41.46 (8.07)	41.33 (7.11)
Family size	6.66 (2.22)	6.69 (2.08)	6.75 (2.54)	6.56 (2.04)	6.70 (2.21)	6.67 (2.15)	6.77 (2.23)	6.59 (2.12)	6.70 2.26	6.65 2.10
Education level	4.60 (3.43)	4.17 (3.51)	4.41 (3.46)	4.50 (3.48)	4.5 1(3.37)	4.38 (3.55)	4.48 (3.38)	4.41 (3.55)	4.60 (3.42)	4.25 (3.52)
Farm experience	19.60 (6.97)	18.90 (7.40)	19.92 (7.33)	18.20 (6.65)	19.44 (6.37)	19.07 (7.31)	19.61 (7.28)	18.91 (6.97)	19.60 (7.60)	18.82 (6.48)
Land size	1.3 (0.58)	1.08 *** (0.49)	1.32 (0.59)	1.05 *** (0.44)	1.34 (0.61)	1.10 *** (0.47)	1.34 (0.58)	1.11*** (0.51)	1.42 (0.57)	0.98 (0.43)
Total livestock unit	7.60 (1.42)	7.10 (1.43)	7.52 (1.61)	7.26 * (1.37)	7.50 (1.57)	7.34 (1.49)	7.80 (1.49)	7.10 (1.48)	7.64 (1.51)	7.16 (1.51)
Annual income	56607.69 (21166.65)	47,704.86 * (19558.35)	56944.22 (21516.43)	47676.47 *** (18880.20)	58527.7 7 (21281. 00)	48538.83 (19605.21)	58114.21 (21970.43)	48980.6 7 ** (19087. 99)	58309. 42 (21809 .54)	47428 .72 *** (1835 7.72)
Frequency of extension contact	5.60 (2.92)	1.84 ** (2.89)	5.74(2.72)	1.83 *** (3.03)	6.23 (2.70)	2.36 *** (2.92)	5.87 (2.83)	2.72*** (3.21)	5.61 (2.67)	2.59 *** (3.49)
Duration of training	0.68 (0.39)	0.22 ** (0.43)	0.71(0.43)	0.21 *** (0.37)	0.72 (0.42)	0.33 (0.45)	0.73 (0.42)	0.32 (0.44)	0.77 (0.42)	0.21 *** (0.34)
Distance to market in km	12.28 (2.69)	12.53 (2.93)	12.19 (2.66)	12.67 (2.94)	12.39 (2.71)	12.35 (2.84)	12.51 (2.65)	12.23 (2.89)	12.32 (2.67)	12.43 (2.90)

Source: Own computation based on the survey dataset (2023), ***, **, and * indicate statistical significance at 1%, 5% and 10%, respectively

Interdependence of CSA practices

Table 4 displays the potential positive interconnectedness between the CSA techniques contemplated in this research. The linkage is proved by the coefficients of association of error terms generated from the MVP computation. The null hypothesis that there is no association between the error terms in distinct equations is rejected since the calculated off-diagonal correlation values were collectively significant. Thus, the MVP model has greater precision than the probit model in addressing the acceptance of multiple CSA practices. In addition, Table 4 reveals that nearly all the computed correlation indices are significant and positive. This means that these tactics complement each other and therefore farmers use them together. The results reported in the studies of Teklewold *et al.* (2013), Kassie *et al.* (2015), Wainainaa *et al.* (2016), Mwungu *et al.* (2018), Teklewold *et al.* (2019), Zampaligre and Fuchs (2019), Bedeke *et al.* (2019), Kurgat *et al.* (2020), Ali (2021), and Wordofa *et al.* (2021) are all in concordance with this outcome.

