Poverty and Resilience impacts of conservation agriculture adoption against Climatic-Shocks in Eastern Ethiopia

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Abstract

The aims of this study is to analysis adoption and impacts of conservation agriculture on poverty and resilience to drought in Eastern Ethiopia. Multi-stage sampling method was employed and four districts were randomly selected from Eastern Hararghe Zone. Using cross-sectional survey data collected in 2023 from 430 households, multinomial endogenous switching regression was applied in impact evaluation. The result shows farm experience, education, climatic-socks experience, access to climate information, access to extension, number of oxen, farm size, labor force, livestock and distance to market are determinants of CA adoption in terms of inter-cropping, crop rotation and crop residue retention or mulch practices in its single and combination of practices. Poverty was evaluated based on cost-of-basic-need and resilience to drought is in its index. Results of average treatment effect on treated shows adoption is significantly reduced poverty and increased drought resilience index in the area. The study shows importance role of extension service in adoption of CA practices. Policy implication for these results is that there is a need to encourage extension facilities and awareness to promote better adoption of CA particularly, in its combination. Because, combination of practices increased consumption adopters by 73.3 percent compared to non-adopters, given its significant impact on households' poverty and resilience to drought in moisture stress area of eastern Ethiopia.

***Keywords**: Poverty, resilience to drought, conservation agriculture, MESR model*

1 INTRODUCTION

Climate change has emerged as a major threat to agriculture and rural livelihoods [1]. Climate shocks are defined as events that exceed the capacity of society, including drought and floods [2], and that lead to low agricultural productivity [3, 4]. Droughts are complex climate shocks ranging from one-month moisture stress to decades [5]. Ethiopia is facing drought after three consecutive failed rainy seasons since late 2020, affecting 8.2 million people, and difficulty recovering from drought in 2017 that continued to worsen with successive failed rainy seasons in 2021[6]. Climatic-shock events are challenging agriculture [7] and worsen food security [6]. Mitigating the variability of climatic shocks helps to minimize the drought effect [1].

The severe rural poverty problems adversely impacts the resilience to drought by reducing their coping capacity [5]. In response to climate change (CC), adoption of climate smart agricultural (CSA) practices has been implemented as alternative strategy to support food security [8, 9]. These practices including conservation agriculture, implemented in Ethiopia to improve livelihoods [10, 11, 12]. Conservation agricultural practices minimizing stresses such as drought [13] and helps farmers to be more resilient [14]. It is aimed at rehabilitating the adverse effects caused by soil erosion, soil organic matter decline, soil water loss and soil degradation to improve soil moisture holding [15, 16]. Mulching is a method of covering soil on the surface of land with crop biomass and cover crops [8, 17]. In Ethiopia, identifying how to build households' resilience to drought is essential [12]. Thus, conservation agriculture is among those practices that encourage the linkage between climate change, soil fertility, resilience to drought and rural poverty.

Currently, there is related literature on conservation agriculture, mainly on factors affecting adoption [18,19, 20]. Most of the literature shows an increased weed effect due to minimum tillage [20], but others focus on its benefits [21]. Other literature on the impacts of technology on productivity [20, 22, 23, 24], impact on crop income [19] and impact of practices on farm labor [25, 26]. There is also other literature on the impacts of CA on food security [27, 28, 29]. However, there are limited studies related to the impact of conservation agriculture on poverty [30, 31], with the exception of [32], which shows CA minimizes the occurrence of poverty in Zambia. Even if the Ethiopian government has made different efforts through implementing various adaptation strategies and policies to increase agricultural production, the adoption of climate-smart agricultural practices, including CA, is very low, resulting in low production[33,34,35]. But it is very important to identify the impact of conservation agriculture in terms of intercropping, crop rotation, crop residue retention, or mulch practices in relation to resilience to drought and poverty in eastern Ethiopia.

There is also literature that focuses on the impacts of single technologies on households' poverty and income [36,37]. However, these studies used OLS and logit-based PSMs [37, 38, 39] for impact evaluation models that are criticized for selection bias, endogeneity, and heterogeneity problems. To reduce the problems of selection bias and endogeneity, a multinomial endogenous switching model was implemented in this study. This model is used to correct self-selection bias]40], and it takes into account both observed and unobserved factors to generate consistent and efficient estimates, even when the assumption of the independence of irrelevant alternatives (IIA) fails[41].

Moreover, the study area has been highly affected by drought and food insecurity [42], and that aggravated by drought [43], decreasing productivity from time to time [44], resulted in crop failure [45,46]. In response to this drought, farmers are participating in different adaptation strategies [47]. Similarly, in the area, there are different best practices that are considered as conservation agriculture to reduce soil moisture deficits and improve soil water use efficiency. These methods include the timely removal of leaves from the main cash crop, like 'khat', which reduces evapotranspiration and is then used as soil cover, minimizing soil moisture stress.

However, there were insufficient empirical studies on the issue, and to the best of my knowledge, there are no studies on the impacts of conservation agricultural practices on resilience to drought and poverty in the study area. So, the present study attempts to fill this gap and contributes to the existing literature on these issues. Therefore, the main objectives of this study are to analyze factors affecting the implementation of conservation agricultural practices and their impacts on households' resilience to drought and poverty reduction in the moisture stress area of Eastern Ethiopia.

2 METHODOLOGY

2.1 Study Area

The study was conducted in East Hararghe Zone mainly in Goro-gutu, Kersa, Babile and Gursum districts. The East Hararghe zone is located in Eastern Ethiopia between 07º 36′ N and 09º 41′ N and 41º 18′ E and 43º 00′ E and area of about 24,933 km^2 with lowland (67.8%), midland (24.5%) and highland (7.7%). The total population was 2,723,850 of whom 1,383,198 are men and 1,340,652 are women whereas 211,606 and 2,502,365 of them are urban and rural, respectively [48]. Crops grown in the area includes sorghum, groundnut, khat, coffee, pulses, and vegetables. Khat is an economically important cash crop in the area [49].

2.2 Types, Sources, Methods of Data Collection and Sampling Procedure

2.2.1 Types and sources of data

Both primary and secondary data were used. Primary data was collected from farmers and, secondary data from government offices, central statistics agency and published and unpublished documents. Data was gathered on the plot, crops type and shocks related with each crop grown on plot. This study also used meteorological data from National Metrological Agency for the last 33 years on rainfall for (1990–2022).

2.2.2 Methods of data collection

Household survey: Questionnaire was used to collect the primary data on household characteristics, resource, shocks and types of crops grown on each plot and their production. Finally, enumerators were trained for one day on questionnaire and how to collect data using tablet and smart phone using kobo tool box application. Focus group discussion (FGD) of 8-12 individuals was arranged to collect information. Regarding ethics approval, this study involved a questionnaire-based survey of farmers and No human or animal tissues were used. The study procedure was assessed and approved by Fadis Agricultural Research Center under Oromia Agricultural Research Institute. Moreover, participants provided their verbal informed consent for the survey questions.

2.2.3 Sampling procedure

Multi-stage sampling method was employed and four districts were randomly selected for data collection. Next, *kebeles* were selected randomly. Lastly, sample household were selected using probability proportional to population size (PPPS). To determine sample size [50] formula was used.

$$n = \frac{Nz^2pq}{e^2(N-1)+z^2pq} = \frac{13450*(1.96)^2*0.5*0.5}{(0.05)^2(13450)+(1.96)^2)*0.5*0.5} \approx 374 \quad (1)$$

Where: n = is the minimum sample size, N = is the estimated households comprising both adopters and non-adopters and p= proportion of adopter, q = (1-p), or non-adopter: where p is 0.5 which is taken for developing countries population and, e = acceptable margin of error that is 5% for this study. Or Z = 1.96. However, the total sample size was 430 households including 56 households that were included to provide contingencies for errors associated with data collection.

