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Factors influencing small holder farmers adoption of climate SMART agriculture practices in Welmera Woreda, Central Ethiopia

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Adoption of climate-smart agriculture practices are believed to have significantly lessened the devastating impact of climate change on agriculture. However, in countries like Ethiopia, the adoption and use level of climate-smart agriculture practices remains low. The understanding of farmers' levels of CSA practice adoption and influencing factors is therefore crucial. The goal of the study is to evaluate the degree to which various CSA practices were being used in the study area, as well as adoption determinants. The study was conducted in Welmera district, Oromia, Ethiopia. Three kebeles were chosen from the district, and a random sample of 306 farmers was picked. We used a cross-sectional household survey, a focus group discussion, and interviews with key informants. A multivariate probit model was employed to investigate the factors influencing the 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 male farmers outperformed female farmers in terms of crop diversity and improved animal feed and feeding practice adoption. The age of farmers has a considerable and unfavorable impact on their likelihood of adopting improved soil fertility management and crop diversification practices. However, it has a positive and considerable impact on the adoption of agroforestry practices. With regards to economic factors, having a relatively big farmland area considerably enhances the adoption of conservation agriculture, enhances soil fertility management and crop diversity, and improves livestock feed and feeding methods and post-harvest technology practice. Improved livestock feed and feeding are more likely to be used with higher farm income. Having a significant number of animals strongly promotes the adoption of conservation agriculture, and access to financial services positively impacts agroforestry, diversification of crops, and postharvest technology practice adoption. Furthermore, institutional factors including access to agricultural extension services and training were discovered to be 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

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 agricultural sector (OECD, 2016; Malhi et al., 2021). Climate change lessens the potential of the natural resources to provide its services and will affect the agricultural sector. Climate change has a wide range of adverse effects on agriculture [International Food Policy Research Institute (IFPRI), 2009; Arora, 2019; Holleman et al., 2020; Ahmad et al., 2022]. Erosion, crop health issues, diseases of livestock, and high temperatures for crop development are just a few of the warning signals.

Climate changes have a considerable impact on agricultural outputs in Africa, particularly Ethiopia (Mekonnen et al., 2021; Rahel et al., 2021). Ethiopian agriculture is predominantly rain-fed, making it vulnerable to variations in precipitation (Conway et al., 2011). This implies that food production may cease to be a viable method of livelihood with an inadequate amount or distribution of precipitation over successive growing periods. As a consequence, the dramatic decrease in agricultural productivity is likely to lead to food insecurity.

Climate change and adjacent affairs such as irregular rainfall distribution, severe drought, and degradation of land severely limit the social and economic progress in Ethiopia (Zeray and Demie, 2015; Jirata et al., 2016; Singh et al., 2016; Yalew et al., 2017). Droughts occur regularly in Ethiopia (Mera, 2018), causing food scarcity and affecting a large number of people (Asaminew and Jie, 2019). For example, according to the International Center for Tropical Agriculture (CIAT); BFS/USAID (2017), the droughts of 1984 and 2003, which affected 7.5 and 12.6 million people, respectively, had a significant impact on agricultural livelihoods. In addition, the El Nino event in 2015/16 caused Ethiopia to suffer one of the most severe droughts in decades, with an estimated 10.2 million individuals in need of food aid (CIAT; BFS/USAID, 2017).

To alleviate the mistrust of climate change effects on agriculture, we focused on the creation of means and methods for sustaining agricultural production in Sub-Saharan Africa (SSA) by encouraging small-holder farmers to use climate-smart agriculture (CSA) practices (Branca et al., 2013). CSA 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 (FAO, 2013; Tekeste et al., 2022; Belay et al., 2023).

It has been accepted that implementing CSA practices is the most effective way to lessen the adverse effects of climate change (FAO, 2016; Belay et al., 2023). In Ethiopia, a variety of agricultural development initiatives—both traditional and cutting-edge—are implemented to improve livelihoods and food security. These initiatives are also seen as essential for tackling climate change concerns and aiding in its adaptation and mitigation (Jirata et al., 2016). However, the adoption of CSA practices remains low in developing countries, including Ethiopia (Mazhar et al., 2021). Even though there is evidence in many places about factors that influence the decisions of smallholder farmers to adopt CSA methods, there is a dearth of information about the determinants of the adoption of CSA practices in the study area. The adoption of multiple CSA practices by farmers, as well as the intensity of adoption, is significantly influenced by the age of the household head, education, land size, household total asset value, frequency of extension contacts, farmer awareness of climate change, farmer experience with climatic shocks, parcel fertility, slope, and severity of soil erosion (Mebratu et al., 2022). Similarly, Bamlaku and Abera (2022) found that education, HH size, income, climate change perception, and farmland size all had statistically significant effects on farmers' decision to adopt CSA methods.

