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Adoption of Major Climate-Smart Agricultural Practices in Gimbo District, Southwest Ethiopia

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Abstract

This study investigates the determinants of adoption of Climate-Smart Agricultural Practices (CSAPs) among smallholder farmers in Gimbo District, Southwest Ethiopia. The focus is on three key technologies: agroforestry, improved seed varieties, and improved livestock feed and feeding practices. Primary data were collected from 384 households through structured interviews, and a multivariate probit (MVP) model was employed to analyze the simultaneous adoption of multiple technologies while accounting for potential interdependencies. Descriptive statistics and econometric results revealed that several socio-economic and institutional factors significantly influence adoption decisions. The findings show that education, access to training on CSAPs, extension services, access to credit, and climate information are strong and consistent predictors of adoption across the three technologies. Education and training had significant positive effects at the 1% level, suggesting that knowledge and awareness are central to technology uptake. Access to credit and extension services also enhanced adoption, while greater distance to markets negatively affected the likelihood of adopting agroforestry and improved seed varieties. Livestock ownership significantly influenced the adoption of improved feed practices. The study recommends expanding adult education, strengthening extension systems, improving access to credit and climate information, and investing in rural infrastructure to enhance adoption. The results offer important policy insights for stakeholders aiming to increase climate resilience in smallholder agriculture. Further research is suggested on gender-specific barriers, cost-benefit analysis of CSAPs, and the long-term effects of adoption.

Keywords: Climate information, climate-smart agriculture, Gimbo district, multivariate probit model, smallholder farmers

INTRODUCTION

Agriculture remains the backbone of Ethiopia's economy, employing approximately 70% of the population and contributing significantly to GDP, exports, and food security (Tesfaye et al., 2023) [1]. However, this sector is highly vulnerable to climate change impacts such as erratic rainfall, temperature fluctuations, droughts, and land degradation, which have increasingly undermined agricultural productivity and food systems, particularly for smallholder farmers (Erekalo & Yadda, 2023) [2]. In response to these challenges, Climate Smart Agriculture (CSA) has emerged as a comprehensive strategy aimed at enhancing productivity, improving resilience, and reducing greenhouse gas emissions (Kabato et al., 2025) [3]. Climate Smart Agricultural Practices (CSAPs) such as agroforestry, improved seed varieties, soil and water conservation, and integrated crop-livestock systems are now being promoted to help smallholder farmers adapt to and mitigate climate-related risks.

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Despite the known benefits of CSAPs, the rate of adoption among smallholder farmers in Ethiopia remains relatively low and uneven across different regions (Hailu & Abate, 2023) [4]. This is particularly true in the Gimbo District of the Southwest Region, where climate variability is becoming more frequent and severe, yet adoption of practices like agroforestry and improved seed varieties is lagging. This gap raises critical questions about the determinants of adoption and the factors that facilitate or hinder the uptake of these practices. Understanding these determinants is crucial for designing targeted interventions and support mechanisms that can enhance farmers' adaptive capacity and long-term sustainability.

Numerous studies have emphasized that the adoption of CSAPs is influenced by a wide range of factors, including demographic characteristics (age, education, gender), institutional variables (access to extension services, credit availability, land tenure security), and agro-ecological conditions (Jaleta et al., 2019; Kassie et al., 2015; Asfaw et al., 2021) [5, 6, 7]. For instance, access to information and training from agricultural extension services has been found to significantly influence farmers' decisions to adopt climate-smart technologies (Meshesha et al., 2022) [8].

Similarly, land ownership and size of landholding often determine whether farmers are willing to make long-term investments such as agroforestry or adopt improved seed technologies (Kansanga et al., 2011; Teklewold et al., 2013) [9, 10].

In Gimbo District, the combination of increasing climate pressure, population growth, and agricultural dependence makes it an important case study for examining the drivers and constraints of CSAP adoption. Although governmental and non-governmental organizations have introduced interventions to promote climate-resilient farming in this area, uptake has varied widely across communities and households. Moreover, there is a lack of localized empirical research that analyzes the specific socio-economic, institutional, and environmental factors affecting CSAP adoption in this district, especially regarding agroforestry and improved seed varieties. Such a gap in knowledge limits the ability of policymakers and development practitioners to design location-specific and farmer-centered strategies.

