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Adoption and Adoption Determinants of Climate Smart Agriculture Practices Among Smallholder Farmers in Welmera District, Oromia Region, Ethiopia

Mesay Hailu[1, *], Esubalew Abate[2]

[1]Ethiopian Institute of Agricultural Research (EIAR), Kulumsa Agricultural Research Center, Assela, Ethiopia
[2]College of Development Study, Addis Ababa University, Center for Rural Development, Addis Ababa, Ethiopia

Email address:
mesayjj@gmail.com (Mesay Hailu), esubalewabate@gmail.com (Esubalew Abate)
[*]Corresponding author

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Abstract: Adoption of climate smart agriculture practices believed to have significant contribution to lessen the devastating impact of climate change on agriculture. However, in countries like Ethiopia, adoption and use level remains low. Understanding farmers' levels of CSA practice adoption and influencing factors is therefore crucial. The goal of the study was to evaluate adoption of various CSA practices in the study area, as well as adoption determinants. The study was conducted in Welmera district, Oromia region, Ethiopia. Three kebeles were chosen from the district, and a random sample of 306 farmers was picked. We utilized a cross-sectional household survey, a focus group discussion, and interviews with key informants. A multivariate probit model was employed to investigate factors influencing adoption of multiple climate-smart agriculture practices. According to the result, Conservation agriculture, integrated soil fertility management, and crop diversification are the most often used CSA practices. The results also revealed that men farmers outperformed female farmers in terms of crop diversity and improved animal feed and feeding practice adoption. Farmers' age has a considerable and unfavorable impact on their likelihood of adopting improved soil fertility management and crop diversification. However, it has a positive and considerable impact on the adoption of agroforestry practices. According to economic factors, having a relatively big farmland area considerably enhances the adoption of conservation agriculture, enhances soil fertility management, crop diversity, improved livestock feed and feeding methods, and postharvest technology practice. Improved livestock feed and feeding are more likely to be used if farm income is higher. Having significant number of animals strongly promotes conservation agriculture adoption, and access to financial services positively impacts agroforestry, diversification of crops, and postharvest technology practice adoption. Furthermore, institutional factors including access to the agricultural extension services and trainings were discovered important and beneficial for crop diversification; similarly, access to field day participation was discovered to have a significant and positive impact on the adoption of conservation agriculture and improved soil fertility management practices. It is critical to raise awareness about climate change among farmers and experts, as well as to incorporate location-specific CSA practices into agricultural programs.

Keywords: Climate Change, Climate Smart Agriculture, Adoption, Multivariate Probit, Determinants

1. Introduction

Agriculture is both the most sensitive and one of the most significant contributors to climate change [1-3]. Rises in mean temperatures, precipitation irregularities, the intensity and frequency of droughts, floods, unreliable rainy seasons, hurricanes, and the level or concentration of atmospheric CO_2 are all visible signs of climate change that have impacted and will continue to impact the agriculture sector [4, 1]. Because the environment is so important to agriculture, climate change will have an impact on the agriculture industry and reduce the ability of natural resources to supply the services they currently provide. Climate change has a wide range of adverse effects on agriculture [2, 5, 7]. Erosion, crop health issues, livestock diseases, and high temperatures above the optimum for crop requirements are just a few of the warning signals.

In Ethiopia climate change have a considerable impact on agricultural outputs [8, 9]. The impact is series due to Ethiopian agriculture is primarily rain-fed, hence it is sensitive to changes in precipitation [10]. This implies that food production may cease to be a viable method of livelihood if precipitation is inadequate in amount or distribution over successive growing periods and confirms climate change is significantly contributes to food insecurity.

Climate change and adjacent affairs including irregular rainfall distribution, severe drought and degradation of land, severely limits the Ethiopian social and economic progress [11-14]. Droughts occur on a regular basis in Ethiopia [15], and causing food scarcity and affecting a large number of people [16]. For instance, according to [17], the drought in 1984 and 2003, that affected 7.5 and 12.6 million individuals respectively, caused an enormous effect on farmers' livelihoods. In the meantime, the El Nino event in 2015/16 caused Ethiopia to suffer through one of the most severe droughts in decades, with an estimated 10.2 million individuals in need of food aid [17].

Climate change is not only the cause for recurrent drought but it also the reason for heavy rainfall in some parts of the country. High intensity rainfall in the central highlands, including in Welmera district, is contributing to erosion and soil acidity in the area. One of the reason for existence of soil acidity is abundant precipitation [18]. Decrease in soil reaction and an increase in soil acidity is the consequence of agricultural land degradation [19]. Research indicates, Welmera district has a predominantly acidic soil type, ranging from moderate to strong [20, 21]. The district is one of the area that have been affecting by climate change [22]. Thus, adoption of CSA practices is acknowledged and believed important for mitigating the negative effect of climate change [23]. Despite its importance, adoption level of CSA practices in Ethiopia remains low [17]. There are multiple of factors and the reason why low implementation of the practices. Ethiopian smallholder farmers continue to underuse CSA practices including agroforestry and conservation agriculture due to lack of capital for initial investments and the country's precarious land tenure system.

CSA is a method that involves location-specific analyses to identify viable agricultural production technology and practices to solve the complex, interconnected concerns of food security, development, and climate change [23, 25]. Moreover, past research concentrated on factors influencing specific CSA practices. However, there is no studies conducted regarding adoption and adoption determinants of CSA practices in the study area so far. Thus, understanding the adaptive potential of the farm community, the reaction of institutions, and the integration of the method into research and development are important for facilitating the adoption of CSA practices. As a result, the primary goal of this study was to investigate whether farmers were adopting numerous climate-smart agriculture practices, synergy across practices, and adoption drivers.