The likelihood ratio test (chi ^{2} = chi2(10) = 90.3494, $p < 0.000$) of the error terms of each of the CSAPs equations from the MVP model was significant at the 1% level of significance, thus refuting the null hypothesis that the equations were distinct (Table 5). The findings showed that the algorithms to execute distinct CSAPs were interconnected. As a result, an alternate argument of the interconnection between error terms of CSAPs was concurred. Accordingly, the reasoning for employing the MVP model in examining the factors influencing the uptake of multiple CSAPs is maintained. Both positive and negative coefficients of association between the various CSAPs revealed complements and substitutes. Our result was analogous to that of Ndiritu *et al.* (2014), who revealed how smallholders in Kenya's sustainable intensification strategies complement and substitute for one another. As per the results of the simulated maximum probability estimation, $\delta = 21$ (a positive affiliation was found at the 1% significance level between the application of integrated disease, pest, and herb control and drought-resistant, high-yielding cultivars. This finding revealed that farmers who practiced drought-resistant, high-yielding crop varieties were more likely to practice integrated disease, pest, and herb management activities. Drought-tolerant, high-yielding crop varieties and soil and water conservation showed a positive correlation with ($\delta = 31$), with a significance level of 1%. This result led to the hypothesis that farmers were more willing to conserve soil and water when they used high-yielding, drought-tolerant crops and vice versa.

Table 4
Climate-smart agriculture practice' correlation value

Correlation between CSA practices	correlation coefficient
Drought-tolerant high-yielding cultivar and integrated disease, pest, and herb control (rho 21)	0.545***
Drought-tolerant high-yielding cultivar and soil and water conservation (rho 31)	0.450***
Drought-tolerant high-yielding cultivar and organic fertilizer (rho 41)	0.032
Drought-tolerant high-yielding cultivar and crop diversification (rho 51)	0.460***
Integrated pest and herb management and soil and water conservation (rho 32)	0.487***
Integrated pest and herb management and organic fertilizer (rho 42)	0.009
Integrated pest and herb management and crop diversification (rho 52)	0.463***
Soil and water conservation and organic fertilizer (rho 43)	0.431**
Soil and water conservation and crop diversification (rho 53)	0.369***

Table 4 Continues,

organic fertilizer and crop diversification (rho 54)	-0.061

Source: Own computation results, ***, **, and * exhibit statistical significance at 1%, 5% and 10%, respectively

In δ = 51, there was a positive association between drought-resistant, high-yielding improved cultivars and crop diversification at a 1% significance level. Therefore, the study findings led to the hypothesis that farmers were further inclined to adopt crop diversification and vice versa if they used high-yielding, drought-tolerant crop varieties. Regarding δ = 32, the integrated disease, pest, herb management, and soil and water conservation showed a positive relationship at the 1% significance level. This result led to the hypothesis that farmers who implemented soil and water conservation were more likely to do so when they practiced integrated disease, pest, and herb management, and vice versa. In the same technique, δ = 52, there was a positive correlation between integrated disease, pest, and herb management and crop diversification at a 1% significance level. This outcome brought about the contention that farmers who practiced integrated disease, pest, and herb management were more inclined to engage in crop diversification and vice versa. The outcome revealed that there is a positive correlation between soil and water conservation and organic fertilizer (δ = 43) as well as soil and water conservation and crop diversification (δ = 53) at 5% and 1% significance levels, respectively.

Determinants of climate-smart agriculture adoption practices

The outcome of the multivariate probit regression model illustrates the variables that determine the uptake of CSA (Table 5). The outcome of the models revealed that several explanatory variables influenced the adoption of specific CSA technology by farm households in the research area. Accordingly, the adoption of DTHICV is positively and significantly influenced by the total livestock unit, accessibility of meteorological information at 5% significance levels, whereas access to credit, engagement in farmer cooperatives, and perceived benefits impact climate-smart agriculture practices at 1% and 10% significance levels, respectively. IDPHM is positively and strongly correlated with the level of training, access to credit, membership in farmer cooperatives, accessibility to weather information, drought occurrence, and perceived benefits of climate-smart agriculture at 1% significance levels, respectively. SWC is significantly and positively associated with sex, marital status, family size, access to credit, contact with extension personnel, soil fertility, availability of weather information, and drought exposure. Agroecology, family size, ownership of livestock, access to credit, access to extension, duration of training, drought exposure, access to weather information, and contact with non-governmental organizations are all positively and strongly related to the embracing of OFR practices.

The age of the farm household is negatively and significantly associated with OFR espousal. CD is significantly and positively correlated with farmer experience, land size, total livestock unit, access to credit, contacts with extension personnel, members of farmer cooperatives, duration of training, soil fertility, and drought exposure (Table 5). Because farmers in different Agro-Ecological Zones (AEZs) respond differently to extreme weather events, they do not employ identical CSA tactics to mitigate climate change-related vulnerabilities and hazards (Rahaman et al., 2019). Table 5 indicates that, in contrast to farmers in midland AEZs, households in highland areas are more probable to espouse organic fertilizer.