2.3 Method of Data Analysis

2.3.1 Measurement and Extent of Household Poverty Line in the Study Area

To analysis impacts of conservation agriculture on poverty, poverty line should be estimated first. There are three methods of poverty line estimation. The first method is direct caloric intake method that considers nutritional requirement of 2200 Calories per day per person. It need to know the quantity of food item consumed and calculate total calorie content of the food consumed then derive an equivalent daily caloric intake per capita for each household. The second method is food-energy intake that finds the value of per capita total consumption at which a household can be expected to fulfill its caloric requirement, and determines poverty based on that expenditure. Expenditure includes an allowance for both food and non-food. It does not need price but needs to rank households by their per capita caloric intakes and calculate expenditure for households who consume specified per capita caloric intake requirement.

The third method to estimate the poverty line is the cost of basic need (CBN) method because the indicators will be more representative and the threshold will be consistent with real expenditure across time, space and group following [51]. This technique is based on the evaluated cost of the bundle of goods sufficient to ensure that basic necessities are met. Constructing a line begins with defining and selecting a basket of food items regularly consumed by rural poor. In this study 50 percent of rural poor households was identified as reference group based their wealth ranking of per capita income and then identified their common food items. Food consumption behavior of reference group was identified to determine average quantities in per AE of basic food that makeup reference food basket. Accordingly, food basket makes up of the 22 food items were observed. Then each food consumed by reference group was evaluated by calorie value of each food by using [52] of nutrition table.

The consumed Kcal of food item was scaled out to generate 2200Kcal per day per AE, which is minimum food calorie to lead healthy life and valued this food items by local average price then generate food poverty line of the area. Finally, household was evaluated based on expenditure per AE using nutrition based AE conversion factors. In food poverty line estimation, total calorie obtains from consumption of this basket of quantity per adult is:

$$\sum q_i Kcal_i = T^* \text{ With } T \cong T^* \text{ but } T \neq T^* \quad (2)$$

Where T^*=total calories obtained by individual from mean quantities of food, qi = quantity per adult consumed of food item 'i '. $Kcal_i$ =the caloric value of the respective food item ' i 'consumes by adult. T = recommended calorie of per day per adult that is 2200 kcalorie in this cases. The average quantity per adult of each food item should be scales up and down by a constant value of $\left(\frac{T}{T^*}\right)$, in order to provide total of 2,200kcalorie per adult per day. Then, multiply each food items after scaling up and dawn by the average local price and sum up to get a food poverty line. That become minimum amount of money that a household needs to purchase basic-needs of food bundle. The food expenditure poverty line was calculated per year per AE and the poverty line was used to categorize households as poor and non-poor [51].

Evaluation for non-food expenditure is important to get total poverty line after determining the food poverty line. The non-food share of total expenditure estimates through regressing the food share (s_i) of each household 'i' on a constant and the log of the ratio of total consumption expenditure to the food poverty line (Z_{fod}). Regression approach estimates the share of non-food basic needs by applying a linear regression for the households, which are sampled in the same way as Engel's coefficient approach. Following [53] a food-share Engel curve is written as follows:

$$Si = \alpha + \beta \log\left(\frac{Y_I}{Zf^*}\right) + \varepsilon_i \quad (3)$$

Where Si denotes the share of food items from the total household's expenditure, Yi refers household's total consumption expenditure, Z_{fod} is the food poverty line, β regression coefficient ,**α** is intercept of the food share when Z_{fod} = Yi, and εi refers error term. The household spends all of its expenditure on food baskets with equal amount of the food poverty line i.e., consumption expenditure (Z_{fod} = Yi) food share is equal to the amount of the constant value "α" , and then non-food share of the reference group becomes (1−α).So, α can be interpreted as the mean food share of households that can have enough money to buy basic food needs and $1 - \hat{a}$ shows the share of non-food needs in compared to basic food needs. Therefore,

$Z_{nofod} = Z_{fod}$ (1-α) , Where Z_{fod}= food poverty line and Z_{nofod} = non-food poverty line

Thus, the total poverty line of the population for the study area is given as: $Z_{tot} = Z_{fod}$ (2−α)

The study used annual consumption expenditure per adult equivalent to measure household poverty in the area. Comparison also involves estimation of poverty line that is from summation of food poverty line and non-food poverty from cost of basic need approach. The study also used poverty indices to estimate the percentage of the poor (headcount index), the aggregate poverty gap (poverty gap index) and the distribution of income among the poor (poverty severity index) as presented by [54]. It comprises the most desirable properties of a poverty index and defined as:

$$P_a = \frac{1}{n}\sum_i^q\left(\frac{Z-Y_i}{Z}\right)^a \qquad \alpha \geq 0 \text{ for } Yi \leq Z \quad (4)$$

Where Pα is a measure of poverty, **z** is the poverty line (in terms of consumption expenditure), n is total population, q is total number of poor whose consumption expenditure is below the poverty line and Yi is the total per adult equivalent consumption expenditure estimated for the i^{th} poor household. When α = 0, the formula reduces to the headcount ratio that measures the proportion of households below the poverty line. When α = 1, it provides the poverty-gap that shows the extent of poverty that shows how poor are far from the poverty line. When α = 2 measure degree of inequality among poor.

2.3.2 Method of households' resilience to drought measure

The resilience to drought was estimated as an index from consumption and income as indicators using the principal component analysis (PCA) method [55,56].Different variables may be used to observe drought effects and this needed the use of principal component analysis (PCA) due to its preserving the maximum proportion of the total variation in the original variables[57]. Determinants of household resilience to droughts drawn from the literature [55, 56, 58, and 59] and also adopted then used to construct a drought resilience index (DRI) for this particular study.

So, different variables including proportion of food consumed by households during droughts (PFd) as compared to normal season in the area, months of food scarcity by households (MFs), and consumed meals per day in times of scarcity (CMs) as measures of consumption smoothing capacity and number of alternative sources of income (NSI) and proportion of total income that is off-farm/non-farm (PTI) as measures of income stability was also used. Generally, drought resilience index (DRI), constructed by principal components analysis (PCA) based on mentioned variables and used as outcome variable.

Drought Resilience Index **(DRI)** = $PFd w_d + MFs w_m + CMs w_s + NSI w_i + PTI w_t$ (5)

Where w_n, $n = d, m, s, i, t$ is value that was explained by the given factor in PCA that used as weights.

2.4 Econometrics Model

This study estimates the impact of Conservation agriculture (CA) on household poverty and resilience to drought. Households' choice to adopt CA as random utility framework in which they choose one or more combination of practices that increase utility following random utility framework [60, 61, 62]. The farmer makes polychotomous adoption decision whether to adopt CA as: cereal- legume inter cropping (L), crop rotation (R) and crop residue retention or mulch (M) and with their combinations. The choice of these three CA practices in isolation or in combination leads to eight mutually exclusive practices including reference categories. Considering the adoption of multiple CA practices, a farmer may decide to adopt either a single CA practice or a combination of CA practices, if the expected benefit from adoption of CA practices is higher than the benefit from non-adoption.

Analyzing impact of CA on household resilience to drought and poverty outcomes may subject to various endogeneity problems. Since adoption behavior is not random, CA choice decision is likely to be determined by unobserved characteristics that also be correlated with poverty and resilience to drought following [63, 64].There is doubt of self-select into conservation agricultural practice due to its non-randomness assignment similar to [65]. So, regression of the outcomes on CA adoption without correcting for the self-selection may lead to incorrect estimates for the effects of CA practices adoption. This motivates the implementation of an MESR (endogenous switching regression) that accounts for both endogeneity and sample selection following [40] and implement the method of [41] to correct for selection bias. MESR also accounts for both self-selection bias and the relation between the choices of different adoption practices [66, 67] as well as unobserved heterogeneity related with estimations of the non-random adoption of CA practices. In contrast to other impact evaluation methods, such as the propensity score matching (PSM) which only controls for observed heterogeneity [68], this approach has a benefit since it allows the establishment of a counterfactual based on adopters' and non-adopters' characteristics [61].