In order to effectively implement CSA in Ethiopia and recover maximum benefits, it is imperative to uncover the determinants of the CSA adoption process, understanding the adaptive potential of the farmer community, the reaction of institutions, and the integration of CSA into research and development, which are important for facilitating the adoption of CSA practices. Therefore, identifying CSA practices for implementation in the study area and investigating the factors influencing CSA practice adoption were the objectives of the study.

2 Potential benefits of CSA practices

Climate-smart agriculture fulfills the need for an agricultural system that encourages climate change mitigation and adaptation activities, while enhancing food security (FAO, 2013; Neufeldt et al., 2013). It enhances productivity and incomes while mitigating forest degradation, adjusting to climate changes, and reducing greenhouse gas (GHG) emissions in situations where possible (Nkumulwa and Pauline, 2021). Site-specific CSA practices benefit users while safeguarding natural resources. A study done in Uganda by Zizinga et al. (2022) indicated that compared to the control treatment, CSA practices considerably enhanced total water storage of the soil by 1–12%. This type of advantage derived from adopting CSA techniques encourages and supports the adoption of CSA practices in areas where soil erosion and vegetation loss have lowered crop production. Sustainable land management is critical for preventing land degradation, restoring damaged areas, and ensuring that natural resources are used appropriately for present and future generations.

CSA practices are location-specific in the sense that they would be effective if executed in accordance with the specific requirements of the field; as a result, there are different practices that are believed to be climate-smart. A terrace is a region that has been flattened out on the edge of a hill just to produce crops (The Britannica Dictionary). It minimizes the amount and velocity of water traveling across the soil surface, which dramatically reduces soil erosion. Terracing changes steep slopes into a manmade sequence of relatively flat surfaces, thereby minimizing slope length and gradient, which reduces sediment yield and runoff (Deng et al., 2021). Terracing allows for more intensive cropping than would otherwise be possible.

Crop diversification, mainly, drought-tolerance has the potential to withstand the effect of a temperature rise that could probably affect soil moisture level and crop yields. Drought-tolerant varieties were thought to have a higher rooting depth in the soil profile, which enables the absorption and extraction of soil water (Tesfaye et al., 2018). Consequently, this makes it easier for plants to receive water even in dry conditions, which together with the other factors could increase crop yields.

The weather has a significant impact on agricultural yield, growth, and development as well as on the prevalence of diseases and pests, the need for fertilizers and water, the quality of products during transportation services, and the viability and vigor of planting materials and seeds during storage (Aditya et al., 2021). Access to weather information, such as temperature and rainfall, helps farmers prepare appropriately for farming tasks.

The promotion of afforestation and replanting is crucial for climate change mitigation efforts because trees absorb and store atmospheric carbon dioxide (CO_2) through photosynthesis over time. 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 (Meybeck et al., 2021). In addition to these advantages, forests play an important role in increasing soil organic matter and avoiding erosion. The thick canopy of trees helps reduce the impact of rain on the ground. Rainfall runs down the leaves and branches and gradually absorbs into the soil rather than forcefully hitting the ground, reducing the quantity of soil washed away by the rain.

3 Materials and methods

3.1 Study sites

This study was conducted in Welmera district. Welmera district is located in West Shewa Zone of the Oromia region at a distance of 29 km 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, of which 37,411 hectares are agricultural land or are under agriculture. The altitude of the district spans from 2,060 to 3,380 meters above sea level. The district lies between 8^0 50′ and 9^0 15’ N latitude and $38^0$25′ and 39^0 45′ E longitude. It has a total population of 104,143, consisting of 52,403 men and 51,740 women.

The district has two agro-ecologies: highland and midland. The Highlands account for 61% of the total, followed by the Midlands at 39%. The mean annual rainfall lies between 834 mm and 1,300 mm, and the annual temperature lies between 0°C and 27°C. The soil type composition is as follows: 60% red soil, 37% black soil, and 3% mixed soil. The agriculture system is primarily reliant on rain, making it very sensitive to climate change. Erosion is a major issue in several regions of the district. As a result, it is vital to understand farmer's adoption of CSA practices and the associated problems that smallholder farmers face while implementing the approaches (Figure 1).