Recent literature underscores the importance of context-specific analysis when addressing climate change adaptation in agriculture. For example, a study by Sisay et al. (2023) [11] in southern Ethiopia found that heterogeneity in household characteristics and institutional settings led to significant variation in adoption rates of CSAPs. Similarly, studies conducted in different agroecological zones have demonstrated that farmers' risk perceptions, market access, social capital, and climate information access critically shape their adaptive behavior (Nigatu et al., 2022; Biratu et al., 2023) [12, 13]. These findings suggest that a one-size-fits-all approach may not be effective in promoting climate-resilient agriculture across diverse regions.

Therefore, this study aims to investigate the determinants of the adoption of climate smart agricultural practices among smallholder farmers in Gimbo District, Southwest Ethiopia. Specifically, it focuses on the adoption of agroforestry and improved seed varieties, which are essential practices for improving resilience and productivity in the face of climatic stresses. By identifying the socio-economic, institutional, and environmental factors influencing adoption decisions, this research seeks to provide empirical evidence to guide policy and programmatic interventions that can enhance the climate resilience of smallholder farmers in the district and similar agro-ecological zones.

CONCEPTUAL FRAMEWORK OF THE STUDY

Climate change poses significant challenges to agricultural productivity and rural livelihoods, particularly in developing regions where farmers are vulnerable to climate variability. To address these challenges, Climate-Smart Agricultural Practices (CSAPs) such as agroforestry, improved seed varieties, and better livestock feed have emerged as adaptive strategies that enhance resilience and sustainability.

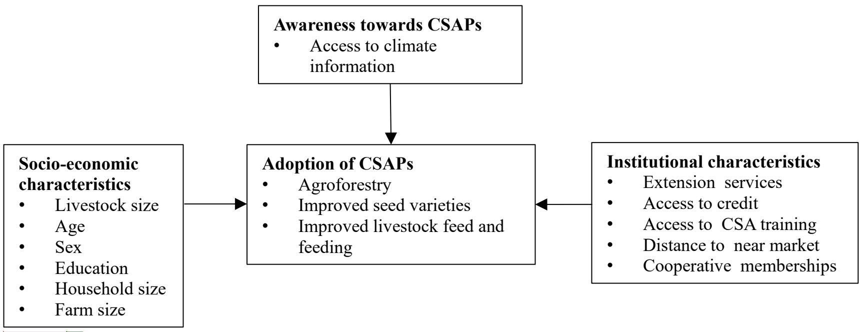

Figure 1. Conceptual framework.
Source: Own construction based on reviewed related literature (2024).

This conceptual framework outlines the key factors influencing the adoption of CSAPs, categorized into three domains: socio-economic characteristics, institutional characteristics, and awareness shaped by access to climate information.

The framework is guided by according to Rogers' Diffusion of Innovations Theory (2003) which asserts that the adoption of innovations depends on both individual traits and systemic factors, including knowledge, social support, and resource availability. In this context, socio-economic factors like education, age, sex, household size, and livestock or farm size influence a farmer's capacity and willingness to adopt CSAPs. For example, better-educated farmers are typically more receptive to new technologies (Dadi et al., 1988) [14].

Institutional characteristics such as access to extension services, credit, training, markets, and cooperatives create the enabling environment for adoption. These services provide the technical, financial, and social support that reduces barriers to implementation (Kifle and Mulugeta, 2022) [15]. Finally, awareness, primarily driven by access to climate information, acts as a cognitive trigger for behavior change. As noted by Ado et al. (2020) [16], farmers informed about climate risks are more likely to adopt adaptive practices

Together, these interrelated components illustrate that CSAP adoption is not just a technical decision but a socio-institutional process, requiring integrated interventions that improve knowledge, support systems, and household capacity.

METHODOLOGY

Description of the Study Area

Gimbo district is one the districts in Kaffa zone, which is found in the southwest regional state of Ethiopia. The name of Gimbo comes from the province in the former kings of Kaffa. It is far from Addis Ababa, 452 km. Gimbo is bordered by Decha in the south, Chena in the west, Gewata in the northwest and Gojeb in the north. Gimbo is located at approximately 7°23'53" N latitude and 36°13'57" E longitude (Birhanu et al., 2023) [17].

The whole population for this woreda is 117,588 and from which 58,559 were men and 50,059 were women. Most of these populations were rural dwellers and only 13,438 were urban inhabitants. The total number of households of the district is 12,806; and from these 11,322 are men and 1484 are women headed households (GWAFEPCO, 2024). The three largest ethnic groups reported in this district were the Kaffficho (76.74%), the Amhara (15.19%), and the Oromo (4.25%) (Birhanu et al., 2023) [17]. Gimbo district agro-ecology is 10.3% high land, 74.4% mid land, and 15.3% lowland.