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The technique involves two stages. In the first stage, the farm household's choice of combination of CA practices was evaluated using a multinomial logit selection model while identifying the interrelations among the adoption of different CA practices. In the second stage, the impacts of each of the CA practices on the poverty and resilience to drought outcome indicators were estimated using ordinary least squares (OLS) with included selectivity correction term from the first stage.

2.4.1 Multinomial adoption selection model of conservation agriculture practice

At this stage, Multinomial Logit was applied to determine the factors affecting adoption of conservation agricultural practices. Farmers assumed to maximize their consumption expenditure and resilience to drought status, Yi by comparing the amount of consumption expenditure per AE (Poverty proxy) indicators and resilience to drought (DRI) provided by M alternative CA practices. The necessity for farmer i to adopt any CA, j over other alternatives M is that $Y_{ij} > Y_{iM}, M \neq j$ that is j provides higher expected consumption expenditure than any other practices. Where Y_{ij}^* is a latent variable that represents the expected outcome which contains the observed households and unobserved features:

$$Y_{ij}^* = X_i\beta_j + \varepsilon_{ij} \quad (6)$$

X_i captures the observed exogenous variables household level characteristics while the error term ε_{ij} captures unobserved characteristics. The covariate vector X_i is assumed to be uncorrelated with the idiosyncratic unobserved stochastic component ε_{ij}, that is: $E(\varepsilon_{ij}/X_i) = 0$. Under the assumption that ε_{ij} are independent and identically Gumbel distributed that is under the independent irrelevant alternatives (IIA) hypothesis [41]. The selection model Eq. (6) leads to a multinomial logit model [69] where the probability of choosing adoption practices j (p_{ij}) is:

$$P_{ij} = \text{p}(\varepsilon ij < 0/\text{Xi}) = \frac{\exp(X_i B_j)}{\sum_{M=1}^{j} \exp(X_i B_M)} \quad (7)$$

2.4.2 Multinomial endogenous switching regression model for impact evaluation

Multinomial endogenous switching regression approach is used to correct self-selection bias following [40] and provide treatment effect that takes both observed and unobserved factors into account. This approach helps to get both consistent and efficient estimates of the selection and correction for the outcome equations [41]. And it was used to investigate the impact of each response of CA practice adoption on poverty and resilience to drought indicator by applying selection bias correction model. Farm households can face a total of M regimes with regime $j = 0$ being the reference category (non-adopters).The annual consumption expenditure per AE and resilience to drought equation for each possible regime can be defined as the following equation:

$$\text{Regim1:} Q_{i0} = Z_i \alpha_0 + \mu_{i0} \quad \text{if} \quad \text{i}=0 \quad (8) \quad .$$
$$\text{Regim j:} Q_{ij} = Z_i \alpha_j + \mu_{ij} \quad \text{if} \quad \text{i}=\text{j}$$

From this, Q_{ij} '*s* represents the expenditure or drought resilience index of the i^{th} farmer in regime j and the error terms μ_{ij}'*s* are distributed with $E(\mu_{ij}\backslash \text{x}, z) = 0$ and $\text{var}(\mu_{ij}|\text{x, z}) = \sigma^2_j$. Q_{ij} is observed if, and only if, practices j is used, which occurs when $Y_{ij}* > Max_{M\neq 1}$ (Y_{im}). If error terms in (6) and (8) are not independent, OLS estimates for equation (8) is biased. Consistent estimation of α_j requires inclusion of selection correction terms of the alternative practices choices in equation (8). MESRM assumes the following linearity assumption: $\text{E}(\mu_{ij}|\varepsilon_{i0}\ldots\ldots\varepsilon_{ij)} = \sigma_j \sum_{m\neq j}^{j} r_j\ (\varepsilon_{im} - E(\varepsilon_{im}))$. The correlation between the error terms in (6) and (8) is assumed zero. Using the above assumption, equation (8) can be:

$$\text{Regim1:} Q_{i0} = Z_i \alpha_0 + \sigma_{i0} \lambda_i + \omega_{i0} \quad \text{if} \quad \text{i=0} \quad (9)$$
$$\text{Regim j:} Q_{ij} = Z_i \alpha_j + \sigma_j \lambda_j + \omega_{ij} \quad \text{if} \quad \text{i=j}$$

σ_j Is the covariance between ε'*s* and μ'*s* while λ_j is the inverse Mills ratio computed from the estimated probabilities in equation (7) as the following equation:

$$\lambda_j = \sum_{m\neq j}^{j} \rho_j \left[\frac{P_{imLn(P_{im})}}{1-P_{im}} + \ln(P_{im})\right]$$

ρ_j in the above equation represents the correlation coefficient of ε'*s* and μ'*s* while ω_{ij} are error terms with an expected value of zero. In the multinomial adoption, there were $j-1$ selection correction terms, one for each alternative CA practice. The standard errors in equation (9) were bootstrapped to account for the heteroskedasticity arising from the generated regressors given by $\lambda_{j..}$ The second term, is selection term that captures potential effects of difference in unobserved variables.

2.4.3 Estimation of conditional expectations and average treatment effects of treated

In this MESR models implementation, counterfactual analysis was done to examine average treatment effects (ATT) by comparing the expected outcomes of adopters with and without adoption of a particular practices. ATT in the actual and counterfactual cases was determined as follows based on [70,71]:

Poverty status or drought resilience index with adoption of CA

$$\text{E}(Q_{i1}/\ \text{i=1}) = Z_i \alpha_1 + \sigma_1 \lambda_1 \quad (10_a)$$
$$\text{E}(Q_{ij}/\ \text{i=j}) = Z_i \alpha_j + \sigma_j \lambda_j \quad (10_b)$$

Poverty status or drought resilience index without adoption (counterfactual)

$$\text{E}(Q_{i0}/\ \text{i=1}) = Z_i \alpha_0 + \sigma_0 \lambda_1 \quad (11_a)$$
$$\text{E}(Q_{i0}/\ \text{i=j}) = Z_i \alpha_0 + \sigma_0 \lambda_j \quad (11_b)$$

ATT can be defined as the difference between (10a-11a) which is given by:

$$\text{ATT} = \text{E}(\text{Q}_{i1}\backslash\ \text{i=1}) - \text{E}(\text{Q}_{i0}/\ \text{i=1}) = \text{Z}_i(\alpha_1 \alpha_0) + \lambda_1 (\rho_1 - \rho_0) \quad (12)$$

The right hand side indicates the expected change in adopters' mean poverty status; if adopters' characteristics is the same as non-adopters for instance while λ_j is the selection term that captured all potential effects of difference in unobserved variables.

3 RESULTS AND DISCUSION

3.1 Descriptive statistics

3.1.1 Socio-demographic and economic characteristics of the respondents

In this study adopter means households that have adopted at least one of CA practices on one of his plot. Table 1 shows eight possible practices in the area. So out of total sample of 430, 10.5 percent are non-adopters ($L_0R_0M_0$), whereas 11.2 percent, 8.8 percent, 7.0 percent, 33.7 percent and 12.3 percent are adopters of intercropping ($L_1R_0M_0$), adopter of crop rotation ($L_0R_1M_0$), adopters of crop residue ($L_0R_0M_1$), intercropping and crop rotation ($L_1R_1M_0$) and adopters of full combination ($L_1R_1M_1$), respectively.