Sex of the household head: The value of this parameter strongly and positively influences crop diversification (CD) practices. The results reveal that households with male heads are a higher possibility to opt for crop diversification as a CSA strategy than households with female heads. This might be because women lead households, which means they have less access to labour, knowledge, land, and other resources. In addition, they have more duties at home. This conclusion coincides with an investigation that was accomplished by Zakari *et al.* (2019), which revealed that a greater number of male-headed households engage in agroforestry than female-headed households. Murray *et al.* (2016) confirmed that women-headed households are less inclined to embrace CSA technology than those led by men.

Age: The age of the family head strongly and inversely impacts the adoption of organic fertilizer (OF) and crop diversification (CD). Among the potential arguments for the inverse association is that elderly individuals typically want to adhere to agricultural activities already functioning in their locality. This finding is consistent with investigations conducted by Justin *et al.* (2017), Hailemariam *et al.* (2019), Ayenew *et al. (*2020), and Faleye and Afolami (2020) that found that as household heads get older, the likelihood of selecting and implementing climate-smart agricultural practices decreases because older farmers tend to engage in less labour-intensive tasks than younger farmers.

Farm size: Farm size has a significantly positive effect on the probability of crop diversification at 1% level of significance. The positive impact of farm size suggests that farmers with large farm size practice crop diversification than small farms. This is in agreement with our hypothesis formulated regarding the relationship between crop diversification and land holding size of the household. This implies that larger farms offer greater opportunities to spread risk by planting a wider variety of crops, manage complex agricultural practices, and utilize resources more efficiently to produce diverse outputs for both home consumption and market sales. On average, each additional hectare of land increases the probability of farmer crop diversification by 76.9%. The result supports the finding of Micheni et al. (2024), who confirmed that land size had a positive and significant effect on the extent of crop diversification, meaning farmers with larger land were more likely to grow diverse crops.

Livestock ownership: This attribute was expected to enhance the possibility that farmers could decide to employ and execute CSA innovations. As hypothesized, it has a positive and significant impact on uptake of DTHICV, OFR, and CD at 5%, 1%, and 10% significance levels, respectively. As the livestock holding increased by one TLU, the chance of practicing DTHICV, OFR, and CD increased by 12.9, 25, and 9.5, respectively. The association between livestock ownership and selected climate-smart agricultural techniques agreed with the earlier predictions. The findings proved that farmers with more total livestock units practiced DTHICV, OFR, and CD more successfully than farmers with fewer total livestock units. One explanation might be that animals provide a significant portion of the manure required to maintain soil fertility. Farmers with a higher number of livestock have a greater opportunity to generate extra cash to spend easily on purchasing agricultural inputs, for instance, improved crop varieties or labour needed in soil and water conservation practices. Furthermore, they easily procure materials and tools required for the CSA innovations (DTHICV, OFR, and CD). A comparable result was drawn in earlier investigations by Zakari *et al. (*2019).

Access to extension: Interaction with extension personnel led to a substantial rise in the application of organic fertilizers and conservation of soil and water, but the variable had the opposite effect on crop diversification techniques. The result may have to do with the technical know-how required to replace old methods like livestock manure with soil and water management techniques. The farmers could have benefited greatly from the extension personnel's connections if they had been equipped with real-world knowledge of SWC and the application of ORF techniques and strategies to boost agricultural output and prepare for climate change. Our findings corresponded with those of Anang *et al.* (2020) and Emmanuel *et al.* (2016), who underlined the contribution of extension programs to the espousal of agricultural technology interventions. The application of SWC and OFR techniques is positively impacted by extension service availability. Comparing farmers with and without extension service, the results indicate that the former have implemented more SWC and OFR, with probabilities of 24.6% and 11.1%, respectively. This suggests that farmers who have more extension contact would likely embrace policies such as using organic fertilizer and conserving water and soil, whereas crop diversification will likely be less common. This could be as a result of the farmer obtaining extension assistance being more conversant about adopting organic fertilizer adoption techniques and conserving soil and water than the other farmer. This result is analogous to the investigation of Tura *et al.* (2017), Ali et al. (2018), and Gelgo *et al*. (2017) in their respective studies. Adoption of CD is negatively impacted at the 1% statistical significance level. This may be explained by the lack of specialized knowledge, skills, and experience necessary to support farmers, as well as a lack of farm workers able and willing to do the work, can all be significant reinforcing factors affecting on the adoption of crop diversification negatively. This result is analogous to the investigation of Iles and Marsh (2012), in their respective studies.