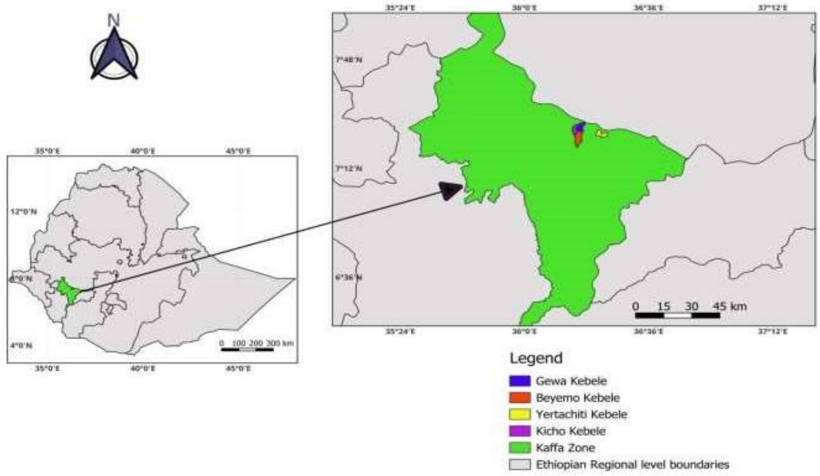

Figure 2. Map of the study area.

From the highland, 10% has an altitudinal range of 2000–2500 m a.s.l., 75% is within an altitudinal range of 1500–2000 m a.s.l., and the lowland is found within an altitudinal range of 1000–1500 m a.s.l. The area has a rugged and mountainous topography and also has a gentle and flat landscape towards the Gojeb River. Gimbo district has a rainy season from March to November, with the wettest seasons being May and June. The district has a minimum temperature of 15 ºC and a maximum temperature of 35 ºC, with rainfall ranging from 1750 to 2750mm (Birhanu et al., 2023).

Sampling and Data Collection

A multistage sampling approach was employed to select the study participants, beginning at the woreda level, followed by kebele selection, and finally targeting individual households.

Purposive sampling methods were employed during Woreda and PAs/kebele selection. The word a where the study takes place is selected purposively based on the potentiality of agroforestry, the use of improved seed and improved livestock feed, and the feeding extent. In the first stage, from a total of 28 rural kebeles in the district, this study randomly selected four kebeles. Then, using probability proportional to the size of households in each kebeles, 384 households were randomly drawn from the official dwellers' list obtained from the selected kebeles administration offices.

The sample size was determined using a formula developed by Cochran (1977), an appropriate method for studies with infinite populations. According to Cochran (1977), when dealing with a large population and an unknown variability of the proportion 'p,' it is possible to assume a conservative value of p = 0.5. At a 95% confidence level with ±5% precision, this method yields a sample size that accounts for potential variability in the population attribute. The formula used to determine the sample size was:

$$n = \frac{z^2pq}{e^2} = 384 \quad (1)$$

Where, n = sample size, Z is the standard cumulative distribution that corresponds to the desired confidence level (95%); e is the desired level of precision (±5%); p is the estimated proportion of an attribute present in the population with the value of 0.5 (where q =1-p).

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Table 2. Summary of definition, measurement and hypothesis of explanatory variables.

Variables	Unit of Measures	Types of Variables	Expected sign
Dependent Variables • Agroforestry • Improved seed varieties • Improved livestock feed and feeding • Independent variables			

Table. ???

Independent Variables			
Age	Age of household in year	Continuous	-
Sex	Gender of household head (1 for male 0 for Female	Dummy	+
Education	Year of education of household	Continuous	+
Family size	Number of family size in adult equivalent	Continuous	+
Land holding size	Farm Size of own land holding in hectare	Continuous	+
Livestock size	Livestock holding in TLU	Continuous	+
Access to credit	1 if farmers have access to credit and 0 otherwise	Continuous	+
Extension services	Farmers obtain agricultural extension services 1 if there is access, 0 otherwise	Dummy	+
Participation in CSAP training	1 if there is access, 0 otherwise	Dummy	+
Access to climate information	1 if farmers access to climate information, 0 otherwise	Dummy	+
Cooperative memberships	If 1 member otherwise 0	Dummy	+
Minutes	Distance to near market	Continuous	-

Source: Own observations based on reviewed empirical studies in the literature (2024)

Methods of Data Analysis

The collected data were edited, translated from Kafino to English, coded, and entered into SPSS 26 and analyzed using descriptive and econometric methods. The STATA software 17 version was used, and a multivariate probit model was used to analyze the determinants of the adoption of climate-smart agricultural practices among smallholder farmers:

Descriptive Statistics

The quantitative data was analyzed using descriptive statistics, including frequency distribution, mean, standard deviation, and percentage. Chi-square and T-tests were used to describe and summarize the information gathered from sampled household level.