Table 1 Description of conservation agriculture practices

No	Practices	Legume inter-cropping	Crop rota-tion	Mulching/Residue reten-tion	Frequency	Percent
1	$L_0R_0M_0$				45	10.5
2	$L_1R_0M_0$	√			48	11.2
3	$L_0R_1M_0$		√		38	8.8
4	$L_0R_0M_1$			√	30	7.0
5	$L_1R_1M_0$	√	√		145	33.7
6	$L_1R_0M_1$	√		√	35	8.1
7	$L_0R_1M_1$		√	√	36	8.4
8	$L_1R_1M_1$	√	√	√	53	12.3
Total					**430**	**100.0**

Source: Author data results (2023)

The results presented in Table 2, shows the mean consumption expenditure per adult of all adopters of all CA practices was found to be 10280.94ETB out of which adopters of intercropping ($L_1R_0M_0$) have mean of 8472.8ETB, adopter of crop rotation ($L_0R_1M_0$) have mean of 10506.1ETB, adopters of crop residue retention or mulching ($L_0R_0M_1$) have 13743.3ETB, adopters of intercropping and crop rotation ($L_1R_1M_0$) have 9014.5ETB, and adopters of all combination of CA ($L_1R_1M_1$) have mean of 14659.9ETB in consumption expenditure per adult whereas the mean of consumption of non-adopters ($L_0R_0M_0$)was found to be 8472.8ETB in the study area. The mean age of all adopters is 37.4 years, the average farm experience of adopters is 23.9, the average farm size is 0.47 ha and average dry experience or climatic shocks is 3.7 years with in the last 10 years. On average adopters have 3.22 livestock in TLU and 1.3 number of oxen in the area. Out of total sample, 54 percent of the respondents were male with 66.5 percent of respondents were accessed extension service and 60.2 percent were accessed climate information.

Similarly, the mean households resilience to drought for adopters of intercropping ($L_1R_0M_0$) is 2.04, adopter of crop rotation ($L_0R_1M_0$) have mean of 4.38, adopters of crop residue or mulching ($L_0R_0M_1$) have 3.09, adopters of intercropping and crop rotation ($L_1R_1M_0$) have mean of 2.2, and adopters of all combination ($L_1R_1M_1$) have mean of 2.12 in drought resilience index whereas the mean of index for non-adopters ($L_0R_0M_0$) was found to be 3.56 in the study area.

Table 2 descriptive summary of selected variables used in estimation

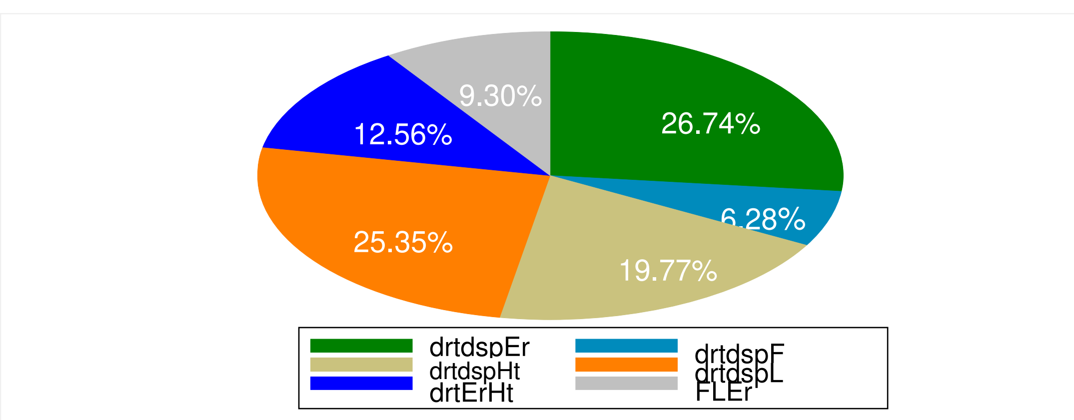
Non-Adopter	Adopters of

	$L_0R_0M_0$	$L_1R_0M_0$	$L_0R_1M_0$	$L_0R_0M_1$	$L_1R_1M_0$	$L_1R_0M_1$	$L_0R_1M_1$	$L_1R_1M_1$
Variables	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)	Mean(SD)
Expenditure	8206.1	8472.8	10506.1	13743.3	9014.5	9525.4	11524.7	14659.9
DRI	3.56	2.04	4.38	3.09	2.2	1.94	2.62	2.12
Age	46.09 (9.5)	38.52 (13.2)	36.66 (11.1)	34.70 (11.1)	36.76 (10.6)	37.03 (10.4)	38.11 (9.0)	39.26 (11.6)
Farm Experic	14.67(6.4)	20.83(6.2)	22.89(6.6)	28.83(3.5)	23.75(8.3)	23.23(8.7)	23.50(8.0)	25.83(7.3)
Education	1.47(1.2)	3.44(3.13)	4.50(4.0)	4.03(3.4)	6.00(3.9)	4.171(3.6)	6.17(2.9)	7.25(2.7)
Dry Experien	3.27(1.14)	3.29(1.05)	3.18(1.06)	4.13(1.14)	3.72(1.39)	4.29(1.51)	3.83(1.61)	3.83(1.49)
Family Size	6.02(2.45)	6.52(2.04)	6.00(2.05)	5.80(1.96)	6.43(2.25)	5.69(1.89)	6.50(2.47)	6.11(2.19)
Labor Force	4.09(1.73)	5.19(1.48)	4.87(1.73)	4.63(1.63)	4.99(1.53)	5.46(1.40)	4.75(1.52)	5.08(1.27)
Farm Size	0.42(.18)	0.49(0.22)	0.44(.17)	0.44(.17)	0.48(.19)	0.51(.25)	0.51(.25)	0.43(.21)
Plot Number	2.067(.94)	2.38(.98)	2.21(1.02)	2.23(.86)	2.71(1.08)	2.29(1.05)	2.56(1.08)	2.45(1.07)
Market distanc	10.04(4.9)	8.25(5.6)	10.32(5.8)	8.67(4.9)	11.42(5.7)	10.29(7.2)	12.78(4.9)	12.30(5.9)
Livestock	1.01(0.63)	2.41(1.91)	3.16(1.80)	2.14(1.60)	3.37(2.58)	2.57(1.87)	4.08(3.56)	4.07(2.99)
Oxen Numbr	0.87(1.18)	0.85(1.35)	1.10(1.33)	0.73(1.36)	1.41(1.54)	1.17(1.49)	1.58(1.48)	1.79(1.46)

Source: Author result (2023), DRI=drought resilience index, Expenditure =Consumption Expenditure in ETBirr(ETB)

3.1.2 Major climatic-shocks and rainfall trends in the area

The farmers were asked to list the most three important climatic-shocks challenging them with in the last ten years and result was presented in figure 1. Out of 430 total sample, 26.7 percent were replied as drought, dry spell and erratic rainfall are the most three climatic-shocks in the area while 25.35 percent were replied as drought, dry spell and locust in the area. Similarly, around 19.8 percent of the respondents were replied as drought, dry spell and increased or higher temperature are the most three climatic shock where as 12.6 percent of them replied drought, erratic rainfall and increased temperature the are most climatic shocks. So, drought, dry spell, flood, desert locust, erratic rainfall and increased temperature. In case of dry spell the rainfall deficit for around 2-5 week period during crop growth were asked. Seasonal rainfall below minimum seasonal plant water requirement that prevent crop growth causing crop production failure is considered in case of drought.



*Drt =drought, dsp=dry spell, Er=erratic rainfall, Fld=flood, Ht=high temperature, Lct=locust

Fig. 1 Major three ranked climatic shocks in the study area

Regarding the trends of the rainfall the following Figure. 2 shows results of Babile station for distribution of rainfall over the last 33 years. The purpose of this rainfall trend analysis is to investigate if a series of rainfall is generally increasing or decreasing with time in the study area. In this study, the non-parametric Mann-Kendall tests was used in rainfall trend detection. The magnitude of the existing trend was also estimated with the Sen's slope estimator method. The trend analysis technique was applied to the annual rainfall data collected from 1990 to 2023 years. The *Z*-statistics obtained from Mann–Kendall tests for Babile stations revealed -1.96. The negative value result shows statistically significant decreasing trends of rainfall over the last 33 years at 5% significance level. The Sen's slope techniques was also applied to estimate the magnitude of the trend. The results obtained from the analysis was presented in Figure 2, bellow with signs of the slopes are confirming the results from *MK* test. Using Sen's slope estimator, for Babile station shows -7.389 which indicated that the slopes magnitudes was large indicating that each year rain reduced by 7.4 in the last 33 years.