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 Welmera district was chosen since it is one of the potential areas for crop and livestock production in the zone for adopting CSA practices. The study involves

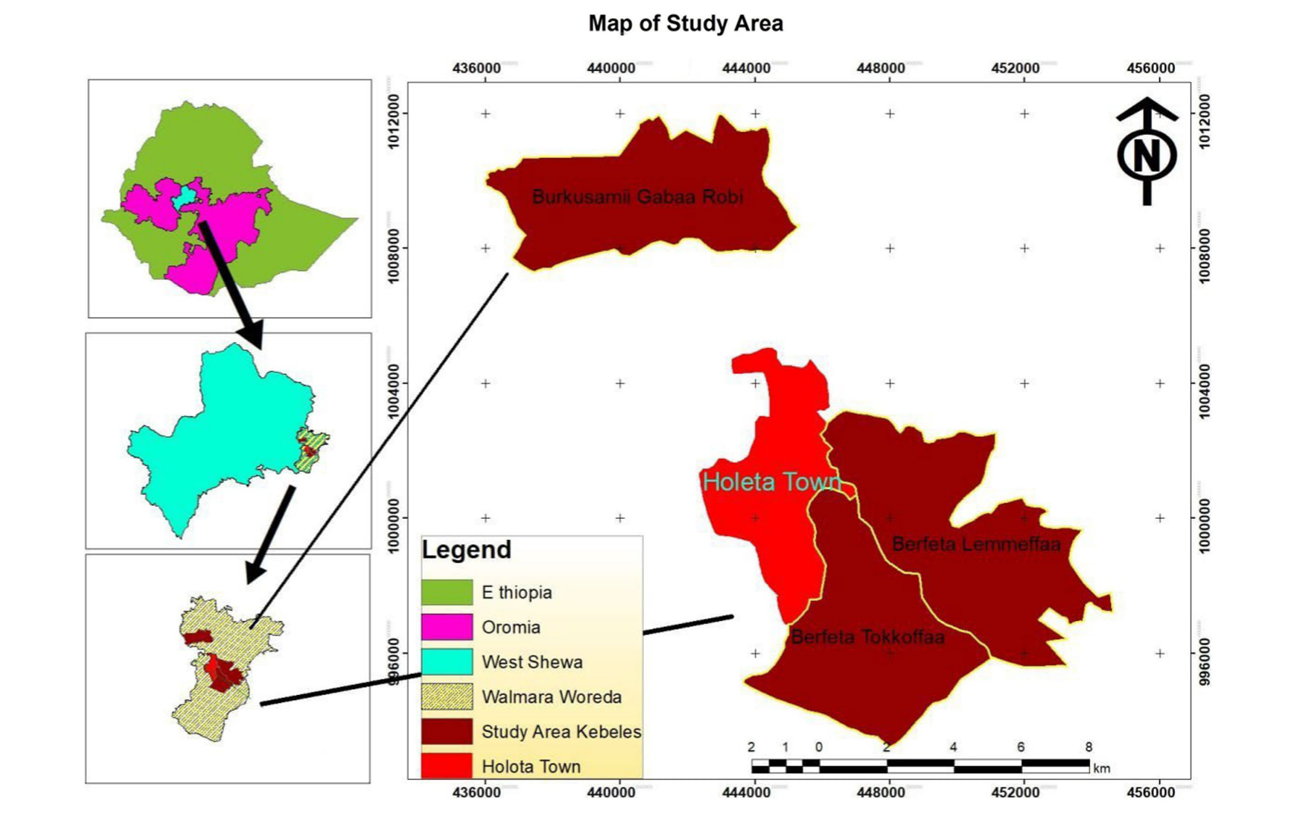

FIGURE 1
Map of the research area.

a purposive selection of three kebeles that have strong agricultural production potential. 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 were collected for main variables including demographic factors, economic factors (land holding, livestock holding, farm income, and access to credit services), and institutional factors (access to agricultural extension services and participation of farmers in field day). Additionally, adoption of different types of CSA practices by farmers is among the kinds of information collected from the respondents.

To provide a representative sample, the sample size was determined using Yamane's (1967) sample size formula (Sajjad, 2016).

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

Where

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

The total farm households of the three kebeles are 1,308/sampling frame/ households. Based on the above formula, the total sample size included 306 households.

3.3 Econometric model and data analysis

Adoptions of multiple CSA practices are correlated (Mebratu et al., 2022; Samuel et al., 2022; Tamirat, 2022; Abyiot et al., 2023). The 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. This is the preferred model for several dependent variables (two categories) that are interrelated.

