Adoption of Climate Smart Agricultural Practices by Smallholder Farmers in Western Oromia

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Abstract

The study employed multi-stage random sampling technique to select representative sample farm households. Adoption of climate smart agricultural (CSA) practices is a recommended pathway as a means of adaptation to climate change and attaining sustainable productivity. However, the uptake of these practices by smallholder farmers is minimal. Factors determining farmers' adoption decision of climate smart agricultural practices were examined using household and plot level survey data collected in Gimbi and Diga distrcits. Multivariate Probit (MVP) model is applied to assess adoption decisions by farm households facing a decision of multiple CSA practices with a particular focus on the adoption of minimum tillage, crop residue and intercropping which can be adopted in various combinations. Results show that, though farmers have got the same exposure to CSA practices through on-farm demonstrations, their level of uptake of the CSA practices varies depending mostly on their level of education, resource endowment and access to markets. In general, the study results show that adoption of CSA practices enable farmers to increase productivity and reducing the risk of crop failure, as well as by reducing the adverse impacts of climate change by increase farmers' capacity to the adaptation and mitigation to climate change. In general, results of this study show that adoption of CSA practices are highly household-specific where different targeting and support mechanisms might need to be in place to enable farmers see the long-term benefits of these practices. Thus, the main message from the study is that technical change for farm-level improvement in agricultural production through adoption of feasible technologies or new farming practices requires farmer's understanding their farming system, changes on their environment, persistent struggle to the unanticipated change, interventions by governments and non-governments organizations are the factors that govern agricultural production, value chains and natural resource management.

Keywords: adoption, climate smart agriculture, productivity, smallholder, multivariate probit (MVP), model Ethiopia.

1. Introduction

Climate change and variability is posing challenges to agriculture. Climate change and variability continue putting immense stress on agricultural production systems as they seek to meet the food requirements of a growing population. Thus, it demands an urgency to the need for adaptation in its widest sense in the natural resources sphere: agriculture, forestry, Natural Resources Management, livestock, aquaculture, fisheries (FAO,2020).For agriculture to successfully address the issues of food security brought on by a severe climate change, considerable changes must be made. Climate smart agriculture (CSA) is a plausible option for the adoption of accessible farming methods to adapt to a changing climate and allow farmers to achieve improved productivity and revenue. It also helps farmers to contribute to the mitigation of greenhouse gas (GHG) emissions.

Rather than being a "one-size-fits-all" strategy that can be used everywhere, climate smart agriculture incorporates many features into local contexts to benefit both the agricultural sectors and farming communities (FAO, 2018). Conservation, integrated soil fertility management, small-scale irrigation, agroforestry, crop diversification, and improved animal feed and feeding techniques are the main categories of climate smart agriculture in Ethiopia (Jirata *et al.*, 2016).

Therefore, CSA methods have been concentrated on reclaiming degraded lands through soil and water conservation strategies in Ethiopia, where a significant share of rural farmland regions are experiencing acute soil erosion or land degradation. The government and its development partners provide substantial support for such CSA practices through research and development, rural extension and consultancy services, as well as direct implementation.

Even though maize productivity in Ethiopia is increasing it could not reach its optimal productivity level due to the strain from the changing patterns of temperature and precipitation and increased occurrences of extreme events like droughts and floods (Di Falco, 2016). Frequent changes in temperature and precipitation patterns have been exposing the country's agricultural production systems to tremendous risks, causing more long-term production declines and short-term crop failures and hence an unstable food supply (Lasco *et al.*, 2014). If appropriate responding strategies are not adapted to the climate change events, losses in crop and livestock productivity are expected to undermine the rate of gain from technological and management efforts (Lobbell and Gourdji, 2012).

Implementation of conservation agricultural practice is one of the key CSA for the improvement of livelihoods and food security. Since 1998, numerous traditional as well as innovative climate adaptation and mitigation, and agricultural development activities have been conducted in Ethiopia (Jirata *et al.*, 2016). Understanding the adoption decision on climate smart agricultural practices and their determinants contributes to the identification of smallholder farmers' production constraints especially in addressing land degradation, low agricultural productivity at farm and household level thereby improving the food security and income of smallholder farmers. Past research also focused on the adoption of component of agricultural technologies

in isolation, whereas farmers typically adopt and adapt multiple technologies as complements or substitutes that deal with their overlapping constraints (Hailemariam *et al.*, 2013).
Although some studies were made on adoption of climate smart agricultural practices with different crop variety and resource management in Ethiopia, there were no comprehensive earlier studies which investigated the effect of separate and combined effects of adoption of minimum tillage, intercropping and crop residue on maize crop production by smallholder farmers. Virtually, no study has been done on the adoption of components of climate smart agricultural practices among maize producing farmers in Ethiopia, particularly in the study area, Gimbi and Digga districts Western Oromia region, where the International Maize and Wheat Improvement Center (CIMMYT) project has been diligently operating on the adoption of these practices could bring about maize yield improvement on maize yield, food consumption, marketed surplus, labor saving, income in the study area.

Ethiopian agriculture depends on different agro-ecological settings of the country which enabled diversified farming system dominated by small-scale, mixed crop and livestock production. Due to a strong dependence of the country's economy on agriculture, the government of Ethiopia has given top priority to the agricultural sector development and has taken a number of initiatives to increase productivity. However, the sector is very sensitive to climate change and variability. Ethiopia's annual greenhouse gas (GHG) emissions were estimated at 150 Mt CO_2 in 2010, with 50 percent and 37 percent of these emissions resulting from the agricultural and forestry sectors respectively. In agriculture, livestock production accounted for more than 40 percent of the emissions results from enteric fermentation, followed by manure left on pasture, while in forestry the main guilty action was deforestation for expansion of agricultural land, which accounted for over 50 percent of forestry-related emissions, followed by fuel-wood consumption at 46 percent of forestry-related emissions (Melkamu, et al., 2016).

The available arable land per farming family, due to population growth, is shrinking in many rural areas of Ethiopia. Rural farmers have been taking actions that help them expand farmland through clearing forests areas, shrubs, and marginal lands. This unwise act of rural farmers resulted in widespread deforestation, land degradation associated with soil erosion and loss of biodiversity. All these activities will intensify the greenhouse gas effect which ultimately aggravates the global warming coupled with climatic change and variability and recurrent drought in many places has severely damaged agricultural productivity and the livelihood of the farming community; and the cumulative effect has been manifested in food insecurity (Weldelul, 2016).