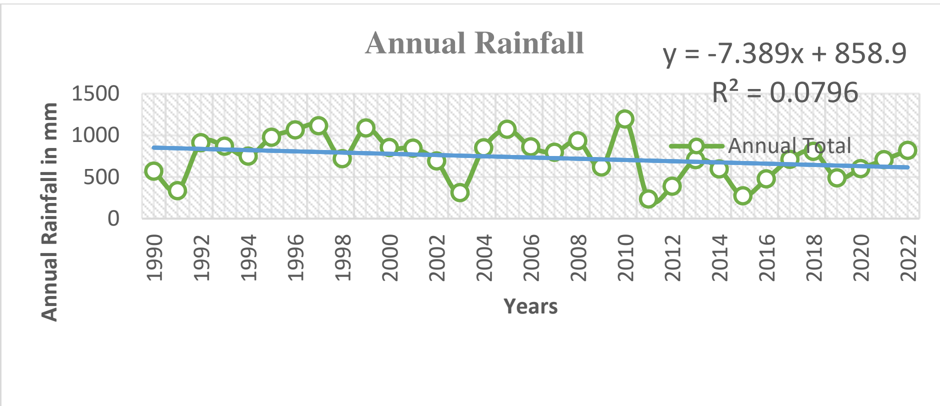


Fig. 2 Annual rainfall trends of Babile station (1990-2022).

3.1.3 Poverty Line determination in the Study Area

To measure poverty, cost of basic needs (CBN) approach was applied. It include evaluation of food poverty line that is defined by choosing a bundle of food typically consumed by the poor. In addition non-food poverty line is calculated by considering necessary allowance for the basic non-food items like clothes and shoes, cooking materials and lighting, educational expenses, and etc. Total poverty refers to a combination of both the food and non-food expenditure.

Food consumption poverty line

For determining food poverty line, the data was collected and analyzed for 50 percent of the poor households based on their annual per capita consumption expenditure as reference group, who consumed bundle of food items that consumed by rural households. A food poverty line was constructed based on the bundles of food item giving the minimum caloric requirement that provides 2,200 Kcal/day/AE by pricing a bundle of that food at the local average market price. Kcal is the least amount of energy required for a human being to lead a healthy life [72]. To get annual adult equivalent consumption of food items that is scaled and priced food items was multiplied by 365 days. Accordingly, the food poverty line was found to be 6582.66ETB per AE in the study area Table 3, which is 76.36 percent of the total consumption expenditure (total poverty line) Table 4.

Table 3 Food consumption for poor people and value of food poverty line in the study area

Food Item	Kcal/ Kg	Food basket /adult/day in Kg/lt	Kcal per day per Adult	Basket/adult/ day in Kg/lt (Scaled)	Kcal/adult/dy needed to get 2200 kcal	Mean price/kg/lt(Birr)	Cost per month (Birr)	Poverty line Food per year in (Birr)
Teff	3589	0.0058	20.86	0.0028	10.04	35.8	3.00	36.52
Maize	3560	0.4685	1668.00	0.2256	803.03	21.5	145.15	1766.05
Sorghum	3805	0.4392	1671.05	0.2114	804.50	26.0	164.92	2006.49
Wheat	3574	0.0716	255.77	0.0345	123.14	29.3	30.23	367.83

Barley	3723	0.0057	21.36	0.0028	10.29	32.5	2.69	32.77
Mango	3700	0.0068	24.98	0.0033	12.03	26.0	2.54	30.85
Bean	3553	0.0046	16.19	0.0022	7.80	26.0	1.71	20.82
Linseed	5109	0.0025	12.93	0.0012	6.23	27.3	1.00	12.15
Fenogrek	3824	0.0170	64.93	0.0082	31.26	39.0	9.56	116.36
Swt/potato	1360	0.0088	12.03	0.0043	5.79	19.5	2.49	30.31
Garlic	118	0.0016	0.18	0.0007	0.09	52.0	1.17	14.19
Onion	713	0.0590	42.05	0.0284	20.24	39.0	33.22	404.15
Paper	933	0.0061	5.73	0.0030	2.76	26.0	2.31	28.07
Potato	1037	0.0281	29.09	0.0135	14.00	19.5	7.90	96.12
Coffee	1103	0.0028	3.05	0.0013	1.47	227.5	9.08	110.52
Beef	1148	0.0020	2.33	0.0010	1.12	260.0	7.61	92.54
Milk	737	0.0254	18.71	0.0122	9.01	45.5	16.68	202.96
Egg	61	0.0111	0.68	0.0054	0.33	7.8	1.25	15.27
Sugar	3850	0.0253	97.34	0.0122	46.86	52.0	18.99	231.03
Oil	8964	0.0133	119.52	0.0064	57.54	78.0	15.02	182.76
Rice	3550	0.1277	453.34	0.0615	218.25	32.5	59.94	729.30
Salt	1700	0.0174	29.56	0.0084	14.23	18.2	4.57	55.61
Total			4569.67		2200.00			6582.66

Source: Survey results(2023)

Non-food consumption poverty line

To get total poverty line, non-food expenditure was evaluated after defining the food poverty line. The non-food share of total expenditure was estimates through regressing the food share on a constant and the log of the ratio of total consumption expenditure to food poverty line (6582.66ETB).According, non-food expenditure was found to be 2038.0ETB, that is 23.64 percent of annual consumption expenditure (total poverty line). Thus, the total poverty line of the household was obtained after adjusting for non-food consumption by using food poverty line constructed from the poor reference household. Therefore, total households' poverty line in the study area was found to be 8620.70ETB Table 4. This implies that households in the study area spent more of their money on food consumption than on non-food. Moreover, it shows farmers were forced to buy food item at inflated price rather than expending on non-food.

Table 4 Poverty line and consumption share

Expenditure	Poverty Line	Share (%)
Food expenditure	6582.66 ETB/year/AE	76.36
Non-Food expenditure	2038.04 ETB/year/AE	23.64
Total	8620.70 ETB/year/AE	100.00

Source: Survey results (2023), ETB=Ethiopia Birr

3.1.4 Extent of poverty and adoption of conservation agriculture in the area

In this study, evaluated total poverty line is used which has been determined as total consumption poverty line of 8620.70ETB per adult per year as Table 4 presents the headcount incidence, gap, and severity of poverty. Moreover this results revealed that poverty headcount, gap and severity indices were found to be lower among adopters than non-adopters. This implies that adoption of practices had a poverty reduction effect as Table 5. Therefore, headcount index value of the results revealed that the headcount index, which measures the proportion of the population whose consumption expenditure is below the poverty line of the study area or the share of the population that cannot afford to buy a basic basket of goods and found to be 36.3 percent which is 33.8 percent for adopter and 57.8 percent for non-adopter indicating lower value for adopter. This proportion of the total households in the study area could not achieve their daily minimum consumption expenditure, indicating the shattering status of poverty in the study area.

As presented in table 5 the poverty gap index value results shows the mean consumption poverty gap in the population compared to the poverty line. Total value was estimated to be 8.37percent, whereas 7.7 percent for adopter and 14.2percent for non-adopter, that provides how far households are from the poverty line. This result indicated that poverty is deep, with a higher gap between poverty line and the average consumption level of the poor. This measure indicates the mean consumption expenditure shortages relative to the poverty line across the whole population using formula developed by [73]. Poverty Severity value results was estimated by the squared poverty gap index also found to be 2.77percent. The findings shows the severity of poverty which takes into account not only the distance separating the poor from poverty line (the poverty gap), but also inequality among the poor.

Table 5 Household poverty level(Indices) by adoption of conservation agriculture (CA)

No	Adoption status	Poverty Extents		
		Head count(P_0)	Poverty gap(P_1)	Poverty Severity (P2)
1.	Adopter of CA	0.3377	0.0768721	0.0259294
2.	No-adopter CA	0.5777	0.14167	0.0428475
3.	Total	0.36279	.083653	.0276999

Source: Survey result (2023)

In this study households whose absolute poverty expenditure per AE per year is greater than and equal to 8620.70 ETB were designated as non-poor otherwise poor in the area as Table 6. This implies that, absolute poverty or annual consumption expenditure poverty line of 8620.70ETB in study area was greater than national annual consumption expenditure poverty line which is 7184ETB according to [74]. The probable cause of this incremental could be due to current inflation of food price that may forces the households to spend on food items at prevailing high price that increase food-consumption expenditure and also minimize the money spend on non-food items to satisfy their non-food need in the area.