Access to credit: Adoption of DTHICV IDPHM, SWC, and CD has a significant and positive effect by making credit available at 1%, respectively. DTHICV, IDPHM, SWC, and CD applications rise by 78, 62.5, 60.7, and 82.1 percentage points, respectively, as households receive credit services. As expected, there was a correlation between credit and certain climate-smart agriculture practices. This reveals how farmers can better use DTHICV, IDPHM, SWC, and CD technologies when they have credit accessibility. This is because having credit improves farmers' cash reserves and the capacity to cover the transaction expenses pertaining to any CSA technologies they may wish to implement. The results of this investigation are in line with those of Mango *et al.* (2018), Franco (2020), and Landers *et al.* (2021).

Climate information: Availability of climate information is vital for mitigating the challenges caused by climate variability and change, specifically in sectors like agriculture, energy, and disaster risk management. This parameter has a positive and profound influence on IDPHM and SWC adoption. The findings confirmed that farmers with access to meteorology data have become better at implementing SWC and IDPHM than farmers without such information. This may be because farmers with trustworthy information about present and future temperature and precipitation are empowered to make choices about disease, pest, and weed control, and maintain soil fecundity. It appears that this result is comprehensible and corresponds with the results of other investigations (Abegunde *et al*., 2020; Dung, 2020; Sardar *et al.,* 2021).

Access to training: This variable has a positive and significant impact on the practice of DTHICV, IDPHM, and CD. The findings indicate that farmers with training access using DTHICV, IDPHM, and CD more effectively than those without it. This is due to the fact that farmers are more inclined to utilize CSA technology when they receive greater technical assistance and training from extension staff. Some research reports a related finding (Mango *et al.,* 2018; Franco, 2020).

Multivariate probit (SML, # draws = 5)
Number of obs = 404
Wald chi^2 (120) = 565.47
Log likelihood = -612.36041
Prob > chi^2 = 0.0000

Table 5
Determinants of climate-smart agricultural practices adoption among smallholder farmers

	DTHICV		IDPHM		SWC		OFR		CD	
	Coef.	Std.er.	Coef.	Std.er.	Coef.	Std.er.	Coef.	Std.er.	Coef.	Std.er.
AGRECO	-0.037	0.200	-0.298	0.219	0.097	0.236	0.676***	0.249	0.067	0.214
SEX	-0.068	0.424	-0.444	0.450	1.190**	0.522	-0.455	0.500	0.786	0.519
AGE	-0.039	0.028	-0.037	0.030	-0.028	0.035	-0.065*	0.034	-0.083***	0.031
MARSTA	0.063	0.200	-0.016	0.210	0.500*	0.267	0.106	0.218	0.120	0.220
FAMSZE	0.061	0.063	0.041	0.066	0.141*	0.078	0.145*	0.080	0.103	0.071
AGAVEGTN	-0.043	0.081	-0.026	0.088	-0.008	0.088	0.059	0.099	0.081	0.087
EDULEVL	0.014	0.028	-0.043	0.028	-0.033	0.032	-0.035	0.035	-0.001	0.028
FAEXP	0.026	0.025	0.039	0.026	-0.005	0.032	0.024	0.029	0.052**	0.026
LADSZE	-0.329	0.234	-0.162	0.258	0.160	0.265	0.154	0.264	0.769***	0.262
TLU	0.129**	0.055	0.008	0.056	0.001	0.060	0.250***	0.071	0.095*	0.054
ACCRDT	0.780***	0.200	0.625***	0.202	.607***	0.228	2.870	0.303	0.821***	0.207
FEXC	0.045	0.044	0.029	0.046	0.246***	0.058	0.111***	0.045	-0.142***	0.046
MFG	1.355***	0.455	1.409***	0.541	0.403	0.533	-0.650	0.498	1.817***	0.457
PARTDOM	-0.084	0.172	-0.131	0.182	0.160	0.204	-0.203	0.219	-0.335*	0.186
ACMIDA	-0.079	0.212	-0.074	0.217	0.035	0.240	0.260	0.260	-0.019	0.223
ANUINCM	0.000	0.000	-0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
OFINCM	-0.000	0.000	-0.000*	0.000	-0.000	0.000	-0.000	0.000	-0.000***	0.000
DURTNG	0.680**	0.316	0.916***	0.341	-0.487	0.389	-0.340	0.368	1.417***	0.332
DSTMKTK	-0.010	0.031	-0.058*	0.034	0.054	0.036	0.046	0.039	-0.035	0.033
SOILFER	0.028	0.179	0.380**	0.190	0.391**	0.198	-0.007	0.213	0.455***	0.191
PERVBENFT	0.370*	0.191	0.449**	0.203	-0.250	0.256	0.359	0.251	-0.487**	0.225