Regarding to West Wollega zone where this study was to be conducted, economic activity of rural farers is dominated by agricultural activity, with maize crop dominating cereal crop production. In Gimbi district of west Wollega zone, the total area allotted for maize under annual crops allotted is about 32%, while the total area allotted for maize under annual crops allotted is about 32%, in Digga districts of East wollega Zone. However, its productivity (3-4 t/ha) is far below its potential (7-8 t/ha) in these districts (Agricultural district office annual report, 2018). Though its productivity is constrained with a number of limiting factors, maize remains the most

important cereal crop in the study areas in terms of area share, total production, and its role in family consumption.
Although land allotted to maize has been increasing in the two districts of the study area, it productivity was not increasing to the expected level chiefly due to the impact of climate change and variability, besides other limiting factors. The production and productivity of agricultural products particularly maize, therefore, have been constrained by several factors including soil erosion, poor soil fertility, adverse effects of use of inorganic chemicals, low adoption of technologies, crop diseases and pests like maize stalk borer, weevil, termites, etc (FAO. 2021).

To tackle these appalling impacts of climate change and variability, different studies have been made so far. However, impact of CSA adoption and food security status of farm household at project intervention level is rarely studied. This study, therefore, aims at examining the determinants of adoption of climate smart agricultural (CSA) practices by maize cultivators using 2018/19 production year survey data collected at plot and household level from the study area. The general objective of this study is to examine the adoption of climate-smart agricultural practices by smallholder farmers in Gimbi and Digga districts, Oromia Western National Regional State.

2. Literature Review

In this chapter, comprehensive review of relevant literature on smallholder farmers' perception of climate change and variability, adoption of climate-smart agricultural practices and its impact on food security status was compiled. Furthermore, underlining concepts and theoretical framework, analytical and methodological frameworks that explain relevant variables and approaches to study adoption. The theoretical and empirical reviews which serve as evidence from earlier related studies and the gaps to be bridged by this study help for the establishment of a conceptual framework. The review also provides insights on key variables and analytical models to be used in examining and identifying factors affecting adoption of CSA practices in the study area.

Historical evolvement of climate-smart agriculture based on FAO (2010) that it coined the term CSA in the background document prepared for the 2010 Hague Conference on Food Security, Agriculture, and Climate Change. It was defined as CSA is "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes greenhouse gas, and enhances achievement of national food security and development goals". The CSA concept was developed with a strong focus on food security, for now, and the future, including adaptation to climate change. Besides FAO, climate-smart agriculture (CSA) has been defined by different authors. For example, According to Lipper *et al.* (2014), CSA is defined as an approach for transforming and reorienting agricultural development under the new realities of climate change.

In this definition, the principal goal of CSA is identified as food security and development (FAO 2013a) while productivity, adaptation, and mitigation are identified as the three interlinked pillars necessary for achieving this goal. The world population will grow from the current 6.7 billion to 9 billion by 2050 with most of the increase occurring in South Asia and sub-Saharan Africa. Taking into account the changes in the composition and level of consumption associated with growing household incomes, estimates indicate that feeding the world population will require a 70 percent increase in total agricultural production (Bruinsma, 2009). Most of the Greenhouse Gas Emissions (GHG) of the agricultural sector is directly driven by the use of natural resources for instance new land being deforested or turned from grassland to cropland, use of fertilizers, livestock rearing, and energy. Fertilizer applications lead to the production and emission of nitrous oxide (N_2O), whilst livestock especially cattle, produce methane (CH_4) as part of their digestion (EPA, 2015). Increasing efficiency in the use of resources (simply put, producing more of a given output using less of a given input) is thus key to reducing emissions intensity per kilogram of agricultural output as well as to improve food security, especially in resource-scarce areas. In addition, agriculture is recognized as an important practice leading to high levels of deforestation, therefore if we reduce agricultural expansion through sustainable intensification on already cultivated land (increasing the output on the same piece of land without further deforestation), this could have a major lessening effect on rates of deforestation (FAO,2017).

2.1. Theoretical framework for adoption of climate-smart agricultural practices

Rational choice theory

Rational choice theory, also known as the choice theory or rational action theory is a framework for understanding and often formally modeling social and economic behavior (Amartya, 2008). Households are assumed to maximize their utility, subject to the constraints, and adopt a given technology if and only if the technology is available and affordable, and if at the same time, the selection decision is expected to be beneficial (in terms of profits or otherwise) (de Janvery *et al.,* 2010). Farmers are also more likely to adopt a mix of measures to deal with a multitude of production constraints than to adopt a single practice.

The rational agent is assumed to take account of available information, probabilities of events, and potential costs and benefits in determining preferences, and to act consistently in choosing the self-determined best choice of action (Susannel, 2008). Early neoclassical economists writing about rational choice assumed that agents make consumption choices so as to maximize their happiness or utility. Contemporary theory bases rational choice on a set of choice axioms that need to be satisfied and typically does not specify where the goal (preferences, desires) comes from. It mandates just a consistent ranking of the alternatives (*Grüne-Yanoff, 2012).*

Individuals choose the best action according to their personal preferences and the constraints facing them. Rational choice theorists do not claim that the theory describes the choice *process*, but rather that it predicts the outcome and pattern of choices. Regarding the adoption of a new technology, farmers are faced with choices and trade-offs. Differences in adoption decisions are often due to the fact that farmers have different cultures, different resource endowments, different objectives, different preferences, and different socio-economic backgrounds (Francis *et al.*, 2017).

2. 2. Analytical framework for adoption of CSA

The decision of whether to use any of CSA practices or not could fall under the general framework of farmers' utility maximization (Komba and Muchapondwa, 2012). Household's decision can be modeled as maximizing the expected utility for choosing the j^{th} adoption strategy among the J discrete strategies (Amare and Simane., 2017). Consider the i^{th} farm household (i = 1, … , n) who is facing a decision on whether or not to adopt the available CSA practice on his plot and U_k represent the benefit of adopting the k^{th} CSA practice, then a farmer decides to adopt the k CSA practice if $y^*_{ijk} = U^*_{jk} - U_{jk} > 0$ (k denoting choosing minimum tillage (t), crop residue (r), and intercropping (c)). The net benefit y^*_{ijk} that the i^{th} farmer derives utility from the adoption of U^*_{jk} CSA practice is a latent variable determined by observed farmer's socio-economic characteristics and plot characteristics X_{ij} and unobserved characteristics captured by the stochastic error term ε_i.