Model Specification

The adoption of Climate-Smart Agriculture Practices (CSAPs) was captured using a binary (dummy) variable, where a value of 1 indicates that the maize farmer adopted at least one CSAP such as agroforestry, improved seed varieties, or enhanced livestock feed and feeding practices and 0 otherwise. To estimate the determinants of adoption, a multivariate probit (MVP) model was employed. This model is appropriate because it accounts for potential correlations among the adoption decisions of multiple CSAPs, which univariate binary models like standard probit or logit fail to capture due to their assumption of independence between choices. Since the analysis involves three CSAPs, it is likely that the decision to adopt one practice is influenced by unobserved household-level characteristics and may affect the likelihood of adopting other practices.

This interdependence may arise from complementarity, substitution, or competition among the practices (Greene, 2008). The MVP model accommodates this by jointly estimating multiple correlated binary outcomes using a shared set of explanatory variables. The empirical specification of the model is presented in Equation 2.

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$$Y1i = X1ij\beta1 + e1i \quad (2)$$
$$Y2i = X2ij\beta2 + e2i$$
$$Y3i = X3ij\beta3 + e3i$$

Where, i farmers identification, $Y1i$ if farmer adopt Agroforestry, 0 otherwise, $Y2i$ if farmer adopt improved seed varieties, 0 otherwise, $Y3i$ if farmer adopt improved livestock feed and feeding, 0 otherwise, $X1i$ vectors of factors affecting use CSA practices, βJ vectors of unknown parameters (j=1, 2, 3) and e is error term. To identify to the determinates of climate smart agriculture practices adoption a multivariate probit model of the following Eq.3 was used to test the hypothesis:

$$Yij = X1ij\beta j + eji \quad (3)$$

Where $Yij(j = 1,2,3)$ represents the three CSA practices used by i^{th} farmers (i…384), X^{1ij} is a 1xk vector of observed variables that affect the choices of decision of farmers, βj is a 1xk unknown parameters (to estimated), and ei is unobserved error term.it is assumed that the error terms (across j=1 m alternatives) are multivariate and are normally distributed with mean vector equal to zero. Thus, the unknown parameters in Eq. (3) are estimated using simulated maximum livelihood.

RESULT AND DISCUSSION

Multicollinearity Diagnosis

The test of multicollinearity among the variables used in the multivariate probit model variance inflation factor (VIF) was done for continuous independent variables and contingency coefficients for discrete independent variables. The VIF value displayed in appendices (4) indicates that there was no multicollinearity among six continuous independent variables because their VIF mean value was 1.05, which is less than 10. Gujarat (2003) states that if the VIF value is greater than 10, there is a multicollinearity problem among continuous variables. Contingency coefficients were also calculated to test the multicollinearity problem among the categorical independent variables. Table 3 (appendices) illustrated that the value of coefficients indicates there is no multicollinearity problem among the six categorical independent variables. This is for the reason that of all the variables, 0.75 had a contingent coefficient value, which is the threshold. (Gujarat, 2003).

Descriptive Statistics of the Explanatory Variables

Descriptive statistics for continuous variables

Table 3. Summarizes the adoption status of selected CSAPs among 384 sampled households in the study area. The findings reveal a high adoption rate of improved seed varieties and agroforestry, with 82.81% and 80.99% of households adopting these practices, respectively. This high uptake may reflect increased awareness, better access to improved inputs, and strong institutional support, such as extension services and training, promoting crop-related CSAPs. It also showed that these practices are well-aligned with farmers' needs for productivity enhancement and climate resilience.

In contrast, the adoption of improved livestock feed and feeding practices remains relatively low, with only 43.49% of households reporting usage, while 56.51% are non-adopters. This discrepancy highlights a potential gap in either awareness, resource availability, or perceived benefits related to livestock-specific interventions.

Table 3. Climate Smart agricultural practice adoption status of the sampled households study area.