2. Potential Benefits of CSA Practices

Climate-smart agriculture has recently arisen as a reaction to the need for agricultural system that encourage climate change mitigation and adaptation efforts while improving food security [24, 26]. It promotes production and incomes while preserving degrading forests, adapting to climate change, and lowering GHG emissions in situations where possible [27]. Site-specific CSA practices benefit users while safeguarding natural resources.

Study done in Uganda by [28], indicated that compared to the control treatment, CSA practices considerably enhanced total water storage of the soil by 1-12%. This encourages and supports CSA practices adoption in the area where soil erosion and vegetation loss have reduced food output. Sustainable land management is crucial for preventing land degradation, rehabilitating damaged areas, and ensuring that natural resources are used wisely for current and future generations.

Climate-smart agriculture practices are location-specific in the sense that they would be effective if executed in accordance with the field's specific requirements; as a result, there are different practices that are believed climate smart. Terrace is a region that has been flattened out on the edge of a hill just for producing crops. It minimize the amount and velocity of water traveling across the soil surface, which dramatically reduces soil erosion. Terracing changes steep slopes into a man-made sequence of relatively flat surfaces and thereby minimizing slope length and gradient, which reduces sediment yield and runoff [29]. Terracing allows for more intensive cropping than would otherwise be possible.

Crop diversification, mainly, drought-tolerant have a potential to withstand the effect of a rise in temperature that could probably affect soil moisture level and crop yields. Drought-tolerant varieties were thought to have a higher densely rooted that level depth in the soil profile, to get and extract soil water [30]. Consequently, this makes it easier for plants to get water even in dry conditions, which together with the other factors could raises crop yields.

Weather has a significant impact on yield, growth, and development of agriculture as well as on the prevalence of diseases and pests, the need for fertilizer, and water, and even the quality of produce at the time of transportation services, the viability and vigor of planting material and seeds during storage [31]. Access to weather information, such as temperature and rainfall, aids farmers in planning what to sow when and where.

The promotion of afforestation and replanting as essential climate change mitigation strategies. Because trees absorb atmospheric carbon dioxide (CO_2) through photosynthesis and store it for a long period. Forests and trees safeguard watersheds, support the resilience of farming systems and habitations, support temperature regulation, support the provision of water and shade, protect coastal regions from storms and help regulate climate at the regional and continental scales [32]. In addition to these benefits, forests play a major role in improving soil organic matter and preventing soil erosion.

3. Materials and Methods

3.1. Study Sites

This study was conducted in Welmera district. Welmera district is located in west shewa Zone of Oromia region, Ethiopia at a distance of 29 kilometres from Addis Ababa on the main route to Ambo. It is bounded on the south, west, north, northeast, and east by Sebeta Hawas district, Ejere district, Mulo district, Sululta, and Addis Ababa, respectively. It has a total surface area of around 80,927 hectares, 37411 hectares of which are agricultural or under agriculture. The district's elevation spans from 2060 to 3380 meters above sea level. The district lies between 8^0 50' to 9^0 15' N latitude and $38^0$25' to 39^0 45' E longitude. There are 104,143 people in total, with 52,403 men and 51,740 women living in the district.

The district has two agro-ecological zones: highland and midland. Highland regions make up 61% of the total, with the midlands representing 39%. The mean annual rainfall lies between 834 mm and 1300 mm, and the annual temperature lies between 0°C to 27°C. In terms of soil type, red soil (60%), black soil (37%), and mixed soil (3%). The agriculture system mainly depend on rain, thus, their production system is climate-dependent. Erosion is a major issue in several regions of the district. As a result, it is critical to appreciate the adoption of climate-smart agriculture as well as the challenges that smallholder farmers encounter while employing the approaches.