One farmer decides to implement the Kth climate smart agriculture (CSA) practices if $Y^*kj = U^*k\text{-}U^0 > 0$,

where Uk represents a benefit from one of the CSA practices and U0 represents a benefit from implementation of traditional/unimproved methods. The farmer's net gain (Y^*kj) from Kth CSA practice is a latent variable influenced by observed sociodemographics, institutional economic factors, and climate change perception level (Xkj) as well as unobserved attributes (Ukj).

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

By transforming the unobserved preference in the preceding equation (equation 1) into the observed binary outcome formula for each CSA practice option, we obtain the following:

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

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

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

As per equation (1), it is assumed 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. Bk is the vector of parameters to be estimated in this model. Given the latent characteristic 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 techniques 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, $Ukj \sim$ MVN (0, Ω). 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 techniques are CA, ISF, SSI, AF, CD, ILF, IWI, and PH, then (μCA, μISF, μSSI, μAF, μCD, μILF, μIWI, μPH) ~ MVP (0, Ω) and the symmetric [8 × 8] covariance matrix Ω is given as follows:

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

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

3.3.1 Descriptive statistics result

Collected data were analyzed using descriptive statistics for the mean divergence of explanatory variables among adopters and non-adopters of specified CSA activities in the area. Gender, age, levels of education, family size, farming system, farmland size, livestock holding (TLU), revenue from farming, access to credit, access to agricultural extension services and training, access to field day involvement, and climate change perception level are among the explanatory variables considered in the study. From all randomly chosen sample HHs, approximately 15.4% were female-headed HHs and 84.6% were male-headed HHs, a figure that is nearly identical to national statistics from the Central Statistical Agency/CSA (2012), which indicated that approximately 16% of households were led by men. The farmers' lowest and highest ages are 25 and 82 years, respectively, with a mean age of 47 years. The mean family size of the respondents is 5.9, whereas the mean land size is 1.77 ha. Approximately 34.3% of respondents have access to financial services, and approximately 46.1 and 35.6% have access to agricultural extension and training and field day participation, respectively.

4 Results and discussion

4.1 Types of CSA practices implemented in the study area

Climate change negatively influences production and productivity. 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 implement different CSA practices, including those which have the potential to improve soil fertility, such as vermicompost. Based on different negative effects of climate change, farmers are implementing various coping strategies (Keller, 2009; FAO, 2013; Jirata et al., 2016). Adoption of practices such as nitrogen-efficient and heat-tolerant or resistant crop varieties, zero-tillage or minimum tillage, and integrated soil fertility management (Hellin et al., 2014; FAO, 2016) would improve productivity and farmers' incomes and help lower food prices. Adoption of CSA practices is likely to 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 (Komarek et al., 2018). Saguye (2017) proved that agroforestry, soil and water management, crop management, and livestock management practices are among the most common CSA practices.

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

The farmers are assumed to be adopters of the practices such as conservation agriculture if they adopt at least one of the components of the practice, for example, bund or reduced tillage or crop residue or crop rotation (Table 1).

4.2 Interdependency of adopted CSA practices

CSA practices implemented in the study area include conservation agriculture.

The result of correlation coefficient error components based on the estimation of eight practices of climate smart agriculture by the MVP model 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' interconnected and collaboratively adopted CSA practices. This is caused by either practice complementarity or practice substitutability. Furthermore, it is suggested that those behaviors are mutually beneficial. The result is in line with the findings of Mebratu et al. (2022), Samuel et al. (2022), Tamirat (2022), Abyiot et al. (2023).

4.3 Adoption determinants of climate smart agriculture practices

A multivariate probit model was used to investigate the factors that influence the adoption of climate-smart agriculture practices (Table 3). Institutional, socioeconomic, and demographic factors are identified explanatory variables in the analysis result. Response variables are conservation practices of agriculture, management of improved soil fertility, small-scale irrigation, agroforestry practices, crop diversification, improved livestock feed and feeding, improved weather information, and post-harvest technology. The value of the response variables is assumed to be 1 if the practice is used by farmers and 0 otherwise. The coefficient result of the multivariate probit model is shown in Table 4. The following are independent variables: household head sex, age, family size, education level, climate change perception, land/farm size, livestock holding (TLU), farm income, household farming system, access to credit service, availability of agricultural extension and agricultural training services, and farmer field day participation.