CSAPs	Agroforestry		Improved Seed varieties		Improved livestock feed and feeding	
	Frequency	percent	Frequency	percent	Frequency	percent
Adopter	311	80.99	318	82.81	167	43.49
Non-adopter	73	19.01	66	17.19	217	56.51
Total	384	100	384	100	384	100

Sources: Own survey result, 2024

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The relatively lower adoption may also reflect constraints such as limited access to feed resources, technical knowledge, or climate information tailored to livestock management. These findings illustrated that while crop-based CSAPs are widely accepted, livestock-related climate-smart innovations require more focused attention in policy, training, and infrastructure development to enhance adoption rates and maximize their benefits.

The Table 4 results show a statistically significant and positive correlation between agroforestry and improved seed varieties (ρ = 0.4653, $p < 0.01$). This implies that the adoption of one is likely to be associated with the adoption of the other, possibly due to shared enabling conditions such as farmer awareness, access to extension, and motivation to invest in sustainable practices. Similar findings were reported by Teklewold et al. (2013) [10] and Kassie et al. (2015) [6], who noted that sustainable practices are often adopted in combinations due to complementarity in function and resource use. For example, integrating trees (agroforestry) may improve soil fertility, which enhances the benefits of using improved seed varieties.

Likewise, a positive and significant correlation is observed between improved seed varieties and improved livestock feed and feeding practices (ρ = 0.2991, $p < 0.01$), suggesting that farmers adopting better seeds may also adopt improved feed strategies. This could reflect the presence of mixed farming systems, where crop residues are used for livestock feed, creating synergies between crop and livestock components (Bryan et al., 2013). A similar pattern is observed between agroforestry and improved livestock feed and feeding (ρ = 0.2376, $p < 0.01$), though the correlation is weaker. Nevertheless, the significance indicates that decisions are not made independently and that bundled promotion of these practices may increase adoption efficiency.

These findings reinforce the validity of using the multivariate probit model, as adoption decisions are not mutually exclusive. They also support policy recommendations for integrated agricultural extension and climate-smart intervention programs, as multiple CSAPs are more likely to be adopted together when complementarities exist (Kassie *et al*., 2015).

Table 4. Correction coefficients for multivariate probity regression equation.

	Agroforestry	Improve seed variety	Improved livestock feed feeding
Agroforestry	1.0000		
Improve seed variety	0.4653***	1.0000	
Improved livestock feed feeding	0.2376***	0.2991***	1.000

Sources: Own survey result, 2024

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Descriptive Statistics for Continuous Variables

The Table 3 results showed that several socio-economic variables significantly influence the adoption of specific agricultural technologies. In agroforestry, adopters are significantly older at 5% level and more educated at 1% level than non-adopters, suggesting that both age and education are positively associated with adoption. Older farmers may have more farming experience or long-term perspectives that make agroforestry appealing, while higher education levels could enhance understanding and appreciation of its benefits. For improved seed varieties, adopters have significantly larger farm sizes at 1% level indicating that farmers with more land are more likely to take risks or invest in new seed technologies that may increase productivity.

In the case of improved livestock feed and feeding, adopters are significantly more educated 1% level and own more livestock 1% level compared to non-adopters. This implies that farmers with better education and greater livestock assets are more inclined to adopt improved feeding practices, possibly due to better knowledge access and a higher incentive to improve animal productivity. These patterns collectively suggest that education, resource endowment, and experience are critical determinants of technology adoption across different agricultural innovations.

Table 3. Descriptive statistics for continuous variables.

Variables	Agroforestry		Improved Seed varieties		Improved livestock feed and feeding	
	Adopter	***Non-Adopter***	***Adopter***	***Non-Adopter***	***Adopter***	***Non-Adopter***
Age	44.92** (10.52)	41.45 (9.81)	44.39 (10.49)	43.63 (10.39)	44.7 (9.73)	43.93 (11.00)
Education	4.53*** (3.78)	3.09 (3.82)	4.22 (3.77)	4.42 (4.08)	4.90*** (3.81)	3.75 (3.77)
Households size (AE)	8.02 (2.22)	7.55 (2.23)	7.98 (2.29)	7.68 (1.93)	8.06 (2.22)	7.83 (2.23)
Farm Size	2.10 (1.26)	2.05 (1.15)	2.18*** (1.31)	1.69 (1.17)	2.07 (1.39)	2.11 (1.23)
Livestock size (TLU)	9.46** (4.05)	8.52 (3.94)	9.20 (3.98)	9.67 (4.35)	9.99*** (4.52)	8.73 (3.54)
Distance to near market	51.00 (37.36)	56.72 (35.23)	50.29 (36.57)	60.75 (38.02)	52.090 (41.30)	52.094 (33.38)

*Note: ** and *** mean significant at 5% and 1%, respectively. Sources: Own survey result, 2024*

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Table 4. Descriptive statistics for discrete choice variables.