If adoption of a particular CSA practice is independent of whether or not a farmer adopts another CSA practice (i.e., if the error terms, y^*_{ijk} are independently and identically distributed with standard normal distribution), then univariate probit models, where information on farmers' adoption of one farming practice does not alter the prediction of the probability that they will adopt another practice (Wondwossen *et al.*, 2008). However, if adoption of several farming practices is possible, a more realistic specification is to assume that the error terms jointly follow a multivariate normal (MVN) distribution, with zero conditional mean and variance normalized to unity.

2.2.1. Multivariate probit model specification

The multivariate probit model is characterized by a set of binary dependent variables y_{ij} and used without multivariate normal integral evaluation of farmer adopting different CSA practices that the model allows unobserved and unmeasured factors (error terms) to be freely correlated (Oyo and Baiyegunhi, 2018). If a farmer adopts one or more CSA practices, the error terms are positively freely correlated that assumes the practices are complementary or supplementary if the model equations error terms were negatively and have a synergetic effect on each other. Hence, in this multivariate model, where the adoption of several CSA practices are possible, the error terms jointly follow a multivariate normal distribution (MVN) with zero conditional mean and variance normalized to unity (for identification of the parameters). Where $U_{ijk} \sim MVN(0, \Omega)$ and the covariance matrix Ω.

Apparently, adoption models could be grouped into two broad categories based on the number choices or options available to an economic agent (Greene, 2008). Econometric analysis. 4th ed.

New Jersey: Prentice-hall Inc. farmers decision on the use of adaptation options involves multiple response in which the dependent variable is discrete, and thus it is more appropriate to treat factors which are supposed to determine farmers' decision on the use of adaptation options as a multiple choice decision (Dorfman,1996).Based on this argument, the appropriate econometric model would be either multinomial logit or multinomial probit regression model. Regarding estimation, both of them estimate the effect of explanatory variables on dependent variable involving multiple choices with unordered response categories (Greene, 2008). However,Farmer's decision choice is 'inherently a multivariate decision' (Dorfman,1996). Attempting bivariate modeling excludes useful economic information contained in the interdependent and simultaneous choice decisions.

Thus, for the analysis of adoption of CSA, multivariate probit model was selected over other estimation models like multinomial probit, and multinomial logit model. The multivariate probit model (MVP) is be able to account for this interdependency, we use a multivariate probit (MVP) technique applied to multiple plot observations to jointly analyze the factors that increase or hinder the probability of adopting each CSA agricultural practice. MVP approach simultaneously models the influence of the set of explanatory variables on each of the practices, while allowing the unobserved and unmeasured factors (error terms) to be freely correlated.

$$y^*_{ijk} = x_{ij}\beta_j + \varepsilon_{ij} > 0 \tag{1}$$

Using the indicator function, the unobserved preferences in equation (1) translate into the observed binary outcome equation for each CSA choice as follow: An appropriate normalization that removes indeterminacy in the model could be made supposing that $\beta_1 = 0$ (this arises due to the underlined assumption that probabilities sum to 1. Thus, only *J* parameter vectors are needed to determine the *J* + 1 probabilities) so that exp ($x_{ij}\beta_j$) = 1

$$y_{ijk} = \begin{cases} 1 \text{ if } y^*_{ijk} > 0 \\ 0 \text{ Otherwise.} \end{cases} \quad \text{Where k denotes the type of CSA} \tag{2}$$

The probability that a farm household chooses adoption strategy j, P_{ij} is modeled as

$$\Pr\left(y_i = j / x_i\right) = P_{ij} = \Pr(d_{ij} = 1) = \frac{\exp\left(X_i\beta_j\right)}{\sum_{j=0}^{m}\exp\left(X_i\beta_j\right)}\text{; for all } j = 0,1,2,3 \tag{3}$$

where y =j is a polytomous outcome variable with m categories coded from J= 0,1, 2,3.With the requirement that $\sum_{j=0}^{m} p_{ij} = 1$ for any i, where P_{ij} is the probability of the i^{th} respondent falling into CSA practice adoption category j; X_i = predictors of response; β_j = Covariate effects specific to j^{th} adoption of CSA practices category with the first category as the reference. For the model to be convenient, the appropriate normalization that removes an indeterminacy in the model assumes that $\beta_1 = 0$ (this arises because probabilities sum to 1, so only J parameter vectors are needed to determine the J + 1 probabilities) (Greene, 2004). So, the marginal effects of the explanatory variables on the choice of alternative adoption of CSA practices are usually derived as in (Greene, 2000):

2.2.2. Definitions of variables for smallholder farmers' Adoption of Climate Smart Agricultural Practices by Smallholder Farmers

Dependent variable: The dependent variable refers to Adoption of Climate Smart Agricultural Practices by Smallholder Farmers in western Oromia Region: Adoption of Climate Smart Agricultural Practices in the study area was categorized into four feasible choices available to the farmer. These possible choices were:

Y_1 using minimum tillage (y_1=1 for users and 0 for non-users)
Y_2 using crop residue (y_2=1 for users and 0 for non-users)
Y_3 using intercropping (y_3=1 for users and 0 for non-users)

Independent variables: Farmers' decisions about to adopt new technology are conditioned by the dynamic interaction between characteristics of the technology itself and the array of conditions and circumstances (Loevinsohn *et al*., 2013). The following variables were hypothesized to affect farm household adoption of Climate Smart Agricultural Practices based on the literature reviews and theoretical basis.

Age of the household head: Age **of the household head** was also assumed to be one of a determinant of adoption of CSA practices. It is a continuous variable measured in years. Older farmers are assumed to have obtained better understanding and experience over time and are better able to evaluate technology information than younger farmers (Mignouna et al, 2011; Kariyasa and Dewi 2011). Mauceri *et al*. (2005) explained that as farmers grow older, there is an increase in risk aversion and a decreased interest in long-term investment in the farm. Thus, the more aged the household, the more exposure to climate change and variability he/she would have and hence the more experience he/she would obtain that helps him for the adoption of CSA practices.