The results also revealed that out of total sample 63.7 percent respondents were found to be non-poor whereas 36.3 percent of them were found to be poor. The overall sample respondents' annual average consumption expenditure per AE for the poor and non-poor groups was found to be 6632.9ETB and 12017.2ETB, respectively. With an average family size of 5.25 adult equivalent, a given representative respondent in the study area requires an income of Birr 8620.70ETB per annual which is 1987.79ETB per AE per annual to escape absolute poverty as table 6. The overall annual average consumption expenditure per adult equivalent for respondent was found to be 10,063.8ETB per AE in the study area. Generally, in both situation adopters have higher average consumption expenditure per AE, implying that the adoption of CA leads to situation of being non-poor.

Table 6 Households average poverty status by adoption of conservation agriculture

Adoption status	**Household categories**	
	Poor	**Non-poor**
Adopter of CA practices	6658ETB	12127.87ETB
Non-adopter of CA	6506.88ETB	10531.37ETB
Total	**6632.91ETB**	**12017.2ETB**

Source: Survey results (2023)

3.1.5 Variables used to construct a households' drought resilience index (DRI)

In this study drought resilience index was constructed by principal component analysis (PCA) using number of alternatives income, proportion of off/non-farm income, number of meals in drought, proportion of daily food in droughts compared to normal time and months for food crop scarcity as revealed in table 7.

Table 7 Results of Principal components (eigenvectors)

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Unexplained
Proportion of non/off-Income	0.6778	-0.2182	0.0355	0.0147	0.7011	0
Alternative Income source	0.6874	-0.1165	-0.0006	0.1364	-0.7037	0
Month of Food Scarcity	0.1061	0.5763	-0.6524	0.4702	0.0999	0
No of Drought Time Meal	0.2269	0.5631	-0.0412	-0.7932	-0.0253	0
Proportion of Drought Time food Consumption	0.0726	0.5382	0.7559	0.362	0.0514	0

Source: Own survey results (2023)

So the first principal component can be used to construct drought resilience index (DRI).

Drought Resilience Index (DRI) = 0.6778* Proportion of non/off-farm income +0.6874* Number of Alternative source of income+0.1061* Number of months for food crop scarcity +0.2269* Number of meals per day during drought+0.0726* Proportion of daily food in droughts compared to normal (13)

3.2 Econometric analysis

3.2.1 Factors influencing the adoption of conservation agricultural practices

To analysis determinants factors of conservation agricultural practices adoption as climatic-shocks mitigation strategies, the first stage multinomial endogenous switching model that is multinomial logit model was applied. The non-adopters of practices ($L_0R_0M_0$) were used as reference category in the multinomial logit model. The results from the multinomial logit model as marginal effects was presented in the following Table 8.The parameter estimates or marginal effects of the multinomial logit model was interpreted as the change in the probabilities of dependent variables as a unit change in the independent variables indicating direction and magnitude effect on outcome variables. The wald test results ($Chi^2(112)$ = 395.24 and p-value= 0.0000) which shows that all the coefficients in regression are jointly zero was rejected. Likelihood-ratio test, LR $Chi^2(112)$= 569.86, Prob-value = 0.0000 that shows the restricted model significantly differs from the full model.

Age of respondent: The model coefficients result in table 8 revealed that age of the households head was found to be related negatively and significantly to the adoption of combination all three practices that is legume intercropping, crop rotation and crop residue retention ($L_1R_1M_1$) at 1 percent significance level. The marginal effect shows that as age of the household head increases by a one year, then the probability of adopting full combination of CA ($L_1R_1M_1$) decreases by 0.6 percent, keeping other at constant. This implies that older farmers are more likely to be risk averse to adopt any new technologies including CA. This finding also consistent with [31, 34, 75].

Farm experience: The coefficient of farm experience of household head was found to be related positively and significantly to adoption of full combination of practices ($L_1R_1M_1$) at 1 percent and to adoption of crop rotation only ($L_0R_1M_0$) at 5 percent. The marginal effect estimates of the results also revealed that, as farm experience of the farm household head increased by a year, then the probability of adopting full combination of legume intercropping, crop rotation, crop residue retention ($L_1R_1M_1$) and crop rotation only ($L_0R_1M_0$).increased by 0.6 percent and 0.02 percent, keeping other things at constant, respectively. This implies that as farmers years of experience in farming activities increases it encourage farmers in mitigating the negative effects of drought through the adoption of different agricultural technologies including adoption of CA practices in their environments. As farmers advanced in farming experience, their level of taking any advantage of mitigation strategies increases mostly due to their past experiences. This results in agreed with study of [76, 77] that sows positive relation between farming experience and conservation agriculture.

Education level: The coefficient of household head education in formal years of schooling found to be related positively and significantly to adoption of legume-intercropping, residue retention ($L_1R_0M_1$) and adoption of full combination of CA ($L_1R_1M_1$) at 1 percent and 10 percent significance level, respectively. The estimates of the marginal effect showed that as formal years of schooling of the household head increased in a year, the probability of adopting legume-intercropping, residue retention ($L_1R_0M_1$) and adoption of full combination of CA ($L_1R_1M_1$) increased by 1.0 percent and 0.7 percent as climatic-shocks mitigation strategies, respectively. This implies that education have encouraged farmers to adopt new agricultural technologies that will help them to increase production and productivity of the farm including conservation agricultural practices that help them to mitigate the effect of climate change. In addition to this educated farmers would have easier access to information, be better able to interpret every situation more effectively than less educated farmers. This finding agrees with work of [78] and [79] that education increase the adoption of new technology.

Climatic-Socks experience: The coefficient of the marginal effect showed that dry/climatic-shocks experience in the last 10 year was found to be related positively and significantly to adoption of crop-rotation ($L_0R_1M_0$), residue retention or mulching ($L_0R_0M_1$), legume-intercropping and crop rotation ($L_1R_1M_0$), and to adoption of crop-rotation and crop residue retention or mulching ($L_0R_1M_1$) at 1 percent, 1 percent, 10 percent and 10 percent, respectively. The model results revealed that as dry experience of the farmers increase by a year, the probability of adopting crop-rotation only ($L_0R_1M_0$), residue retention or mulching ($L_0R_0M_1$), legume-intercropping and crop rotation ($L_1R_1M_0$), and adoption of crop-rotation and crop residue retention or mulching ($L_0R_1M_1$) increased by 2.3 percent, 3.4, 3.0 and1.7 percent, as drought mitigation strategies, respectively. This implied that past exposure to dry spells may affect probability of expectations about rains in the current season as well as the expected performance of alternative technologies including adoption of practices based on past experiences. These expectations may affect adoption of intercropping, residue retention or mulching and crop rotation on their plots.

Access to climate information: Agricultural activities are mainly seasonal that depend on precipitation and temperature, which is further influenced by climate change, it requires timely weather information. The estimate of marginal effect showed that access to climate information services of farmer or household head was found to be related positively and significantly to the adoption of legume intercropping and crop rotation ($L_1R_1M_0$), and intercropping and crop residue retention ($L_1R_0M_1$) both at 5 percent significant level, respectively. The results showed that as farmers or head accessed to climate information services, the probability of adopting and applying legume intercropping and crop rotation ($L_1R_1M_0$), and intercropping and crop residue retention ($L_1R_0M_1$) increased by 8.0 percent and 7.0 percent respectively. This implied that farmers who have accessed to climate information are better at adopting practices than the farmers who has no access to the service. This is possibly because farmers who have access to reliable information on current and future rainfall could have a chance to choose among different alternatives of drought mitigating strategies including drought resistance, soil fertility and disease pest resistance.