Variables		**Agroforestry**			**Improved Seed varieties**			**Improved livestock feed and feeding**		
		Adopter (%)	***Non-Adopter (%)***	***X2-value***	***Adopter (%)***	***Non-Adopter (%)***	***X2-value***	***Adopter (%)***	***Non-Adopter (%)***	***X2-value***
sex	Male	82.64	20.55	0.407	80.82	87.88	1.85	83.23	81.11	0.29
	female	17.36	79.45		12.1	12.12		16.77	18.89	
Access climate info	Yes No	82.32 17.68	73.97 26.03	2.64*	83.02 16.98	69.70 30.30	6.24*	94.01 5.99	70.51 29.49	33.51***
Access training on CSAPs	Yes No	50.48 49.52	15.07 84.93	30.13***	45.91 54.09	33.33 66.67	3.51*	59.28 40.72	31.80 68.20	28.97***
Extensions service	Yes No	55.95 44.05	28.77 71.23	17.48***	50.94 49.06	50.00 50.00		58.08 41.92	45.16 54.84	6.30*
Accesses to credit	Yes No	33.12 66.88	10.96 89.04	14.13***	30.19 69.81	22.73 77.27	1.48	34.73 65.27	24.42 75.58	4.88**
Farmer cooper membership	Yes No	50.16 49.84	42.47 57.53	1.40	51.57 48.43	34.85 65.15	6.12**	52.69 47.31	45.62 54.38	1.89

*Note: ** and *** mean significant at 5% and 1%, respectively. The numbers in the parenthesis are the standard deviation (SD)*
Sources: Own survey result, 2024

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Descriptive statistics for dummy variables

The table shows the relationship between discrete socio-economic and institutional factors and the adoption of agroforestry, improved seed varieties, and improved livestock feed and feeding technologies. Statistically significant differences are evident in variables such as access to climate information, training on climate-smart agricultural practices (CSAPs), extension services, and access to credit. For agroforestry, adopters were significantly more likely to have access to climate information, training on CSAPs, extension services, and credit indicating that information, knowledge support, and financial access strongly influence agroforestry adoption. For instance, 82.32% of agroforestry adopters had access to climate information compared to 73.97% of non-adopters which significant at the 10% level, while access to training significant at the 1% level showed a large gap between adopters 50.48% and non-adopters 15.07%.

In the case of improved seed varieties, access to climate information and membership in farmer cooperatives were significantly associated with adoption, `which impressive the importance of information and group support in decision-making. For improved livestock feed and feeding, access to climate information (94.01% vs. 70.51%), CSAP training (59.28% vs. 31.80%), extension services (58.08% vs. 45.16%), and credit (34.73% vs. 24.42%) were all significantly higher among adopters, highlighting the strong role of institutional support and access to knowledge. Notably, access to climate information showed a very strong association with adoption in this case significant at the 1% level, suggesting that informed farmers are more likely to adopt improved feeding practices.

Determinants of the Adoption of Climate Smart Agricultural Practices

The results of the multivariate probit model reveal that education significantly influences the adoption of all three climate-smart agricultural practices (CSAPs) agroforestry, improved seed varieties, and improved livestock feed and feeding at the 1% significance level. This recommends that more educated farmers are better equipped to understand, evaluate, and implement sustainable agricultural innovations. Education enhances farmers' access to and interpretation of agricultural information, as well as their willingness to try new technologies.

These findings align with Sindie *et al*. (2024a) [18], who found that educated wheat producer farmers have more probability to implement crop rotation and improved wheat varieties as compared to uneducated wheat producer farmers in northwestern Ethiopia. Similarly, Belachew *et al*. (2020) [19] who emphasize the importance of education in the adoption of innovative agricultural practices in Ethiopia

Access to training on CSAPs also shows a strong and positive association with the adoption of all three practices, significant at the 1% level. This implies that structured training programs are highly effective in building farmers' skills and awareness, enabling them to adopt and integrate climate-resilient practices into their farming systems. These findings are in line with previous research by Gemechis *et al*. (2023) [20] which showed that access to training had a significant and positive association with the livelihood of improved maize varieties which increases the degree of the knowledge of the farmers, allowing them to seek out more productive information and be more dedicated to farming. Similarly, Kassie et al. (2015) [6], who found that farmers received training on the benefits of improved seeds and intercropping, are more likely to adopt these practices due to a better understanding of their long-term advantages.