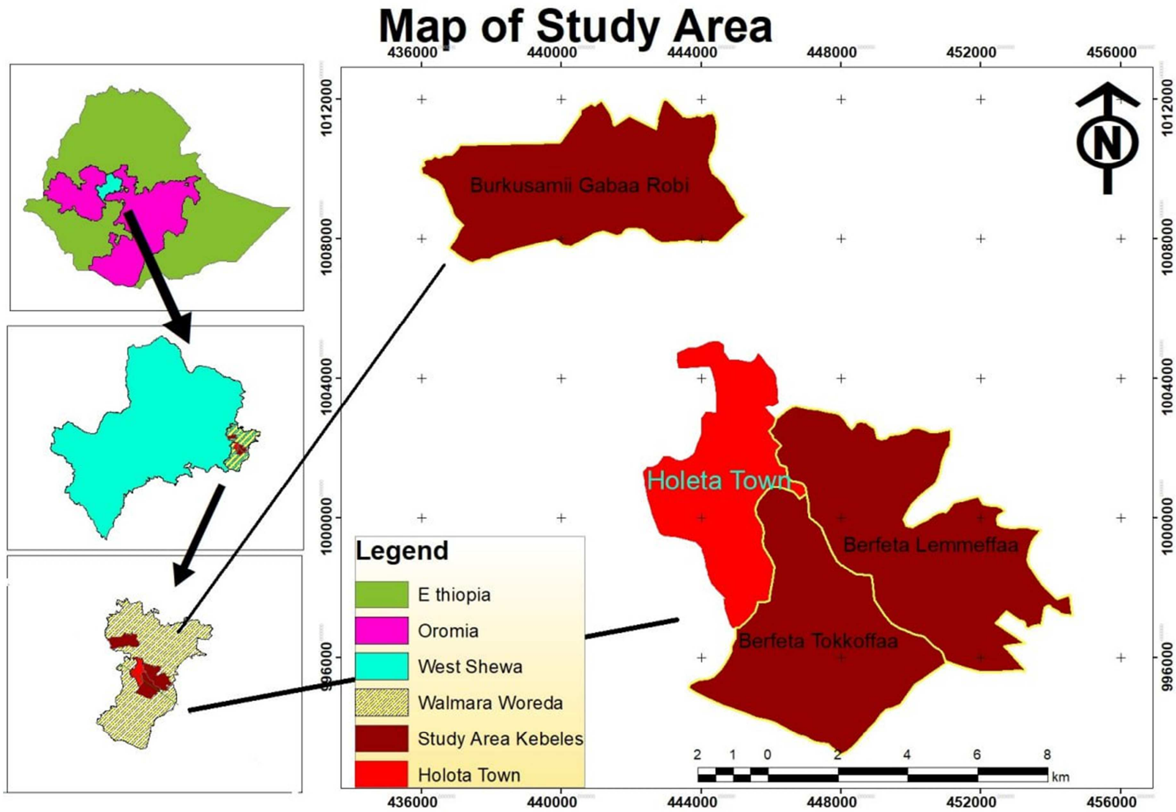


Figure 1. *Map of the research area.*

3.2. Sampling and Data Collection

This study employed multistage sampling methods. During district and Kebele (the smallest administrative unit) selection, targeted sampling procedures were applied. The district was chosen since it is one of the potential areas for crop and livestock production in the Zone to see adoption status of CSA practices. The study involves three kebele selections purposively, which have a potential agriculture production. Finally, respondents were picked at random from all designated kebeles. A well-organized questionnaire was developed and used to collect data from a total of 306 respondents. The study data was collected on main variables including demographic factors, economic factors (including; land holding, livestock holding, farm income and access to credit services), and institutional factors including access to agricultural extension services and farmers field day participation. Additionally, farmers adoption of different types of CSA practices are among the information collected from the respondents.

To provide a representative sample, the sample size was determined using [33] sample size formula.

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

Where

n= sample size, N=population understudy, e=error term

The total farm households of the three kebeles are 1308/ sampling frame/ households. Based on the above formula the total sample size was 306 households.

3.3. Data Sources and Collection Tools

Two types of data sources were used. Primary data from respondent farmer, key informant and focuss group discussion. Structured questionnaire for qualitative and quantitative data from respondent farmers and checklist for qualitative data from key informant and focus group discussion were used. Respondent farmers were individual farmers including model farmers in the area, women headed household with different age groups. Key informant were men headed household, women-headed households, district experts and development agents. Focus group discussion was held with farmers composed men headed household and women-headed households to better comprehend the adoption of CSA practices, as well as people's perceptions about climate change and its effect, and their responses to the climate change. Secondary data was acquired through desk reviews of published and unpublished materials. It includes peer-reviewed journals, books, work reports, conference papers and dissertations.

3.4. Descriptive Statistics

Quantitative data collected by structured questionnaire were analyzed using descriptive statistics and econometric methods. Descriptive statistics includes frequency distribution, percentage, mean and standard deviation. Multivariate probit model, which is an econometric model, was used for analysis of the relationship between dependent and independent variables. Qualitative data collected by a methods of focus group discussion and key informant interview were analyzed using thematic content analysis.

3.5. Econometric Model and Data Analysis

Adoptions of multiple CSA practices are correlated [34-37]. The link of correlation is caused by either technology complementarity or practice substitutability. As a result, the multivariate probit model, a generalization of the probit model, is employed to estimate several correlated associated binary outcomes jointly.

One farmer decides implement the Kth climate smart agriculture (CSA) practices if

$$Y^*_{kj} = U^*_k - U_0 > 0.$$

Where U_k represents a benefit from one of the CSA practices and U_0 represents a benefit from traditional/unimproved methods.

The farmer's net gain (Y*kj) from Kth CSA practice is a latent variable influenced by observed sociodemographic, institutional economic factors, and climate change perception level (Xkj) as well as unobserved attributes (Ukj).

$$Y^*_{kj} = \beta_k x'_{kj} + U_{kj}, \text{ where } (k = CA, ISF, SSI, AF, CD, ILF, IWI, PH) \quad (1)$$

Transform the unobserved preference in the preceding equation (equation 1) into the observed binary outcome formula for each CSA practice option as follows.

$$Y_{kj} = \begin{cases} 1 \; if \; Y^*_{kj} > 0 \\ 0 \; otherwise \end{cases} (k = CA, ISF, SSI, AF, CD, ILF, IWI, PH) \quad (2)$$

Where CA to mean conservation agriculture, ISF to mean improved soil fertility management, SSI to mean small-scale irrigation, AF to mean agroforestry, CD to mean crop diversification, ILF to mean improved livestock feed and feeding, IWI to mean improved weather information, and PH to mean post-harvest technology.

k=1, 2, 3, ……m indicates the types of CSA practices, and j=1….n implies sample size.