4.3.1 Demographic factors sex

With climate change affecting production and productivity, it is highly advised to cultivate improved crop varieties that are site- and agro-ecological-specific, including drought and disease resistance and high-yielding crop varieties, 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 agricultural sectors that contributes to greenhouse gas emissions, notably methane gas; hence, working on improvements of livestock feed and breed is therefore essential in this case. Being male as compared to female significantly ($p < 0.1$) increases 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 (Braimoh and Vlek, 2006; Liliane and Charles, 2020). This is why many farmers add fertilizers to their farmland. However, if the farmland is not maintained properly, soil fertility decreases, possibly because of climate change and inappropriate use. In this study, the result

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 and write = 1, grades 1–4 = 2, grades 5–8 = 3, grades 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 have 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 have access to Agri. Ext. and training, 0 otherwise	0.461	0.499
Farmers field day participation	Dummy = 1 if farmers have 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
Post-harvest technology	Dummy = 1 if farmers adopt the practice, 0 otherwise	0.386	0.488

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

indicated age of the household head significantly ($p < 0.05$) and negatively influenced the likelihood of adoption of improved soil fertility practices. This implies that young individuals are more motivated than older people to adopt improved soil fertility practices. 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 head significantly ($p < 0.05$) and negatively affects crop diversification. This result is in line with the findings of Mebratu et al. (2022).

Age of the household head positively and significantly ($p < 0.05$) influences the adoption of agroforestry practices. The result is in line with that of Abyiot et al. (2023), which indicated that age significantly and positively impacts the adoption of agroforestry practices.

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 that the education level of household heads significantly ($p < 0.1$) and positively affects the adoption of agroforestry practices. The result is in agreement with that of Abyiot et al. (2023).

Climate change perception

In this study, it was hypothesized that attitudes toward climate change will significantly and favorably influence the adoption of CSA practices. It has significantly ($p < 0.05$) increased improved weather

TABLE 2 Multiple CSA practices implemented in the study area.

CSA practices	Kebeles							
	Berfeta lemefa $n = 66$		B/Gaba Robi $n = 105$		Berfeta Tokkofa $n = 135$		Total % $N = 306$	
	Adopter	Non adopter	Adopters	Non adopter	Adopters	Non adopter	Adopters	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 and 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

information adoption. This suggests that with growing awareness of climate change, the willingness to accept and make use of better weather information also increases.

4.3.2 Economic factors

Land holding (farm land size)

The farm land size of households significantly ($p < 0.01$) increased the implementation of agroforestry practices. The findings are in line with those of Samuel et al. (2022), who found that adoption of minimum tillage (a conservation agriculture technique) was substantially and favorably influenced by total land holding, and Tamirat (2022) found that adoption of conservation tillage was significantly and positively influenced by land size.

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

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 smaller 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 performed to preserve, protect, or process a commodity after it has been harvested. According to the study's findings, the size of the land holding significantly ($p < 0.01$) enhanced the likelihood that post-harvest technical practices would be adopted.

Farm income

Farmers use their farm income to cover household expenses, which has a significant ($p < 0.01$) and favorable impact on the adoption of improved livestock feed and feeding practices. This demonstrated that with increase in their wealth, 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 farmers are lacking financial resources. The outcome further demonstrated that access to financial services had a substantial ($p < 0.05$) favorable effect on improved crop implementation. The reason could be that enhanced crop seed and the inputs that go with it need finance services, which not all smallholder farmers always have on hand. Therefore, having access to financial services may aid farmers in filling this gap.

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 to embrace post-harvest technology than farmers who do not.

TABLE 3 Covariance of the correlation matrix of CSA practices integrated soil fertility management, small-scale irrigation includes, agroforestry practice, crop diversification, practices of improved livestock feed and feeding, improved weather information, and post-harvest technologies.

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 and 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 and 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 and 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 and 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 and 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 and feeding	**0.351***(0.097)**
Post-harvest technology and improved weather information	−0.074 (0.090)

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho81 = rho32 = rho42 = rho52 = rho62 = rho72 = rho82 = rho43 = rho53 = rho63 = rho73 = rho83 = r ho54 = rho64 = rho74 = rho84 = rho65 = rho75 = rho85 = rho76 = rho86 = rho87 = 0: chi2 (28) = 251.988 Prob > chi2 = 0.0000 Stand.er. in parenthesis ***$p < 0.01$, **$p < 0.05$, *$p < 0.01$.