Furthermore, extension services were found to significantly increase the likelihood of adopting agroforestry at 5% level, improved seed varieties at 10% level, and improved livestock feeding at 10% level, indicating that regular contact with extension agents plays a crucial role in transferring knowledge and reinforcing positive attitudes toward innovation. These findings are consistent with research by Gebrehiwot *et al*., (2020) [21], which highlights that access to extension services significantly enhances the adoption of new agricultural technologies by improving farmers' knowledge and decision-making capabilities.

Economic and informational variables also significantly affect adoption. Access to credit is positively associated with all three practices, significant at the 1% level for agroforestry and livestock feeding, and at the 5% level for improved seed varieties. This highlights the role of financial resources in reducing liquidity constraints and facilitating investment in technologies.

The finding of this study is also line with the results of Erekalo and Yada. (2023) [2], which showed that extension serves to have a positive effect on the adoption of improved crop varieties, crop diversification, and time adjustment in South Africa Distance to the nearest market negatively affects the adoption of agroforestry at 5% level and improved seed varieties 1% level, suggesting that farmers in remote areas are less likely to access inputs, support services, or market incentives for adoption findings that align with Asasnte et al. (2024) [22]. Furthermore, livestock size significantly increases the adoption of improved feeding practices at 1% level, indicating that farmers with larger herds are more motivated to improve feed management.

Table 5. MVP results on determinants of adoption of climate agricultural practices.

Variables	**Agroforestry**			**Improved seed varieties**			**Improved livestock feed& feeding**		
	Coef.	***Robust Std.err.***	*z*	***Coef***	***Robust Std.err.***	*z*	***Robust Coef***	***Robust Std.err.***	*z*
Sex	.0467	.2112	0.22	-.1673	.1984	-0.84	.1187	.1773	0.67
Age	.0230	0075	4.02	.0054	0069	0.78	.0063	.0069	0.91
education	.0653***	.0241	2.71	.0551***	.0209	2.63	.0623***	.0193	3.24
Family size(AE)	.0487	.0383	1.27	-.0165	.0328	-0.50	.0304	.0342	0.89
Farm size	.0602	.0638	0.94	.0974	.0660	1.47	-.0376	.0541	-0.69
Livestock size(TLU)	.0259	.0198	1.30	-.0002	.0247	-0.01	.0552***	.0177	3.12
Access to climate information	-.1815	.2271	-0.80	-.0150	.1898	-0.08	1.1333***	.2266	5.00
Access training on CSAPs	.8146***	.1780	4.58	.5922***	.1589	3.73	.6356***	.1414	4.50
Extensions service	.3772**	.1845	2.04	.3060*	.1781	1.72	.2606*	.1551	1.68
Accesses to credit	.6942***	.1984	3.50	.4676**	.1905	2.45	.4066***	.1533	2.65
Farmer cooper membership	.0766	.1763	0.43	.1880	.1570	1.20	-.0764	.1436	-0.53
Distance to near market	-.0047**	.0020	-2.38	-.0078***	.0022	-3.62	-.0008	.0018	-0.45
_cons	-1.705***	.5300	-3.22	.3221	.5149	0.63	-2.6485	.4903	-5.4
/atrho21	.7241***	.1243	5.83	Multivariate probit (MSL, # draws = 100)					
/atrho31	.3647***	.1275	2.86	Log pseudolikelihood = -507.75808					
/atrho32	.6752***	.1294	5.22	Wald chi2(36) = 178.53					
rho21	.6194***	.0766	8.09	Prob > chi2 = 0.0000					
rho31	.3493***	.1120	3.12	Number of obs = 384					
rho32	.5883***	.0846	6.95	Likelihood ratio test of rho21 = rho31 = rho32 = 0: chi2(3) = 69.8333 Prob > chi2 = 0.0000					

Note: *, ** and *** mean significant at 10%, 5% and 1%, respectively. Sources: Own survey result, 2024

Lastly, access to climate information has a strong positive effect on improved livestock feeding at 1% level, emphasizing the importance of timely, relevant climate knowledge in managing livestock and feed resources. This is consistent with Bryan *et al*. **(**2014**)** [23], who showed that climate information enables more effective adaptation strategies.