The assumption in Equation (1) is that a rational jth farmer possesses a latent variable Y*kj that captures the unobserved attributes connected with the kth CSA practice choice. This latent variable is believed to be a linear combination of observed attributes x′kj, factors influencing CSA practice adoption, and unobserved qualities reflected by the stochastic error term Ukj. βk is the vector of parameters to be estimated in this model. Given the latent character of Y*kj, the estimations depend on observable binary discrete variables Ykj that indicate whether or not a farmer implements a specific CSA practice on his/her farmland or plot p. If a farmer's choice to implement one CSA practice is not influenced by other practices, and if error terms are normally distributed, equations (1) and (2) indicate univariate probit models in which information on a farmer's acceptance of one CSA practice does not affect the prediction of the probability that they will adopt another CSA practice. When many CSA practices can be adopted, a more realistic specification is to presuppose that the error terms in equation (1) jointly follow a multivariate normal (MVN) distribution, with zero conditional mean and variance normalized to unity, $U_{kj} \sim MVN(0, \Omega)$. This means that in the multivariate model, when several practices can be adopted, the error terms jointly follow a multivariate normal distribution with zero conditional mean and variance normalized to unity, assuming the CSA practices are CA, ISF, SSI, AF, CD, ILF, IWI AND PH, then $(\mu_{CA}, \mu_{ISF}, \mu_{SSI}, \mu_{AF}, \mu_{CD}, \mu_{ILF}, \mu_{IWI}, \mu_{PH}) \sim MVP(0, \Omega)$ and the symmetric [8×8] covariance matrix Ω is given:

$$\Omega = \begin{bmatrix} 1 & PCAISF & PCASSI & PCAAF & PCACD & PCAILF & PCAIWI & PCAPH \\ PISFCA & 1 & PISFSSI & PISFAF & PISFCD & PISFILF & PISFIWI & PISFPH \\ PSSICA & PSSIISF & 1 & PSSIAF & PSSICD & PSSIILF & PSSIIWI & PSSIPH \\ PAFCA & PAFISF & PAFSSI & 1 & PAFCD & PAFILF & PAFIWI & PAFPH \\ PCDCA & PCDISF & PCDSSI & PCDAF & 1 & PCDILF & PCDIWI & PCDPH \\ PILFCA & PILFISF & PILFSSI & PILFAF & PILFCD & 1 & PILFIWI & PILFPH \\ PIWICA & PIWIISF & PIWISSI & PIWIAF & PIWICD & PIWIILF & 1 & PIWIPH \\ PPHCA & PPHISF & PPHSSI & PPHAF & PPHCD & PPHILF & PPHIWI & 1 \end{bmatrix}$$

The coefficient pairwise correlation of the error terms of any two of the estimated adoption equation of CSA practices in the model represented by *p*.

4. Results and Discussion

4.1. Farmers Profile

Collected data was analyzed using descriptive statistics for the mean divergence of explanatory variables among adopters and non-adopters of specified CSA practices in the study area. Table 1 depicts Gender, age, levels of education, family size, farming system, farmland size, livestock holding (TLU), farm income, access to credit, access to agricultural extension services and training, access to field day participation, and climate change perception level. From all randomly chosen samples HHs, approximately 15.4% were female-headed HHs and 84.6% were male-headed HHs. The farmers' lowest and highest age are 25 and 82 years, respectively, with a mean age of 47 years. The mean family size of the respondents are 5.9, whereas, the mean land size is 1.77ha. Approximately 34.3% of respondents have access to financial services; approximately 46.1% and 35.6% have access to agricultural extension & training and field day participation, respectively.

Table 1. *Description of the study variables.*

Variables	Description	Mean	Std. Dev.
Independent Variables			
Sex	Dummy=1 if farmers sex is male, 0 otherwise	0.846	0.361
Age	Age in years	47.5	11.6
Education	unable to read& write=1, grade 1-4=2, grade 5-8=3, grade 9-12=4, >grade 12=5	2.297	0.941
Perception level	1=very low, 2=low, 3=medium, 4=High and 5=very high	3.892	0.912
Family size	Family members in Number	5.9	1.97
Farm land size	Land size in hectare	1.77	0.90
Farming system	only crop=1, only livestock=2, Both=3	2.961	0.278
Farm income	Households Farm income Birr in thousand	23.83	19.53
Access to credit service	Dummy=1 if farmers access to credit, 0 otherwise	0.343	0.476
Livestock holding	Livestock holding in TLU	5.542	2.492
Access to Agri. Ext. services & agri. training	Dummy=1 if farmers access to agri.ext. and training, 0 otherwise	0.461	0.499
Farmers field day participation	Dummy=1 if farmers access to field day participation, 0 otherwise	0.356	0.480
Dependent Variables			
Conservation Agriculture	Dummy=1 if farmers adopt the practice, 0 otherwise	0.418	0.494
Improved soil fertility	Dummy=1 if farmers adopt the practice, 0 otherwise	0.588	0.488
Small scale irrigation	Dummy=1 if farmers adopt the practice, 0 otherwise	0.382	0.487
Agroforestry	Dummy=1 if farmers adopt the practice, 0 otherwise	0.333	0.472
Improved crop varieties/crop diversification/	Dummy=1 if farmers adopt the practice, 0 otherwise	0.516	0.501
Improved Livestock feed and feeding	Dummy=1 if farmers adopt the practice, 0 otherwise	0.363	0.482
Improved weather information	Dummy=1 if farmers adopt the practice, 0 otherwise	0.353	0.479
Postharvest technology	Dummy=1 if farmers adopt the practice, 0 otherwise	0.386	0.488

The mean family's earnings or income in thousand birr is 23.8 birr. The mean household's livestock holdings is 5.54 (TLU).