Sex of the household head: This is a dummy variable that takes a value of 1 if the household head is male and 0 if female. Gender issues in adoption of agricultural technology have been considered for a long time and mixed results have been reported regarding the different roles men and women play in technology adoption. The sex of household heads has also been found to affect CSA adoption because of financial or resource constraints, access to information, extension services, and available adaptation strategies, which tend to create higher labor loads for women (Atinkut and Mebrat 2016; Jost et al. 2016). For instance, a study by Obisesan (2014) on adoption of technology found that gender had a significant and positive influence on adoption of improved cassava production in Nigeria. It is, therefore, hypothesized that male household head has a positive effect on the adoption of climate smart practices in maize farming area of western Oromia.

Educational level: Educational level refers to formal schooling the household head spent to improve his education. Attaining higher educational level helps farmers to influence their attitudes and thoughts making them more open, rational and able to analyze the benefits of the new technology. Education level of a farmer increases his ability to obtain; process and use information relevant to adoption of a new technology (Mebratu *et.al.* 2022).

Own Land size: This variable refers to the size of land owned by a farmer. It is a continuous variable measured in hectares. Land is one of the most important and scarce resources in agricultural production. Total land holding of the household is expected to be positively related to adoption of CSA as it may enable households to allot their land for multiple crops thereby increasing farm production. Given the uncertainty and the fixed transaction and information costs associated with technologies, there may be a critical lower limit on farm size that prevents smaller farms from making CSA adoption decisions (Dung et al. 2018). Owners of massive farms are more willing to invest in CSA than those who have small farms (Atinkut and Mebrat 2016; Fadina and Barjolle 2018). The larger the area of productive land, the higher the motivation for farmers to learn how to apply CSA to reduce costs, labor, and care time to a minimum. Holding large farm size could be used as a capital base, enhances the risk bearing ability of farmers, and hence could be more efficient than small farms due to its advantage of the economic scale and scope associated with larger sizes (Fadina and Barjolle 2018)'

Experience in maize farming: experience in maize farming is a continuous variable. It refers to the total number of years the household head has spent making farming decisions. Experienced farmers are expected to have greater access to productive resources (such as land and labor) and they are expected to be faster in adopting technologies than inexperienced farmers (Sisay, 2016). It is, therefore, hypothesized that a better-grounded farming experience in maize crop production is positively related to adoption of CSA practices.

Distance to all weathered road: This is about how far the all weathered road to access agricultural inputs and supply his outputs to the market. Distance to all weathered road is a continuous variable measured in a walking hour and shows weather a farmer reside nearer to the all weathered road or not. A farmer, whose residence nearer to all weathered road was hypothesized to adopt CSA practices than the farmers who is too far from all weathered road Dung, 2020; Sardar *et al.*, 2021. Moreover, the proximity of a farmer to all weathered road is important factor in helping the farmer to get access to information, purchase of agricultural inputs to the market.

Distance to the village market: Distance from the farmer's residence to the village market center in walking is a continuous variable measured in walking hours. It was expected to be negatively related to adoption of CSA practices. This is because proximity to market increases framer's information access, reduces transportation and transaction costs of taking produce to market.

Distance to development center (DA):

Lack of information and inadequate extension are the most critical barriers to climate change adaptation (Atinkut and Mebrat 2016; Asrat and Simane 2018; Wassie and Pauline 2018). The agricultural extension service is a formal source of information for producers, based on contact with extension agents and farmer groups Distance of farmer's residence house to the development agent is a continuous variable measured in walking hour was expected to be negatively related to adoption of technology in maize farming. This is because; proximity to development center has the advantage of easily obtaining technical supports from extension workers. A negative relationship was, therefore, hypothesized between distance to development center and CSA practice adoption.

Table 2.1: Description of the variables hypothesized to affect smallholder farmers' adoption of CSA practices

Dependent variables			
Y_1 using minimum tillage (y_1=1 for users and 0 for non-users)			
Y_2 using crop residue (y_2=1 for users and 0 for non-users)			
Y_3 using intercropping (y_3=1 for users and 0 for non-users)			
Independent variables Notation	Variable description and measurement	Unit	Expected signs
Demographic characteristics			
Sex	Sex of household head (1= female, 0= male)	Dummy	-
Age	Age of household head	years	+/-
Socioeconomic characteristics			
Education	Formal education level of household head	Categorical	+
Illiterate	If Illiterate =1, 0 if not	Dummy	+
Read and write	If Read and write =1, 0 if not	Dummy	+
Primary school	If Primary school =1, 0 if not	Dummy	+
Secondary school and above	If Secondary school and above =1, 0 if not	Dummy	+
Marital status	Marital situation of household head	Categorical	+/-
Married living with spouse	Married living with a spouse = 1, 0 if not	Dummy	+/-
ii. Divorced	Divorced =1 , 0 if not	Dummy	+/-
iii. Widow/widower	Widow/widower =1, 0 in not	Dummy	+/-
Livestock	Number of livestock owned	TLU	+
Off/non-farm income	Annual off/ non-farm income in logarithm	Birr	+
Farmer and farm specific attributes			
Farm size	Total land holding size of the household head	Hectares	+
Shared-in land	shared in land size household head	Hectares	+

Experience in maize growing	Number of years a farmer has cultivated a farm	Years	+
Rented in land	Rented in land size household head	Hectares	+
Shared-in land	shared in land size household head	Hectares	+
Experience in maize growing	Number of years a farmer has cultivated a farm	Years	+
Soil fertility	Soil fertility type	Dummy	+/-
good	Good Soil fertility =1, 0 otherwise	Dummy	+/-

Table 4 (continued)

medium	medium Soil fertility =1, 0 otherwise	Dummy	+/-
Soil slope	Soil slope type	Dummy	+/-
gentile	Gentile slope of a plot =1, 0 otherwise	Dummy	+/-
Medium	medium slope of a plot =1, 0 otherwise	Dummy	+/-
Soil depth	Soil depth type	Dummy	+/-
shallow	Gentile slope of a plot =1, 0 otherwise	Dummy	+/-
medium	medium slope of a plot =1, 0 otherwise	Dummy	+/-
Institutional service			
Distance to all-weather road	Distance of farmer’s house from all-weather road	Minute	-
Distance to dry weather road	Distance of farmer’s house from dry weather road	Minute	-
Distance to DA office	Distance of farmer’s house from DA Office	Minute	-
Distance to district market	Distance of farmer’s house from district market	Minute	-
Distance to village market	Distance of farmer’s house from village market	Minute	-
Distance to Fertilizer dealer	Distance of farmer’s house from fertilizer dealer	Minute	-
Distance to local grain mill	Distance of farmer’s house from local grain mill	Minute	-
Herbicides and pesticide dealer	Distance of farmer’s house herbicide and pesticide dealer	Minute	-
Distance to seed dealer	Distance of farmer’s house from seed dealer	Minute	-