SUMMARY, CONCLUSION AND RECOMMENDATION

Summary and Conclusions

The study on the determinants of climate-smart agricultural practice (CSAP) adoption among smallholder farmers in Gimbo District, Southwest Ethiopia, reveals that both socio-economic and institutional factors play crucial roles in influencing farmers' decisions. Education emerged as a key determinant across all three practices agroforestry, improved seed varieties, and improved livestock feed highlighting that better-educated farmers are more likely to understand and implement sustainable farming techniques. Access to training on CSAPs and extension services also significantly increased the likelihood of adoption, underscoring the importance of continuous knowledge transfer and support. Financial access, particularly credit, was another strong predictor, as it helps farmers invest in new technologies. The study further found that ownership of livestock positively influenced the adoption of improved feeding methods, while market distance had a negative effect on the adoption of agroforestry and improved seeds, indicating logistical challenges for farmers in remote areas.

In addition, access to climate information significantly influenced adoption, especially for improved livestock feed, demonstrating that timely and relevant information is critical for effective adaptation. These findings suggest that strengthening institutional support through education, training, credit access, and extension services can significantly improve the uptake of CSAPs. Moreover, improving infrastructure and market connectivity could mitigate the barriers faced by farmers in remote areas. Therefore, integrated policy interventions that address both informational and resource-based constraints are essential to enhance climate resilience in smallholder agriculture. The results provide valuable insights for policymakers, development organizations, and agricultural planners aiming to design strategies that promote sustainable and climate-resilient farming systems in Ethiopia and similar agro-ecological zones.

Recommendations

The findings of this study clearly highlight a range of socio-economic, institutional, and informational factors that significantly influence the adoption of climate-smart agricultural practices (CSAPs) among smallholder farmers in Gimbo District, Southwest Ethiopia. Based on these results, several key policy recommendations are proposed to improve adoption rates and support sustainable agricultural development in the region.

First, improving farmers' education and access to training on CSAPs should be a top priority. Education significantly enhances farmers' ability to understand and apply new technologies. Adult education programs tailored to rural communities should be expanded, and agricultural training must be integrated into local development plans. Regular, practical training sessions on CSAPs delivered through farmer field schools and demonstration sites can enhance awareness, change attitudes, and strengthen the capacity to implement agroforestry, improved seed usage, and improved livestock feed management.

Second, the government and NGOs should strengthen and expand agricultural extension services. The study found a positive relationship between extension service access and the likelihood of CSAP adoption. Therefore, increasing the number of trained extension agents, ensuring their frequent contact with farmers, and equipping them with adequate tools and materials are essential steps. Extension efforts should emphasize a participatory approach, where farmers are not just passive recipients but active learners and transformers.

Third, access to credit must be improved to alleviate financial constraints that prevent many smallholders from investing in new technologies. Development of rural financial institutions and the introduction of low-interest agricultural loans could enable farmers to purchase inputs like improved seeds or invest in livestock feed systems. Additionally, integrating credit provision with extension services and training programs can create a more supportive environment for adoption.

Fourth, the study revealed that access to climate information strongly affects adoption, particularly of livestock feed and management practices. As such, efforts should be made to enhance the dissemination of localized, timely, and actionable climate information. This could involve using mobile technologies, community radio, or establishing rural climate information centers. Farmers need to receive updates not just about weather patterns, but also on how these patterns may affect planting, harvesting, and feeding schedules.

Fifth, geographic isolation and market access barriers were found to negatively impact the adoption of certain practices. To overcome this, policymakers should prioritize investment in rural infrastructure, including feeder roads, market facilities, and transport services. Better infrastructure reduces the cost and risk of adoption, enhances input access, and improves market participation, all of which are critical for the sustainability of CSAPs.

Finally, institutional support must be strengthened by promoting the role of farmer cooperatives. Although membership in cooperatives did not show strong statistical significance in the multivariate model, cooperative groups can still serve as vital platforms for sharing knowledge, accessing group credit, purchasing inputs in bulk, and marketing products. Encouraging and supporting cooperative development can help foster collective action for adaptation.

For future inquiry, longitudinal studies are needed to examine the long-term impact and sustainability of CSAP adoption. Gender-focused research should explore how social norms, land rights, and access disparities affect female farmers' adoption decisions. Additionally, incorporating climate risk exposure into adoption models could offer insights into how shocks like drought influence adaptive behavior. Finally, cost-benefit analyses of CSAPs from a smallholder perspective would be valuable for designing affordable and scalable interventions that align with farmers' economic realities.
Declaration of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data Availability
The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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