4.2. Types of CSA Practices Implementing in the Study Area

Climate change is influencing production and productivity negatively. According to the survey data, FGD (Focus group discussion) and KII (key informant interview), farmers believed that the rise in temperature and the late onset of the main rainy season were indicators of climate change. Soil erosion, hailstorms, late onset, high temperatures, and frost are the main incidences reported by respondents in the study area. These incidences are affecting agricultural production and productivity, both directly and indirectly. In order to lessen the effects of climate change, in the study area, farmers are implementing different CSA practices including those which have a potential to improve soil fertility including vermin compost. Based on different negative effect of climate change, farmers are implementing various coping strategies [12, 38, 24]. Adoption of practices such as nitrogen-efficient and heat-tolerant or resistance crop varieties, zero-tillage or minimum tillage, and integrated soil fertility management [39, 40], would improve productivity and farmers' incomes and help lower food prices.

Adoption of CSA practices is likely vary from place to place due to the diversity of agro ecology and agricultural practices in Ethiopia. CSA practices that have the potential to minimize climate change effects include zero tillage (minimum tillage) and integrated soil fertility management [41]. A study by [42] proves that agroforestry, soil and water management, crop management, and livestock management practices are among the most commonly practiced CSA practices.

The analysis result reveals that adoption rate of CSA practices in the study area is low. Conservation agriculture, integrated soil fertility management, high yielding, disease resistance, and drought tolerance, short-season crop varieties (crop diversification) adopters' percentage indicate 42.5%, 61%, and 52%, respectively, while the other practices were adopted by less than 40% of respondents. The result shows, adoption rate of different CSA practices identified in the study area remains low.

The farmers are assuming adopters of the practices for example conservation agriculture if the farmers adopt at list one of the component of the practice for example bund or reduced tillage or crop residue or crop rotation.

Table 2. *CSA practices implementing by farmers in the study area.*

CSA practices	Kebeles						Total % N=306	
	Berfeta lemefa n=66		B/ Gaba Robi n=105		Berfeta Tokkofa n=135			
	Adopters	Non adopter	Adopters	Non adopter	Adopters	Non adopter	Adopter	Non Adopter
Conservation Agriculture	36.4	63.6	54.3	45.7	32.6	67.4	42.5	57.5
Integrated soil fertility management (Different types of compost, efficient fertilizer application)	78.8	21.2	75.2	24.8	43.7	56.3	61	39
Small Scale Irrigation	54.5	45.5	23.8	76.2	20.7	79.3	38	62
Agroforestry	18.2	81.8	20	80	16.3	83.7	38	62
Crop diversification (high yielding, disease resistance and short season improved varieties)	60.6	39.4	72.4	27.6	31.1	68.9	51.6	48.4
Improved Livestock feed and feeding practices	16.7	83.3	44.8	55.2	29.6	70.4	39	61
Improved weather information system	48.5	515	34.3	65.7	37.8	62.2	38.9	61.1
Post-Harvest technology	18.2	81.8	42.8	57.1	33.3	66.7	38.6	61.4

4.3. Interdependency of Adopted CSA Practices

CSA practices implementing in the study area which believed important for natural resource conservation and believed important for sustainable agriculture include; conservation agriculture.

Table 3. *Covariance of correlation matrix of CSA practices.*

CSA practices relation ship	Corr. Coef.
Improved soil fertility Management and Conservation Agriculture	0.335*** (0.074)
Small Scale Irrigation and Conservation Agriculture	-0.056 (0.080)
Agroforestry and Conservation Agriculture	-0.043 (0.080)
Crop diversification and Conservation Agriculture	0.204** (0.086)
Improved Livestock feed& feeding and Conservation Agriculture	0.192** (0.085)
Improved weather information and Conservation Agriculture	-0.047 (0.076)
Post-harvest technology and Conservation Agriculture	0.898*** (0.023)
Small scale irrigation and Improved soil fertility	-0.110 (0.079)
Agroforestry and Improved soil fertility	0.046 (0.078)
Crop diversification and Improved soil fertility	0.221** (0.084)
Improved livestock feed & feeding and Improved soil fertility	0.219** (0.087)
Improved weather information and Improved soil fertility	0.051 (0.077)
Post-harvest technology and Improved soil fertility	0.398*** (0.087)
Agroforestry and small scale irrigation	0.367*** (0.062)
Crop diversification and small scale irrigation	-0.036 (0.082)
Improved livestock feed & feeding and small scale irrigation	0.006 (0.088)
Improved weather information and small scale irrigation	0.081 (0.069)
Post-harvest technology and small scale irrigation	0.018 (0.089)
Crop diversification and Agroforestry	-0.103 (0.085)
Improved livestock feed & feeding and Agroforestry	-0.021 (0.093)
Improved weather information Agroforestry	0.067 (0.075)
Postharvest technology and Agroforestry	0.022 (0.095)
Improved livestock feed & feeding Crop diversification	0.102 (0.099)
Improved weather information and Crop diversification	0.111 (0.081)
Post-harvest technology and Crop diversification	0.210** (0.096)
Improved weather information and Improved livestock feed &feeding	-0.061 (0.082)
Post-harvest technology and Improved livestock feed& feeding	0.351*** (0.097)
Post-harvest technology and Improved weather information	-0.074 (0.090)

Integrated soil fertility management, small-scale irrigation, agroforestry practice, crop diversification, improved livestock feed and feeding, improved weather information, and post-harvest technologies.