Table 5 Continues,

DISEXP	0.044	0.209	0.571***	0.213	0.499**	0.248	0.479	0.268	0.514***	0.217
AWINF	0.232	0.235	0.453**	0.224	2.166***	0.268	-0.010	0.289	-0.013	0.239
NGOCONT	-0.608	0.459	-0.421	0.539	-0.390	0.455	0.996***	0.372	0.163	0.395
_cons	-1.197	1.182	0.324	1.179	-5.419***	1.482	-5.551***	1.531	-2.221*	1.223

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: $chi^2 (10) = 90.3494$ Prob > $chi^2 = 0.0000$

Source: Own computation results, *, ** and *** denote statistical significance at 10%, 5% and 1%, respectively

Participation in off-farm activities: This variable negatively and significantly affects the probability of crop diversification at 1% probability level. The plausible explanation is that if a household receives income from off-farm work, it is less likely to pursue crop diversification as a strategy to minimize the financial risk associated with farming (Sandretto *et al.* 2004). This finding is similar to findings of Lighton and Emmanuel (2016) and Dessie *et al*. (2019), who also found that off-farm income had a significant and negative effect on crop diversification.

Soil fertility status: This variable significantly and positively impacted CD, IDPHM, and SWC at 1%, 5%, and 5%, respectively. These implied that smallholders experiencing deficient fertility of the soil had a higher likelihood of adopting and utilizing CD, IDPHM, and SWC practices. This would not only benefit individual farmers but also improve the broader well-being of ecosystems and communities. Ultimately, sustainable practices can create a resilient agricultural system that supports future generations. Furthermore, farmers may also make significant investments in techniques for preserving soil water that raise soil fecundity to equip themselves to prevent crop damage or lower returns from unproductive plots. Our results supported the conclusion of Fosu-Mensah *et al.* (2012) and Mulwa *et al.* (2017), who discovered that ownership of productive land may lead to a sense of security and self-sufficiency, which in turn can reduce the motivation to adopt new practices.

Off-farm income: This variable had a significant and adverse impact on the embracing of IDPHM and DC at the 10% and 1% significance levels, subsequently. Farmers who have off-farm occupations may not be competent to invest adequate time in farming tasks. This can make it tougher to adopt CSAp, which entails extra time and concentration. Additionally, if one is less reliant on farm revenue, one may be less willing to devote contending assets to the farm. The outcome corresponds to the findings of Justin *et al. (*2017), Abegunde *et al.* (2019), and Kassa and Abdi (2022), who specify that adopting additional CSAPs was less likely when there was an off-farm source of income.

Distance from market: This variable had a strong and negative consequence on the espousal of IDPHM at the 10% significance level (Table 5). Thus, this finding was analogous to earlier predictions. As the distance from the household's residence to the closest local market increases by one km, the practice of IDPHM declines by 0.058. This suggests that as the distance of the market from the homestead increases, the probability of adopting IDPHM decreases. This might be because farmers who reside distantly from the market are less inclined to get information about IDPHM. Therefore, farm households that reside distant from the market are less probable to implement IDPHM than farmers who reside near the market. This result aligns with the findings of Chaltu (2021), who stated that market distance influenced the adoption of improved crop varieties and soil and water conservation; Tekle and Gemechu (2022), who found in their result that distance from the market negatively affected the adoption of soil conservation practices; and Malefiya (2017), who also reported that distance from the nearest market negatively impacted the adoption of CSA practices.