2.3. Empirical studies on adoption of CSA

Differences in adoption decisions were often due to the fact that farmers had different cultures, different resource endowments, different objectives, different preferences, and different socio-economic backgrounds (Francis *et al.*, 2017). It follows that some farmers adopted the new technology while others did not. Although there were many categories for grouping determinants of technology adoption, there was no clear distinguishing feature between variables in each category. A study conducted by Hailemariam (2013) on adoption of multiple sustainable agricultural practices in rural Ethiopia used a sample size 898 farm households and 4,050 farming plots of maize crop employed multivariate probit models. The analysis further showed that both the probability and the extent of adoption of sustainable agricultural practices are influenced by many factors: a household's trust in government support, credit constraints, spouse education, rainfall and plot-level disturbances, household wealth, social capital and networks, labor availability, plot and market access.

A study on determinants of climate-smart agriculture technology adoption in the drought-prone districts of Malawi was conducted using a multivariate probit (MVP) analysis (Francis *et al.*, 2017). The study revealed that gender, age, location, farmer type, level of education, livelihood status/ off-farm participation, land size and source/ownership, household income, household expenditure, anticipated weather pattern, climate variability knowledge/signs, access to credit, all has an influence on the adoption decision of climate-smart technologies either positively or negatively.

A study on agricultural technology adoption under climate change in the Sahel: Micro-evidence from Niger was conducted by Solomon *et al.* (2016). Multivariate probit models and instrumental variable techniques were employed to model the adoption decisions and their impacts. The study result indicated that adoption of both modern inputs (inorganic fertilizer and improved seed) and organic fertilizer were positively associated with crop productivity and crop income. The use of crop residues didn't seem to correlate positively with crop productivity and could even have a negative effect. A strong negative association on crop productivity was found among households reporting that they had experienced a delayed onset of the rainy season. Factors driving modern input use were found different from those of crop residues and organic fertilizer.

According to Solomon *et al.* (2014) study conducted on Climate variability, adaptation strategies and food security in Malawi, a multivariate probit (MVP) and instrumental variable technique were employed. The research result indicated that exposure to delayed onset of rainfall and greater climate variability as represented by the coefficient of variation of rainfall and temperature was positively associated with the choice of risk-reducing agricultural practices such as tree planting, legume intercropping, and soil and water conservation (SWC); however, it reduces the use of inputs (such as inorganic fertilizer) whose risk reduction benefits were uncertain.

Although extensive studies being done by many researchers on adoption of new technologies like new varieties, new farming practices, and recommendations to use or apply new research output, still there are more problems that needs further investigation on small holder farmer's farming system. For example, diffusion of adoption of CSA practices through farmer's own motivation, application of adoption of CSA practices on crops other than maize, local farmers' knowledge and experience like the very long ago established rules and principles of Oromo Gada systems contribution to fight the adverse impact of climate change and variability to conserve the natural resource and biodiversity.

3. Data and Methodology

3.1. Data

During the 2018/19main cropping season and using structured questionnaire, cross-sectional data was collected from 277 farm households operating on 551 maize plots. During the production season, 733 farmers from the two districts were hosted the CSA practices on their plots for the past two farming seasons. From Diga district, 137 sample households, and 258 sample maize plots were taken. While From Gimbi district, 140 sample households, and 351 sample maize plots were taken for the analysis. The survey data covered plot, household, and village level characteristics. Secondary data were compiled from Central Statistical Agency (CSA) and Historical temperature and rainfall data (from 1987-2017) from National Meteorology Agency of Ethiopia (NMAE), and reports of zonal and district offices of the two East and West Wollega Zones (2018) applicable to the subject matter of this study were collected to supplement the primary data.

The survey questionnaire, developed and constructed with CSPro version 7.2 (Census and Survey Processing System) software, which is a software package developed by the United States Bureau of the Census, was used as a main data collection tool. Besides, field observations, focus group discussions, and key informant interviews were also conducted to substantiate the collected survey data.

A multi-stage random sampling technique was employed to select representative sample farm households. In the first stage, East Wollega and West Wollega Zones were purposively selected for the reason that the climate-smart agricultural (CSA) practices as a pilot project was implemented by CIMMYT in these zones from Oromia National Regional State. In the second stage, Digga district from East Wollega zone and Gimbi district from West Wollega zone were also purposively selected for the same reason mentioned above. In the third stage, four *kebels* for Digga district, and six *kebels* from Gimbi district were randomly selected using probability proportional to size sampling technique. This study employed Kothari (2004) sample size determination formula. The formula is indicated as:

$$n = \frac{z^2 pqN}{e^2(N-1) + z^2 pq} \qquad (4)$$

Where: ‘n’ is the computed sample size, ‘z’ is the upper point $\alpha/2$ standard cumulative distribution at 95% level of confidence which is equal to 1.96, and ‘e’ is the acceptable error at a given precision rate (assumed 5%). The remaining ‘p’ is the estimated proportion of household’s adoption and impact of CSA practices which is assumed to be equal to 0.5 or 50%.

Most conservative cases, q = 1-p, and N is the total farm household population who participated in the CIMMYT's pilot project in the study area. Accordingly, the sample size for the study was:

$$n = \left[\frac{(1.96^2)(0.5)(0.5)(733)}{(0.05^2)(733) + (1.96)^2(0.5)(0.5)} \right] = \frac{703.9}{2.79} = 252 \qquad (5)$$

Including 10% contingency sampling a total of 277 farm households operating on 551 plots were selected based on probability proportional to size from a population of 733 farm households of CSA graduated farmers.

4. Analysis Results

4.1. Descriptive analysis

Out of 551 sample plots over which CSA practices were carried out, more than 37% of the sample plots adopted a single CSA practices (minimum tillage 14.9%, crop residue or permanent soil cover 17.2%, and intercropping 5.1%) (Table1). Of all the sampled plots, 16.9% were covered by all the CSA practices. The remaining 11.4% of the sampled plots were under non adopters of the CSA practices (Table 1).