Livestock holding

Livestock is a valuable asset that supports smallholder farmers in rural areas in a variety of ways, including money generation, the use of animal products for home consumption, and draft animals for plowing. The results demonstrate that the size of the livestock holding, which is one of the farmers' source of income, significantly and favorably ($p < 0.05$) influences the adoption of conservation agriculture practices. The finding is consistent with research from Tazeze et al. (2012) and Samuel et al. (2022), 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 finding is consistent with that of Titay et al. (2022) showing that 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.

4.3.3 Institutional factors

Access to agriculture extension services and trainings

Farmers can obtain various kinds of 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 Mebratu et al. (2022), Abyiot et al. (2023).

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

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

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

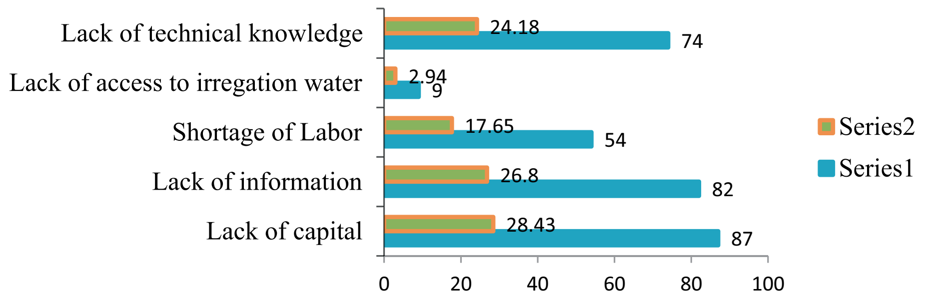

FIGURE 2
CSA adoption barriers Source: survey data (May, 2022).

share information with a bigger group of farmers by providing demonstrations. This strategy is used in more than 90 countries (Emerick and Dar, 2021). The findings of the study showed that participation in farmers' field days significantly and favorably ($p < 0.1$) influences 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.

4.4 Climate smart agriculture adoption barriers

Farmers who 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.

According to a study by Titay et al. (2022) conducted in the East Hararghe Zone, farmers confront several problems that prevent them from putting climate change adaptation measures into practice, 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 recommendation

It is vital for long-term agricultural production to reduce the negative impact of climate change on agriculture and conversely 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 was to examine CSA practices being implemented and determining factors of adoption of CSA practices in Welmera woreda study sites. 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 used by farmers in the study area. There might be a justification for why some CSA practices are being implemented 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 show that male farmers were significantly more likely than female farmers to adopt crop diversification and improved livestock feed and feeding practices. Increase in age has a considerable detrimental impact on the likelihood of farmers implementing improved soil fertility management techniques and crop diversification measures. 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 post-harvest technology practice, according to the results of the economic factors. Higher farm revenue increases the possibility of adopting improved livestock feed and feeding practices. Having a significant number of animals strongly promotes adoption of conservation agriculture, and having access to financing services positively influences agroforestry, crop diversification, and post-harvest technology implementation. We again found that climate change perception level has a positive and significant effect on the adoption of improved weather information. In addition, institutional factor results indicated that access to agricultural extension service and training positively influences the adoption of crop diversification and that access to participation on farmers' field day similarly positively influences the adoption of both conservation agriculture and improved soil fertility management practices.

The results of the study indicate that CSA practices are complementary in terms of adoption. Therefore, concerned bodies ought to give due attention to the complementarity of the practices in the study areas for intensifying adoption of CSA practices in the study. Another consideration for concerned bodies is to look at farmers' demographic, socioeconomic, and institutional characteristics that have a substantial impact on the adoption of CSA practices and to improve these factors, as these factors can influence the adoption of the practices.

Agricultural extension services are significantly important for increasing the public's understanding of agricultural developments. It helps educate and improve the knowledge and abilities of rural farmers to increase the productivity through the use of improved technologies. Since this is an essential element, policymakers and other concerned bodies should pay close attention to the field of factors influencing the agricultural extension and training system. Along with this, it is crucial to work on the identification of site-specific CSA practices to decrease the negative effects of climate change on agriculture. Apart from the previously mentioned points, providing farmers with agro climate consulting services and facilitating access to climate information are more effective for raising awareness. Further investigation is recommended in order to gage the economic impact of CSA practices in the study areas as well as the adoption intensity of these practices.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material; further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the [patients/participants OR patients/participants legal guardian/next of kin] was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

MG: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Writing – original draft, Writing – review & editing. EA: Data curation, Investigation, Methodology, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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