Perceived benefits: The adoption of IDPHM and DTHICV was positively influenced by this attribute at a significant level of 1% and 10%, respectively. This infers that households that also notice technology as being consistent with their desires and in harmony with their surroundings are more inclined to adopt it meanwhile, they find it a profitable investment. It was also revealed that adoption was positively impacted by the expected advantages of CSA in terms of its increase in revenue and productivity (Ntshangase *et al.,* 2018; Ouédraogo *et al.,* 2019).

Contact with NGOs: Interaction with NGOs is significantly and positively associated with the adoption of climate-smart agriculture execution. The finding indicates that farmers who have interacted with local NGOs addressing similar problems are more likely to employ OFR techniques. In the southern nation, Alemitu (2011) and Rahmeto (2007) analogously discovered that contact with NGOs in that region had a noteworthy favorable impact on the state of technology adoption. As part of capacity-building programmes, these farmers might have information, networking, training, awareness workshops, and other support for practicing OFR. Such support might motivate farm households to use ORF. As compared to its effect on the decision to adopt, the importance of collaborating with NGOs on adoption might be associated with boosting self-assurance on practicing and developing skills.

Determinants of climate-smart agriculture practices intensity

Adoption extent is vital among subsistence farmers to maximize yields of crops and earnings and alleviate effects of climate change (Kpadonou *et al.,* 2017; Ndiritu *et al.,* 2014; Oyetunde-Usman *et al.,* 2012). Our research proved that LR Chi^2 = 475.93 and Prob > chi^2 = 0.000 were significant, inferring that the ordered probit model was consistent. The degree of CSA adoption is negatively impacted by household age, for the same logic as the MVP estimate (see Table 5). Age has a negative impact on the pace of CSA adoption. As the head of the household becomes older, the extent of adoption begins to decline. This emphasized that farmers might evolve hesitant to take advantage of new technologies and stick to their conventional farming methods as their age goes up, which is consistent with earlier hypotheses. Furthermore, younger farmers may be more inclined to experiment with innovative practices and adopt modern techniques that could enhance productivity. CSA adoption extent appears to be positively influenced by agricultural experience; however, this is conceivable. This is because farmers may embrace new CSA techniques as they become more knowledgeable about agriculture and realize the benefits of implementing these practices promptly. According to Ainembabazi and Mugisha's (2014) findings, farming expertise is especially important when adopting agricultural technologies in the early phases.

The study also showed that the degree of CSAp adoption by farm households tends to ascent with the sovereignty of livestock. Possession of livestock has a positive and substantial impact on the extent of adoption of agricultural technology. Livestock is a proxy for household wealth, and wealthier farmers have a greater opportunity of procuring advanced agricultural technology. The findings were consistent with those of Ehiakpor *et al.* (2021), who verified that livestock ownership significantly impacted the adoption level of sustainable climate-smart agricultural operations. This was attributed to the possibility of vending livestock to purchase farm inputs, including agrochemicals, fertilizers, and improved seed.

Table 6

Factors influencing the number of climate-smart agricultural practices adopted using an ordered probit model

	Coef.	Std.er.	P-value
AGRECO	.0403899	.1503584	0.788
SEX	.3531435	.3121251	0.258
AGE	-.0661357	.0214121	0.002***
MARSTA	.1523166	.1441074	0.291
FAMSZE	.0834238	.0477659	0.081*
AGAVEGTN	.0568015	.0605573	0.348
EDULEVL	-.0271664	.0202946	0.181
FAEXP	.0336352	.0185211	0.069*
LADSZE	.0769313	.1692957	0.650
TLU	.1007252	.0394766	0.011***
ACCRDT	1.32279	.15542	0.000***
FEXC	.0571594	.0310385	0.066*
MFG	.8437957	.3220466	0.009***
PARTDOM	-.1559968	.1299091	0.230
ACMIDA	.0530947	.15433	0.731
ANUINCM	2.89e-06	4.44e-06	0.516
OFINCM	-.0000231	8.10e-06	0.004***
DURTNG	.6185469	.2302493	0.007***
DSTMKTK	.0033857	.0230726	0.883
SOILFER	.248863	.132014	0.059*
PERVBENFT	.2188622	.1498014	0.144
DISEXP	.4003533	.1553524	0.010***
AWINF	.8278048	.1656661	0.000***
NGOCONT	.0464921	.2752426	0.866
Number of observations=404	LR chi^2 (24) = 475.93	Prob > chi^2 = 0.0000	
Log likelihood = -425.31131	Pseudo R^2=0.3588		