Table 4.1: Summary of CSA practices adopted at plot level

CSA practices	**Total**		**Gimbi**		**Digga**	
	Freq.	**%**	**Freq**	**%**	**Freq**	**%**
Minimum tillage	82	14.9	31	5.6	51	9.3
crop residue (Permanent soil cover)	95	17.2	52	9.4	43	7.8
Intercropping	28	5.1	19	3.4	9	1.6
Full Adopters (three practices)	**93**	**16.9**	**48**	**8.7**	**45**	**8.2**
Non-adopters	**63**	**11.4**	**34**	**6.2**	**29**	**5.3**

Note: The three CSA practices considered in this study are Minimum tillage, Crop residue (permanent soil cover) and maize-legume crop association.
Source: Own Survey data (2018/19).

Farm households were asked about what kinds of farming practices they have been using on each plot he/she operates, giving more emphasis to CSA practices which the CIMMYT project has been operating in the study area (minimum tillage, intercropping and crop residue) with maize crop.

During the 2010/11 production season, 551 plots were under cultivation by 277 households surveyed from the two districts of the study area. The study was conducted to examine whether farmer adopts CSAPs on all or some of the maize plots. Accordingly, we could observe three categories of farm households: full adopters (if farmer adopted all the three practices on all the maize plots), and partial adopters (if one or two of the practices were used on the plots), and non adopters (if none of the practices was practiced on the maize plots).

Regarding distribution of maize plot based on the farmer's education achievement showed that there was a varying mean maize plot distribution. Larger portion of sampled maize plot land (47.6 %) was cultivated by farmers who attained primary school level. In contrast, fewer sampled maize plot land (7.8%) was cultivated by household heads that could read and write. Maize plot of 46.8%, 25.6%, 23.1% and 4.5% were cultivated by farm household who achieved educational levels of Primary Schools, Secondary school and above, illiterate and read and write respectively adopted Minimum tillage practices. The result of this study is consistent with the findings of many researchers (Solomon *et al*. 2016; Ali, E., 2021, Mebratu *et.al*. 2022). Most of the household heads have at least a basic level of education. Regarding to the adopters of crop residue, 47.1%, 26.3%, 18.7% and 8.0% of maize plots were cultivated by farm household who achieved educational levels of Primary Schools, Secondary school and above, illiterate and read and write respectively (Table 2). The result also agrees with the findings of many empirical studie (Bedeke, 2019; Ayenew *et al*., 2020; Dung, 2020; Sardar *et al*., 2021).

Descriptive analysis of the data shows that the mean experience in maize growing was 20.8 years. The mean experience in maize growing for minimum tillage, crop residue, and intercropping CSA practice adopters were19.6 years, 20.9 years, and 20.3 years respectively. Regarding the area of land allocated to maize crop, 0.43 ha, 0.41ha, and 0.38ha were allocated by farmers of minimum tillage, crop residue, and intercropping CSA practice adopters respectively (Table 2).The result also agrees with the findings of many earlier empirical studie (Issahaku and Abdulai, 2019, Ayenew *et al*., 2020; Sardar *et al*., 2021).

The survey results of the plot-level analysis indicated that majority of sample plots 467 (88.4%) were operated by male household heads of which 261 (55.9%), 278 (59.5%) and193 (41.3%) of sampled farmers' plots were adopters of minimum tillage, crop residue, and intercropping of CSA practices respectively (Table 2). Though gender on farm household heads are not equally proportional in the farming communities, the male household heads were observed to be better adopters of crop residue retention CSA practices of in the study area (Table 2). The result of this finding agrees with the findings of many empirical earlier studies (Fadina and Barjolle, 2018; Sardar *et al.,* 2021).

Table 4.2. Descriptive statistics of continuous and discrete variables used for the adoption of CSA practices at the plot level
Table 4.2 (continued)

Variables	Total (n=551)		Minimum tillage				Crop residue				Intercropping			
			Adopters (n=308)		Non adopters (n=243)		Adopters (n=327)		Non adopters (n=224)		Adopters (n=229)		Non adopters (n=322)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Dependent variables														
Adoption of CSA practices	551	100	308	55.9	243	44.1	327	59.4	224	40.7	229	41.6	322	58.4
Explanatory variables														
Age of household head	44	12.1	43.0***	0.7	43.0***	0.7	43.5***	0.6	44.7***	0.9	43.4***	0.7	44.2***	0.7
Own plot under maize	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Maize yield	614.7	184.5	643.9	196.1	476.8	167.4	545.7	138.8	529.6	148.2	591.4	125.5	452.9	153.4
Rented in land	0.5	0.3	0.3	0.2	0.6	0.3	0.4	0.35	0.5	0.3	0.7	0.3	0.4	0.3
Shared-in land	0.5	0.3	0.5	0.3	0.5	0.4	0.5	0.4	0.5	0.3	0.4	0.1	0.5	0.4
Experience in maize growing	20.8	11.5	19.6**	11.8	22.4**	10.9	20.87	11.6	20.76	11.4	20.33	11.3	21.2	11.7
Distance to all-weather road (minute)	26.4	32.4	26.4	29.3	26.4	36.3	30.7	36.6	20.7	24.9	27.2	33.2	25.8	31.9
Distance to dry weather road (minute)	13.7	18.5	12.0	13.4	16.2	23.7	16.2	21.1	10.1	13.1	15.6	23.5	12.4	13.9
Distance to DA office (minute)	22.0	19.5	20.3	17.4	24.1	21.6	24.2	21.9	18.9	14.9	20.9	17.1	22.7	21.0
Distance to district market (minute)	135.6	120.9	133.1	120.0	138.9	122.3	127.2	109.8	147.8	134.8	133.2	116.2	137.3	124.3
Distance to village market (minute)	39.0	39.0	42.5	41	34.2	35.7	43.2	43.8	34.2	32.2	41.2	40.0	37.5	38.4
Distance to farmer cooperative (minute)	39.0	60.3	38.9	62.9	39.2	57.3	42.5	58.9	33.9	62.2	46.5	77.5	33.8	44.0