Access to extension: The coefficient of the marginal effect showed that access to extension services of farmer or household head was found to be related positively and significantly to adoption of legume intercropping and crop residue retention ($L_1R_0M_1$) at 5 percent significant level. Results reveled that as farmers accessed to extension services, the probability of adoption and application of legume intercropping and crop residue retention ($L_1R_0M_1$) was found to be increased 6.6 percent other things kept constant, as climatic-shocks effect mitigation strategies. This implied that farmers who have access to timely information are more likely to adopt new agricultural technology including conservation agriculture, because they would be informed of the availability of the technology and even may have access to on-field demonstration thus increasing the likelihood of adopting the different agricultural technology. Access to extension services was found to have a significant effect on the adoption of technologies and expected that access to agricultural information by the extension workers is crucial in increasing the adoption of practices. Moreover, this is because the extension services helps the farmers to increase their awareness about the availability and benefit of the agricultural technologies, use and their impact on farm productivity. This finding is consistent with [39, 80] and [81]

Sex of household head: The estimates of the marginal effect indicated a positive and statistically significance relation between sex of household head being male and adoption of practices at 10 percent and 5 percent for adoption of legume-intercropping and residue retention on farm ($L_1R_0M_1$), and adoption of all combination of practices ($L_1R_1M_1$), respectively. Thus, the probability of adopting and implementing of legume-intercropping and residue retention on farm ($L_1R_0M_1$), and adoption of all combination of practices ($L_1R_1M_1$) increased as sex of household head was found to be male at 4.5 and 6.3 percent as drought mitigation strategy, respectively. This implied that adoption of practices requires land ownership which might only be available to male farmers in most of rural area, hence the probability of adopting and implement of practice by male farmers is more likely increased since they have access to land. Male farmers are in a better manner to practice different adaptation than female. This result agree with that of [82] that shows most of the adopters are men and [83] study that shows male-headed are more likely to have access to technologies than female-headed households.

Number of oxen: Number of oxen are very important assets for plowing and wealth indicators in rural area of the country. The coefficient of number of oxen was found to be related positively and significantly to adoption of full combination of CA ($L_1R_1M_1$) at 5 percent, 10 percent, 5 percent, 5 percent and 5 percent level of significance. The marginal effect showed that as the household's numbers of oxen increased by a unit, the probability of adopting of full combination of practices ($L_1R_1M_1$) increased by 2.2 percent as climatic shocks mitigation strategies keeping other effect at constant. This implied that farmers that have numbers of oxen used them as a draft power to cultivate the land and encourage adoption of conservation agricultural practices. On the other hand, households who have oxen would be able to cultivate their land on time and they would obtain extra income by renting out their oxen to buy necessary agricultural input.

Farm size: The estimates of marginal effect showed that positive and significant relationship between farm size and adoption of CA practices that is crop residue retention ($L_0R_0M_1$) at 10 percent of significance level. That is as land increased by one unit, the probability of adopting and implementing of crop residue retention ($L_0R_0M_1$) increased by 10.3 percent as climate change mitigation strategy. Land area is crucial asset in rural area of the country for farm community and this results implied that adoption of practices needs plot of land area for implementation different agricultural technologies. Farmers with larger land are more likely to adopt various practices. So, as farm size increases, adoption of practices increases. This result consistent with [84] that shows positive relation of farm size with practices.

Family size: The estimate of marginal effect of family size was found to be related negatively and significantly to the adoption of legume intercropping and crop rotation ($L_1R_1M_0$) at 10 percent level of significance. The results of marginal effects of the model revealed that as the family member of the household increases by a unit, the probability of adopting the legume-intercropping and crop rotation ($L_1R_1M_0$) decreased by 1.8 percent keeping other at constant. This implied that household with more family the economic power of farm household may be reduced and discouraged the adoption of practices. So adoption of practice decreased with increased family member. This result also in line with [85].

Labor force: The estimate of marginal effect of labor force of the households was found to be related positively and significantly to the adoption of legume-intercropping only ($L_1R_0M_0$), adoption of legume-intercropping and crop residue retention or mulching ($L_1R_0M_1$) and all combination of practices ($L_1R_1M_1$) at 5 percent, 1percent and 1 percent of level of significance, respectively. The results also showed that as the labor force of the household increases by a unit, the probability of adopting of intercropping only ($L_1R_0M_0$), adoption of intercropping and crop residue retention ($L_1R_0M_1$) and all combination of practices ($L_1R_1M_1$) increased by 2.0, 2.3 and 0.1percent respectively. This implied that the adoption of CA requires more labor force. This finding in line with [31, 38] and [39].

Number of livestock: The coefficient of livestock shows positive and significant relation to adoption of legume-intercropping ($L_1R_0M_0$), crop residue retention ($L_0R_0M_1$), legume-intercropping and crop-rotation ($L_1R_1M_0$), crop-rotation and crop-residue retention or mulching ($L_0R_1M_1$), and adoption of full combination of CA ($L_1R_1M_1$) at 5 percent, 10 percent, 5 percent, 5 percent and 10 percent level of significance, respectively. The marginal effect shows that as livestock increases in tropical livestock unit, the probability of adopting of legume-intercropping ($L_1R_0M_0$), crop residue retention ($L_0R_0M_1$), legume-intercropping and crop-rotation ($L_1R_1M_0$), crop-rotation and crop-residue retention or mulching ($L_0R_1M_1$), and adoption of full combination of CA ($L_1R_1M_1$) increased by 1.3 percent, 0.7, 2.1percent, 0.9 percent and 1.2 percent, respectively. This implies farmers with number of livestock are more likely to adopt agricultural technologies than that have not, as it helps to get improved technology (as means of income source for input). This is consistent with [31, 81, 86].

Distance to market: The distance to market is negatively and significantly related to the adoption of a crop rotation ($L_0R_1M_0$), legume intercropping crop rotation ($L_1R_1M_0$) adoption of crop rotation and crop-residue retention or mulching ($L_0R_1M_1$) at 10 percent, 1 percent and 10 percent of level of significance, respectively. The marginal effect showed that as the distance to market increases by one kilometer, then the probability of adopting crop rotation ($L_0R_1M_0$), legume intercropping and crop rotation ($L_1R_1M_0$) adoption of crop rotation and crop-residue retention ($L_0R_1M_1$) decreased by 1 percent, 2 percent and 0.1 percent respectively, other things kept constant as drought mitigation strategy in the study area. This implies that farmers with nearby town and market can buy or sell agricultural technologies inputs or agricultural outputs at time and with full price information so as to adopt conservation agriculture. The result is consistent with [31, 36] and [81].