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho81 = rho32 = rho42 = rho52 = rho62 = rho72 = rho82 = rho43 = rho53 = rho63 = rho73 = rho83 = rho54 = rho64 = rho74 = rho84 = rho65 = rho75 = rho85 = rho76 = rho86 = rho87 = 0: chi2 (28) = 251.988 Prob > chi2 = 0.0000 Stand.er. in parenthesis ***p<0.01, **p<0.05, *p<0.1.

The result of correlation coefficient error components from MVP model estimation of eight CSA practices revealed that correlation coefficients are jointly significant. This supports the rejection of the null hypothesis, which holds that there is no correlation or significant relationship among the error terms in any of the eight equations. Table 2 depicts farmers' are adopting different CSA practices simultaneously. This perhaps due to either practice complementarity or practice substitutability. Furthermore, it suggests that those behaviors are mutually beneficial. The result is in line with the findings of [34-37].

4.4. Adoption Determinants of Climate Smart Agriculture Practices

A multivariate probit model was used to investigate factors that influence the adoption of climate-smart agriculture practices. Institutional, socioeconomic, and demographic factors are identified explanatory variables in the analysis result. Response variables are conservation practices, management of improved soil fertility, small-scale irrigation, agroforestry practices, crop diversification, improved livestock feed & feeding, improved weather information, and post-harvest technology. The value of the response variables are assumed to be 1 if the practice is used by farmers and 0 otherwise. The coefficient result from multivariate probit indicated in Table 4 below. The following are independent variables; household head sex, age, family size, education level, climate change perception, farm size, livestock holding (TLU), farm income, household farming system, access to credit service, availability of agricultural extension & agricultural training services and farmer field day participation.

4.4.1. Demographic Factors

Sex

Cultivating improved crop varieties that are site and agro ecological specific, including drought and disease resistance, high yielding crop varieties is advisable when climate change is affecting production and productivity in order to combat the devastating effects of climate change on agriculture. The study shows that being male as compared to female significantly (p<0.01) increased the likelihood of adoption of improved crop varieties.

Livestock production is one of the agriculture sector that contributes to greenhouse gas emissions, notably methane gas, hence working on improvements of livestock feed and breed are therefore essential in this case. Being male as compared to female significantly (p<0.1) increased the likelihood of adoption of improved livestock feed and feeding practice.

Age

The level of soil fertility is one of the determining factors that might alter the output per plot of land in agriculture [43, 44]. This is why many farmers add fertilizer to their farmland. However, if farmland is not maintained properly, soil fertility level probably decreased possibly because of climate change and inappropriate use. In this study, the result indicated household head age significantly (p<0.05) and negatively influenced the likelihood of improved soil fertility practice adoption. This implies that young individuals are more motivated than older people to adopt improved soil fertility practice. One argument is that older people may find it more difficult to apply enhanced soil fertility methods including applying compost and manure. Likewise the age of household significantly (p<0.05) and negatively affecting crop diversification. This result is in line with the findings of [34].

Age of household head is positively and significantly (p<0.05) influenced the adoption of agroforestry practice. This result is in line with [37], which indicated age is significantly and positively impacted adoption of agroforestry practice.

Education level

The effects of climate change can be tempered with the use of agroforestry techniques like tree-based conservation agriculture. Plants and trees can reduce erosion. The study result shows education level of household heads significantly (p<0.1) and positively affecting adoption of agroforestry practice. The result is in agreement with [37].

Climate change Perception

In this study, it was hypothesized that farmers attitude towards the existence of climate change will significantly and favorably influence the adoption of CSA. It has significantly (p<0.05) increased improved weather information adoption. This suggests that as farmers awareness of climate change grows, so does the willingness to accept and make use of better weather information.

4.4.2. Economic Factors

Land holding (Farm Land size)

Households farm land size significantly (p<0.01) increased implementation of agroforestry practices. The findings are in line with [36], who found that adoption of minimum tillage (a conservation agriculture technique) was substantially and favorably influenced by total land holding and [35], who found that adoption of conservation tillage significantly and positively influenced by land size.

Management of improved soil fertility practice is significantly (P<0.01) and positively affected by size of farmland. Likewise, crop diversification significantly and positively influenced by land holding size. This could imply that farmers with larger farms are more likely than farmers with smaller farms to allocate farmland to various improved crop varieties.

The size of a household's land holding has a substantial (p<0.01) favorable impact on improved livestock feed and feeding practices. This indicates that compared to households with relatively small land holdings, families with comparatively greater farmland holdings are more likely to adopt improved livestock feed and different forages for livestock feed. Post-harvest technologies are actions done to preserve, protect, or process a commodity after it has been harvested. Post-harvest technology has been key to maintaining and extending the shelf-life of perishables and reducing food losses [45]. According to the study's findings, the size of the land holding significantly ($p<0.01$) increases the likelihood that post-harvest technical practices would be adopted.

Farm income

Farmers use their farm income to cover household expenses, and has a significant ($P<0.01$) and favorable impact on the adoption of improved livestock feed and feeding practices. This demonstrated that as their wealth increases, farmers are more likely to adopt better livestock feeding practices.

Access to credit service

The results showed that farmers who have access to credit services that help solve their financial deficit are more likely to adopt agroforestry practices than farmers who do not. The possible explanation may be that agroforestry practices require getting different young plants of trees that have multiple advantages both for conserving the soil and for producing fruit, but many people are lacking financial resources. The outcome further demonstrated that access to financial services had a substantial ($p<0.05$) favorable effect on improved crop adoption. The reason could be that enhanced crop seed and the inputs that go with it need money, which not all smallholder farmers always have on hand. Therefore, having access to financial services may aid farmers in filling this gap.