Variables	Total (n=551)		Minimum tillage				Crop residue				Intercropping			
			Adopters (n=308)		Non adopters (n=243)		Adopters (n=327)		Non adopters (n=224)		Adopters (n=229)		Non adopters (n=322)	
	Mean	. Se	Mean	. Se	Mean	. Se	Mean	. Se	Mean	. Se	Mean	. Se	Mean	. Se
Distance to Fertilizer dealer (minute)	30.4	35.8	28.5	35.4	32.6	36.1	34.7	42.8	24.0	19.8	30.4	37.7	30.3	34.3
Distance to local grain mill (minute)	41.3	54.4	43.4	65.3	38.7	36.4	48.4	65.7	31.1	29.1	48.0	74.3	36.6	33.3
Herbicides and pesticide dealer (minute)	69.3	70.9	63.7	67.9	76.3	73.7	71.1	60.5	66.7	84.0	73.9	76.1	66.2	66.9
Distance to seed dealer (minute)	31.5	34.6	29.8	35.3	33.6	33.8	35.8	40.8	25.0	20.6	30.7	37.8	32.2	32.1
Distance to transport station (minute)	80.1	89.7	76.9	85.2	84.1	95.1	73.7	67.4	90.5	116.5	81.0	85.3	79.4	93.0

4.2. Econometric Analysis

The MVP model analysis of adoption of CSA practice at plot level showed that adoption of CSA practice was influenced by several variables. Among the variables found to have a significant influence on the adoption of CSA practice at plot level include the age, sex, education level of the farmer, family size, total land owned, experience in maize growing, family labor supply, distance to seed dealers, soil depth of the plot, and membership to farmers' cooperative (Table

4). The result obtained is consistent with the results of many previous researchers (Alam, 2015, Solomon *et al.* 2016; Faleye and Afolami, 2020; Mebratu *et.al.* 2022)

Table 4 shows that the age of farmers as a key factor of adoption of different CSA practices. Age of household head was positively and significantly influencing the adoption of Minimum Tillage and Crop Residue CSA practices. As the age of a farmer increases, they are getting older, and their strength for working strenuous agricultural activities will decrease. Thus, older farmers are vigorously looking for adoption of available technology, minimum tillage and crop residue in this particular study that could substantiate, save and increase their labor productivity as compared to adoption of intercropping.

Household head education achievement to primary level has a negative effect on the adoptions of minimum tillage. The result of this analysis is similar to the study result of Faleye and Afolami (2020). On the other hand, household head education achievement to secondary and above level is positively associated with the adoption of intercropping CSA practice.

The result of this study indicated that family size has negative association with the adoption of intercropping practice. Farmer's adopt labor saving farming practice like intercropping agriculture that could save family labor. The saved family labor could be used for other agricultural operation, or it may enable farmers to undertake different agricultural activities that could be concurrently undertaken like weeding and harvesting if intercropping CSA practices was adopted. According to Abdulai and Huffman (2014), households switch family labor from the agriculture to nonfarm activities like small businesses and trade, since agriculture has become very risky sector to climate change. The result of this study is similar to the study result obtained by many researches (Ayenew *et al.,* 2020; Mebratu *et.al.* 2022).

Farmer's experience of maize growing was another important variable that was significant and negatively influence the adoption of Minimum Tillage CSA practice. The coefficient of farmer's experience of maize growing was negative indicating that maize growers with less experience had a greater probability of adopting Minimum Tillage CSA practice than those who had large experience of maize growing. The possible reason behind this argument is that increased experience in maize growing of farmers would develop a specialization in maize growing, and specialization helps farmers to develop a more conservative outlook to their own- built farming practices than adopting new technologies in the short run(Table 4)..

Total owned plot size, as a key driver of adoption of different CSA practices, has a positive effect on the adoption of Minimum Tillage CSA practices. The result is convincing because farmers with larger landholdings are more likely to produce more and, hence, have more financial resources which enable them to purchase these modern agricultural inputs. The result also agrees with the findings of many empirical studies. This suggests that households who own more plots of farmland seem more probable to adopt Minimum Tillage CSA practices than farmers who own smaller plots of farmland. This could happen for farmers who owned large plot size could afford to allocate some plots of farmland for adoption of minimum tillage CSA practice than those farmers who own smaller farm size. The result of this analysis was consistent with the findings of many previous researchers (Mihretu *et al.*, 2017; Fadina and Barjolle, 2018; Ayenew *et al.*, 2020; Dung, 2020; Sardar *et al.*, 2021).

Biophysical plot characteristics, especially soil depth of a plot was also found to be important determinants of adoption of CSA practices. As the soil depth of increases the top soil becomes fertile, and farmers are more thoughtful to maintain the fertility of his soil applying available strategies. As analysis of the study result indicates, the medium soil depth was found to be positively associated to the adoption of minimum tillage and crop residue CSA practices. The result of this study in consistent with the findings of researchers (Solomon *et al*. 2016).

Table 4.3. MVP Estimates of determinants of adoption of CSA practice at plot level

Variables	**Adoption of CSA practices**		
	Minimum tillage (n=308)	Crop residue (n=327)	Intercropping (n=229)
	Coeff.(SE)	Coeff.(SE)	Coeff.(SE)
Age (*years*)	0.023** (0.011)	0.020* (0.012)	0.004 (0.011)
Male headed household (*1=yes*)	-0.213 (0.337)	-1.21*** (0.377)	-0.169 (0.305)
Education level			
Read and write	-0.174 (0.364)	0.041 (0.384)	-0.379 (0.373)
Primary School	-0.100** (0.233)	0.016 (0.232)	0.543*** (0.229)
Secondary School and above	0.169*** (0.281)	0.384 (0.301)	0.517** (0.267)
Divorced house hold head	0.401 (0.604)	-2.290*** (0.612)	0.699 (0.601)
Family size	-0.020 (0.074)	0.060 (0.076)	-0.161*** (0.072)
Male family members labor supply	-0.073 (0.100)	-0.048 (0.101)	-0.058 (0.094)
Female family members labor supply	-0.214** (0.104)	0.127 (0.114)	-0.118 (0.098)

Table 4 (continued)