Source: Own computation results, *, ** and *** symbolize statistical magnitude at 10%, 5% and 1%, respectively

The extent of extension interactions is one of the institutional components that strongly influence the extent of CSA practices embraced by farmers in the study area. The level of adoption is also proven to increase with a higher number of extension contacts. These visits allow for personalized support and guidance, fostering a deeper knowledge of the methods being promoted. Utilization of extension has a positive and momentous upshot on adoption level since the more frequently farmers engage with extension services, the more likely they are to implement new techniques and improve their overall productivity. The positive effect of high levels of extension contact on the rate of CSA adoption is ascribed to the identical arguments stated in the MVP analysis.

The positive and significant coefficient of training showed that the degree of espousal of climate-smart agriculture is higher for trained farmers than for untrained farmers. The result is dependable with the results of Zakaria *et al.* (2020) and Aryal *et al.* (2018). The majority of training is delivered through government extension offices in the study area. The lesson encompasses postharvest operations, crop cultivation, and controlling diseases and pests. These training courses are anticipated to greatly enhance farmers' cognizance and, consequently, increase levels of adoption. Training brings farmers into contact with experts who have an inclusive range of expertise, which may enhance their knowledge and skills and hence increase the degree of adoption. The positive impact of training on the adoption of innovative technology is well documented (Rahman *et al.,* 2018; Rahman, 2021). The importance of training in technology adoption has been supported by the results of this study. The positive association between membership in farmer cooperatives and adoption extent suggests that the level of adoption is higher among farmers who are members of farmers' associations compared to their counterparts. Some investigations (Wossen *et al.,* 2017; Massresha *et al.,* 2021; Rahman, 2021) confirm that social affiliation has a positive effect on agricultural technology adoption. Social organizations are expected to close knowledge gaps and reduce research costs for new technologies.

CONCLUSIONS AND POLICY IMPLICATIONS

It is commonly acknowledged that executing CSA practices is a viable and efficient strategy to mitigate the adverse repercussions of climate change. However, smallholder farmers in Ethiopia continue to employ CSA practices at a low rate. This study scrutinized variables that affect the implementation of CSA tactics and the extent to which they are adopted by farm households in the West Arsi zone. A greater understanding of factors that affect the adoption of CSA protocols enables the development of agricultural policies that can expedite the spread of CSA techniques. The five climate-smart agricultural innovations taken into account for this research were drought-tolerant, high-yielding crop cultivars; synchronized pest, disease, and herb control; pest, disease, and herb management; soil and water conservation; organic fertilizers; and crop diversification. The multivariate correlation values indicate that there was a momentous and positive affiliation between dependent variables. Our empirical finding suggests that there may be mutual benefits among CSA activities. Farmers' adoption of numerous CSA tactics, and also their degree of adoption, is strongly impacted by agroecology, sex, age, education, land size, livestock ownership, regularity of extension acquaintances, credit availability, affiliation to farmer associations, training, accessibility to weather information, soil fertility, perceived benefits, exposure to disasters, and non-government contact.

The study's findings must be considered when designing policies to encourage smallholder farmers to establish CSAs and increase their intensity. Most importantly, the data demonstrates how harmonized CSA techniques are in terms of adoption. This implies that agricultural government officials and CSA executioners ought to acknowledge the synergies among CSA practices to promote the adoption of CSA techniques among smallholder farmers and spread the CSA concept all around the nation. Additionally, policymakers should think about household demographics, socioeconomic status, and institutional variables that positively impact CSA espousal. Priority should be given to supporting small-scale farmers with periodic extension contact and consulting activities; in the meantime, the frequency of extension inspection, and assistance empowers smallholder farmers to use further CSA measures. Furthermore, adopting CSA practices and thereby assisting farmers in adapting to the negative consequences of climate change is made possible by raising cognizance and publicizing information through various media venues concerning the advantages of embracing CSA techniques and the effects of climate change. The research findings will have significant policy implications for promoting the adoption and involvement of CSAp among smallholder farmers. These implications could lead to enhanced support systems, including extension services, training programs, access to credit, and weather information, aimed at increasing the resilience and productivity of these farmers.

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