Table 4. *Adoption determinants of CSA practices.*

Variables	Conservation Agriculture	Improved soil fertility	Small scale irrigation	Agroforestry practices	Improved crop/Crop diversification	Improved Livestock feed and feeding	Improved weather information	Post-harvest technology
Sex	0.035 (0.277)	0.154 (0.226)	-0.018 (0.235)	-0.141 (0.226)	0.887*** (0.273)	0.553* (0.311)	-0.156 (0.222)	0.27 (0.252)
Age	-0.206 (0.155)	-0.264** (0.125)	0.152 (0.118)	0.282** (0.119)	-0.316** (0.140)	-0.018 (0.130)	0.149 (0.119)	-0.180 (0.123)
Education Level	-0.155 (0.135)	-0.083 (0.108)	0.057 (0.109)	0.208* (0.107)	-0.273 (0.133)	0.121 (0.122)	0.010 (0.107)	-0.19 (0.111)
CC Perception level	-0.043 (0.194)	0.084 (0.147)	0.027 (0.143)	0.0014 (0.143)	0.192 (0.167)	0.267 (0.174)	0.36** (0.144)	0.005 (0.167)
Family size	-0.038 (0.266)	0.049 (0.206)	-0.094 (0.207)	0.064 (0.206)	-0.028 (0.23)	-0.001 (0.260)	0.103 (0.200)	-0.056 (0.254)
Farm land size	1.919*** (0.234)	0.578*** (0.162)	0.221 (0.154)	-0.064 (0.153)	0.840*** (0.18)	1.120*** (0.204)	-0.080 (0.151)	1.611*** (0.193)
Farming system	-0.167 (0.364)	0.389 (0.296)	-2.383 (50.206)	-0.278 (0.348)	0.174 (0.319)	1.916 (74.25)	-0.021 (0.299)	-0.39 (0.283)
Farm income	-0.0052 (0.0057)	-0.0009 (0.004)	0.00062 (0.0049)	0.0011 (0.005)	-0.0021 (0.005)	0.034*** (0.0061)	0.005 (0.0045)	-0.009 (0.005)
Access to credit	0.158 (0.235)	-0.253 (0.186)	0.221 (0.176)	0.417** (0.175)	0.67** (0.215)	-0.018 (0.218)	-0.046 (0.179)	0.43** (0.213)
Livestock Holding (TLU)	0.121** (0.047)	0.004 (0.038)	-0.147*** (0.040)	-0.073* (0.038)	-0.016 (0.041)	-0.072 (0.044)	0.014 (0.037)	0.13 (0.040)
Access to Agri. Ext. services & agri. training	-0.029 (0.292)	-0.037 (0.230)	-0.0221 (0.235)	-0.367 (0.237)	1.212*** (0.258)	-0.241 (0.29)	0.067 (0.225)	0.0755 (0.248)
Field day Participation	0.504* (0.265)	0.664*** (0.128)	0.256 (0.123)	0.24 (0.23)	0.405 (0.236)	-0.146 (0.254)	-0.263 (0.213)	0.296 (0.134)
Cont.	-2.517 (1.256)	-1.429 (1.056)	6.497 (150.62)	0.449 (1.192)	-2.64 (1.146)	-10.79 (222.7)	0.67 (1.07)	-2.00 (1.043)

Log likelihood = -1144.4475, Wald chi2 (112) = 385.56, Prob > chi2 = 0.0000
Stand.er. in parenthesis ***p<0.01, **p<0.05, *p<0.1

Similarly, access to finance services was significantly and favorably ($p<0.05$) correlated with post-harvest technology usage. This suggests that farmers who have access to finance services are more likely than farmers who do not to embrace post-harvest technology.

Livestock holding (TLU)

Livestock is a vital resource that helps smallholder farmers in rural areas in a variety of ways, including as a source of income and the usage of animal products for domestic consumption. The results demonstrate that the size of the livestock holding, which is one of the farmers' source of income, significantly and favorably ($P<0.05$) influencing adoption of conservation agriculture. The finding is consistent with research from [46] and [36], which demonstrates that a larger livestock holding boosts the likelihood that soil and water conservation practices will be used. The likelihood that a small-scale irrigation practice would be adopted, on the other hand, was significantly and negatively impacted ($P<0.01$) by livestock ownership. The outcome is consistent with [47] study findings that shows small-scale irrigation and cattle could contend for water. Similarly, we discovered a large and unfavorable impact of livestock holding on the adoption of agroforestry practices.