Oxen owned (*number*)	0.010 (0.014)	-0.313* (0.128)	-0.170 (0.124)
Livestock owned (TLU)	-0.050 (0.027)	0.029 (0.029)	0.039 (0.027)
Total land owned	0.150** (0.065)	0.081 (0.065)	0.010 (0.062)
Experience maize growing (*years*)	-0.028*** (0.011)	-0.007 (0.012)	-0.005 (0.010)
Maize yield	0.011** (0.01)	0.001 (0.01)	0.021* (0.01)

Distance to DA	-0.003 (0.004)	-0.0012 (0.005)	-0.007 (0.004)
Distance to fertilizer dealer	0.004 (0.004)	-0.008 (0.004)	-0.006*** (0.004)
Distance to seed dealer	-0.008** (0.004)	0.010** (0.004)	-0.005*** (0.004)
Distance to transport station	-0.002 (0.001)	-0.002 (0.002)	-0.001 (0.001)
Soil fertility level**:** *Poor is reference*			
Medium	0.393 (0.301)	-0.482 (0.321)	0.062 (0.286)
Good	0.066 (0.303)	-0.431 (0.330)	0.071 (0.290)
Soil slope level**:** *Flat is reference*			
Medium	-0.343 (0.367)	-0.557 (0.377)	-0.223 (0.353)
Gentle	-0.422 (0.370)	-0.492 (0.373)	-0.336 (0.355)
Soil depth**:** *Deep is reference*			
Medium	0.59*** (0.203)	-0.470** (0.220)	-0.154 (0.202)
Shallow	0.498 (0.362)	-0.73** (0.364)	-0.078 (0.346)
Social net work			
Member to devel. team	-0.297* (0.202)	0.399** (0.202)	0.314 (0.198)
Idir	-4.549 (159.4)	-4.340 (166.9)	-5.488 (149.0)
Equib	0.265 (0.192)	0.012 (0.195)	0.429** (0.179)
Members to farmers coop.	-0.73*** (0.190)	0.252 (0.191)	0.225 (0.178)
Members to farmers association	0.248 (0.210)	0.704*** (0.214)	-0.446*** (0.196)

Table 4 (continued)

Member to saving and credit	0.158 (0.169)	0.548*** (0.175)	-0.013 (0.160)
Const.	5.91 (139.3)	0.548 (167.9)	5.601 (148.97)
atrho21	0.026***(0.099)		

atrho31	0.289***(0.097)
atrho32	0.208 ***(0.098)
Observation	*551*
Wald Chi² (296)	*217.2*
Prob >Chi²	*0.0004*

*Note: Likelihood ratio test of rho21 = rho31 = rho32 = 0: $Chi^2(3) = 13.66$ Prob > chi^2 = 0.0034; *** p < 0.01, ** p < 0.05, * p <0.1.*
Source: Own Survey data (2018/19).

5. Conclusions and recommendation

Severe climate change-related upshots pose multiple threats to the welfare of farming community mainly by reducing crop yield. Governments in collaboration with civil societies including NGOs, scientific communities, private sectors, and other stockholders should device adaptive strategies so as to minimize and mitigate the burden of climate change and variability consequences.

Increasing agricultural productivity is the primary objective to adopt CSA practices beside intended ultimate goal of minimizing the adverse effect of climate change and variability. Therefore, the results of this study should be interpreted with household productivity maximization objectives in mind. Though farmers were introduced to a package of three practices (minimum tillage, crop residue and intercropping) for two consecutive seasons, there was only handful of farmers who adopted these three packages as they are. Farmers are more likely to adopt one or more of the CSA practices accounting for interdependent and simultaneous adoption decisions than to adopt a single practice. To account for this interdependency, a multivariate probit (MVP) technique was applied to multiple plot observations to jointly analyze the factors that increase or decrease the probability of adopting each agricultural practice in this article. Farmers' adoption of multiple CSA practices is significantly influenced by Education achievement to Primary School, household head sex being male, age of household head, family size, experience in maize growing, medium type of soil depth of a plot, household head member ship to development team, farmers cooperatives, and saving and credit service institutions. Some key policy implications come into view from this study in maize growing rural farmers, who are vulnerable to climate change and variability in Gimbi and Digga districts of the study. Overall, this study puts emphasis on the heterogeneity rural farmers with resource endowment and utilization as a basis for making decision to adopt available agricultural practices so as to shield against the exposure to climate change and variability.

Most importantly, the result of this study suggests very strong consideration on scaling up farmer’s skill and understanding of farming systems. To this end, a primary means is through provision of formal and non-formal education by the provision of educational facilities to rural farmers, better education equips farmers with necessary understanding and promptly respond to climate change and variability, and then building household and system-level capacity development contributing long term benefit from the adoption of CSA practices. Providing formal education to all rural farmers requires long term plan. However, to overcome the limitation brought about lack of formal education to better understanding on CSA benefits, natural resource use and its conservation, a short run capacity improvement program has to be arranged to farmers.

Farmer's experience in growing maize was another important variable that negatively influenced the adoption of Minimum Tillage practice. Thus, farmer's experience sharing for maize grower farmers has to be promoted for it can help to break information asymmetry among rural farmers to promote the probability of farmers' adoption of CSA practices.

Finally, government and other non-governmental organizations should focus and strengthen training rural farmers on economical use of resources and thereby boost their product. In most rural areas, due to increased population, to feed their family, there is a widespread competition and unwise use of natural resources especially clearing forest areas and putting under cultivation of marginal lands without appropriate use of agricultural conservation systems. Such a laissez-faire approach on land use, if continued indefinitely, will eventually intensify environmental degradation and climate impacts and as a result, rural farm households, especially the poor farmers can be caught up with no way out from the population-environment-poverty-trap. Thus, government should device and put into effect appropriate family planning to ease the crises emanating from increasing population.

All of the CSA practices adopted in the study area could be seen as a short-term intervention that could maintain and enhance soil fertility, and in the long term could develop small holder farmer's adaptation capacity to climate change and variability. Thus, the dissemination of information on the benefits of CSA adoption should be emphasized so as to intensify the adoption and diffusion of CSA practices among rural farmers.

Minimum tillage is one of the three core components of CSA practices being adopted in the study area. Minimum tillage requires a onetime furrowing of the farm land, and hence it contributes to minimize soil disturbance and soil compaction, and improve soil structure and infiltration. Further it saves both manpower and draft power that would be used for for minimum tillage application. Thus, Policy makers and pro-development organizations should emphasize the dual benefit of this particular CSA practices so that farmers appreciate the practice and easily adopt it.

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