4.4.3. Institutional Factors

Access to Agriculture extension services& trainings

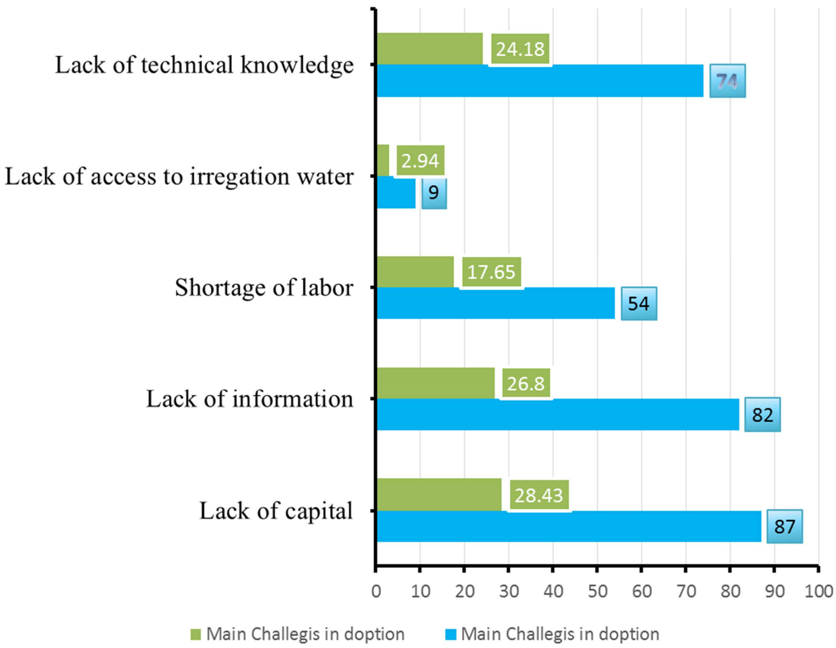
Farmers can obtain various agricultural information through agriculture extension services and trainings, and these services and trainings have a positive and significant ($p < 0.01$) influence on the adoption of crop diversification. The research's findings concur with those of [37, 34] result.

Farmers' field day participation

Field days are a characteristic part of the farmer's field school approach, which happens at the end following trainings and helps to share information with a bigger group of farmers by explaining demonstrations. This strategy is used in more than 90 countries [48]. The findings of the study showed that participation in farmers' field days significantly and favorably ($p < 0.1$) influence the adoption of conservation agriculture techniques. According to this, farmers who have access to field day activities are more likely to adopt agroforestry practices than farmers who do not. Similar to this, farmers are more likely to use soil fertility practices if they have access to field days.

4.5. Climate Smart Agriculture Adoption Barriers

Farmers that responded to the study stated that a variety of obstacles made it difficult to embrace CSA practices. The main obstacles to adopting climate wise agriculture methods as reported by farmers in the research area are shown in Figure 2. The principal barriers to the adoption of CSA methods were a lack of technical expertise, access to irrigation water, labor shortages, particularly for laborious practices, lack of complete information, and lack of financial resources.



Source: Survey data (May, 2022)

Figure 2. *CSA adoption barriers.*

According to a study by [46] conducted in the East Hararghe Zone, farmers encounter a variety of difficulties that prohibit them from putting climate change adaptation measures into reality, and these difficulties include limited access of agricultural information and a lack of financial resources. Information access is one of the barriers preventing the implementation of CSA practices in this study as well. Different CSA practices have varying degrees of relevance, even though the overall goal is to mitigate the effects of climate change; therefore, farmers must be skilled and knowledgeable about the practices that are important to them.

5. Conclusion and Policy Implication

It is vital for long-term agricultural production to reduce the negative impact of climate change on agriculture as well as the negative impact of agriculture on climate. As a result, CSA practices are seen to be critical in mitigating the negative effects of climate change on agriculture. However, the adoption of several CSA techniques in Ethiopia remains limited.

The goal of this study is to examine CSA practices being implemented in the study area and to find determinants of adoption of those practices. The result indicated that Conservation agriculture, integrated soil fertility management, small-scale irrigation, agroforestry practices, crop diversification, improved livestock feed and feeding, improved weather information, and post-harvest technologies are some of the CSA techniques that farmers in the study area have been found to use. There might be a justification for why some CSA practices are implementing by farmers in the research area. The area may be suffering repercussions as a result of climate change, which is one explanation.

The results of the study shows male farmers were significantly more likely than female farmers to adopt crop diversification and improved livestock feed and feeding practices. Farmers' advancing age has a considerable detrimental impact on their likelihood of implementing improved soil fertility management techniques and crop diversification. However, it has a beneficial and considerable impact on the adoption of agroforestry practices. A comparatively large farmland size enhances the adoption of conservation agriculture, improved soil fertility management, crop diversification, enhanced livestock feed and feeding practices, and postharvest technology practice, according to the economic factors' results. Higher farm revenue increases the possibility of adopting improved livestock feed and feeding. Having a significant number of animals strongly promotes conservation agriculture adoption, and having access to financing services positively influences agroforestry, crop diversification, and postharvest technology implementation. We again found that positive and significant effect of climate change perception level on adoption of improved weather information. In addition, institutional factors result indicated access to agricultural extension service and training positively influences the adoption of crop diversification, access to participation on farmers' field day similarly positively influence the adoption of both conservation agriculture and improved soil fertility management practice.

Agricultural extension services are significantly important for increasing public understanding of agricultural developments and have a significant contribution for dissemination of improved agricultural technologies. Since this is an essential element, policy makers and other concerned bodies should pay close attention to the field of factors influencing the agricultural extension and training system. Along with this, in order to mitigate the detrimental effects of climate change on agriculture, it is also imperative to work on ways to hasten the adoption of site-specific CSA practices.

Furthermore, to determine the magnitude of adoption and the economic impact of CSA practices in the studied areas, more research is advised.

Data Availability

The corresponding author will provide data upon reasonable request that backs up the study's conclusions.

Authors Contribution

Proposal design, data collection with enumerators, data anlysis, paper writing by corresponding Author. Data collection, supervision, editing by Co'Author.

This Article is part of the Corresponding Author's thesis work entitled; Climate Change Perception, Adoption And Determinants Of Climate Smart Agriculture Practices In Response To Climate Variability: The Case Of Welmera Woreda, Oromia, Ethiopia.

ORCID

Mesay Hailu: 0000-0002-4854-5371.
Esubalew Abate: 0000-0003-4765-1129.

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Conflicts of Interest

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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