Tables 8 Maximum Likelihood Estimates for the multinomial Logit model

Variables	**$L_1R_0M_0$**	**$L_0R_1M_0$**	**$L_0R_0M_1$**	**$L_1R_1M_0$**	**$L_1R_0M_1$**	**$L_0R_1M_1$**	**$L_1R_1M_1$**
	dy/dx	**dy/dx**	**dy/dx**	**dy/dx**	**dy/dx**	**dy/dx**	**dy/dx**
Age Respndent	0.003(0.001)	0.001(0.001)	0.002(0.001)	-0.001(0.002)	0.001(0.001)	0.001(0.001)	-0.006***(.002)
Farm Experien	-0.005(0.002)	0.0002**(.001)	0.0004(.001)	0.005(.003)	0.0004(0.002)	0.001(0.002)	0.006***(.002)
Educ Respndt	-0.006(0.004)	-0.003(0.004)	-0.002(0.003)	0.009(.006)	0.010***(.004)	0.003(0.003)	0.007*(.004)
Dry Experianc	-0.002(0.011)	0.023***(.008)	0.034***(.009)	0.030*(.017)	0.013(0.010)	0.017*(.01)	-0.008(0.011)
Acess Extentio	0.019(0.032)	0.053(0.036)	0.040(0.031)	0.040(0.052)	0.066**(0.03)	0.030(0.032)	0.043(0.032)
Sex Respndt	0.013(0.026)	0.020(0.029)	0.013(0.024)	-0.007(0.046)	0.045*(.025)	0.030(0.026)	0.063**(.03)
Family Size	-0.005(0.007)	0.001(0.006)	-0.009(0.007)	-0.018* (.01)	-0.009(0.006)	0.000(0.006)	0.009(0.007)
Farm Size	0.019(0.070)	0.070(0.062)	0.103*(.057)	0.058(0.110)	0.062(0.064)	0.085(0.063)	0.102(0.089)
Labor Force	0.020**(0.01)	0.011(0.01)	-0.005(0.01)	0.01(0.02)	0.023***(0.01)	-0.01(0.01)	0.001***(0.009)
Livstock(TLU)	0.013**(0.05)	0.008(0.006)	0.007*(0.004)	0.021**(0.01)	-0.010(0.007)	0.009**(0.004)	0.012*(0.004)
Ac Climt Infor	0.02(0.03)	0.03(0.03)	0.03(0.02)	0.08**(0.05)	0.07**(0.03)	0.05(0.03)	0.11(0.04)
Market Distace	-0.01(0.003)	-0.01*(0.003)	0.002(0.002)	-0.02***(.004)	0.001(0.003)	-0.003*(0.002)	-0.004(0.002)
Market Inform	0.003(0.03)	0.04(0.03)	-0.02(0.02)	0.08*(0.05)	0.07*(0.04)	0.04(0.03)	0.01(0.03)
Orgnz Menber	0.031(0.030)	0.012(0.031)	-0.035(0.022)	0.043(0.050)	0.009(0.031)	0.009(0.030)	-0.036(0.032)
Number Oxen	0.013(0.010)	-0.010(0.012)	-0.009(0.008)	0.003(0.016)	-0.006(0.009)	0.012(0.008)	0.022**(0.01)
Non-Farm Act	-0.105(0.028)	0.008(0.036)	-0.021(0.026)	0.069(0.066)	0.030(0.042)	0.019(0.040)	0.060(0.054)
MN Logit Log pseudolikelihood = -539.61911				Observation 430		Pseudo R^2 = 0.3456	

Source: Author survey result (2023), Model VCE: Robust, *, **and *** mean significant at 10%, 5% and 1% probability level, respectively

3.2.2 Expected outcome and average treatment effect on treated (ATT)

The MESR models was used in this study to analysis the impact conservation agriculture on households' poverty and resilience to drought in the study area. After computing the inverse mills ratio from selection model, the OLS was used to estimate parameters of outcome variables that is poverty and resilience to drought by introducing the mills ratio as correction term for selectivity bias. The estimated coefficients from regression model were used to estimate the conditional expectations of outcome variables, and evaluate the treatment effect of conservation agriculture adoption. The results in Table 9 shows the comparison between expenditure effects of adopting and non-adopting under both actual and counterfactual conditions, respectively. The counterfactual effect measures what would have happened to the adopters of CA practice in the absence of the adoption. The results from impacts of CA on resilience to drought was also presented in the Table 10.

The impact of conservation agriculture adoption on poverty

The results in Table 9 revealed the impact of conservation agricultural practices adoption on annual consumption expenditure per adult equivalent (poverty) in Ethiopian Birr (ETB). In this study the value of annual consumption expenditure under both actual that had adopted and the counterfactual case that had not adopted the conservation agricultural practices were compared. The results shows average treatment effects of adoption of a single and combination of different practices on annual consumption expenditure per adult equivalent.

The results from the actual value shows that adopters of different combination of conservation agricultural practices have higher annual expenditure per AE (poverty indicator) than they had not adopted (if not adopted). This result confirms that adoption of practices provides more annual consumption per adult compared to non-adoption. Moreover, this results revealed that adopters of CA that actually adopted improved their annual expenditure per adult. And also shows if those who do not adopted at this time were to adopt CA, their annual consumption expenditure per adult would be improved in the same manner. It shows that adopters of full combination of CA practices ($L_1R_1M_1$) got the highest annual total expenditure per AE that is which is 14659.9 ETB, followed by adopter of crop residue retention($L_0R_0M_1$) that is 13743.3ETB, then followed by adoptions of combination of crop-rotation and crop-residue retention or mulching ($L_0R_1M_1$) that is 11524.7ETB. The results also revealed that, the adopter of the crop rotation ($L_0R_1M_0$) could obtained around 10506.05 ETB in annual total consumption expenditure per adult in the study area. The minimum annual consumption expenditure per adult is obtained by intercropping ($L_1R_0M_0$) which is around 8472.8ETB. Generally, adopters of practices obtained higher expenditure per AE compared to the non-adopters ($L_0R_0M_0$) that could obtained is 8206.11 ETB in the area.

The adoption of conservation agricultural practices shows significant effect on average treatment effect on treated (ATT) as in Table 9. The average treatment effect on the treated shows that adoption of full combination of CA ($L_1R_1M_1$) increased treatment effects by 73.3 percent compared to the non-adopters, followed by adopters of crop residue retention ($L_0R_0M_1$) which 59.6 percent then by adopters of the combination of intercropping and crop residue retention ($L_1R_0M_1$) with 41.3 percent in terms of annual consumption expenditure per AE effect. Results shows that the ATT, for adopters who actually adopted the practices significantly would have been lower in terms of annual expenditure per adult if they had not adopted. The results from untreated (ATU) for non-adopter which is actually 8206.11ETB in terms of annual expenditure per AE, would be increased by 24.5percent, 20.8 percent and 19.6 percent if they had decided to adopt crop residue retention ($L_0R_0M_1$), adopt combination of crop-rotation and crop-residue retention or mulching ($L_0R_1M_1$), and adopt full combination of practices ($L_1R_1M_1$), respectively.

Generally, the average treatment effect on untreated (ATU) shows that households who actually did not adopted ($L_0R_0M_0$) would have significantly increased their annual consumption expenditure per AE if they had decided to adopt practices on farm. The results from base heterogeneity for non-adopter (BH_0) and adopters (BH_1) revealed that there is some kind of heterogeneity among adopters and non-adopters. The value of negative BH_0 for non-adopter of practices imply that adopters who actually adopted would have higher annual consumption expenditure per AE than who had not adopted, and the negative value of BH_1 of adopters indicates that non-adopters would have higher total consumption expenditure than those who actually had adopted if they had adopted. The negative significant transitional effect (TH) values confirms that the effect of adoption would be significantly lower for those households who actually adopted compared to those who had not adopted, if they had adopted.

Generally, the results endorses that adoption of conservation agricultural practices have significant impacts on the households poverty in terms of annual consumption expenditure per AE indicating positive role in reducing poverty. The overall comparison of adopter and non-adopter shows that, adoption improved consumption expenditure of adopter by 36.34 percent than non-adopter. Similarly, if non-adopter adopted, their expenditure would be increased by 15.9 percent than their current consumption. This implies that higher expenditure explain lower poverty due to adoption of practices. Therefore, adoption of CA can be adopted as mechanism to mitigating adverse effect of climate change and ways of lifting out poor farm community from poverty in moisture stress area. The study results confirmed by the finding of [31, 37, 81, 62].

Table 9 Average Treatment Effects of Adoption on consumption expenditure per adult (ETB)

	Farmers adoption decision of CA			
Sub-sample	CA Packages	To adopt	Not to Adopt	Treatment Effect
		a	c	ATT
Household that adopted Conservation Agriculture	$L_1R_0M_0$	8472.77 (269.54)	7647.52 (401.21)	825.25**
	$L_0R_1M_0$	10506.05 (150.95)	10289.19 (155.89)	216.86
	$L_0R_0M_1$	13743.27 (208.29)	5550.57 (779.91)	8192.69***
	$L_1R_1M_0$	9014.54 (182.16)	7717.10 (309.99)	1297.43***
	$L_1R_0M_1$	9525.36(328.28)	5591.76 (373.49)	3933.60***
	$L_0R_1M_1$	11524.72 (217.19)	8592.27 (466.28)	2932.44***
	$L_1R_1M_1$	14659.94 (425.79)	3911.73 (927.65)	10748.21***
		d	b	ATU
Household that do not adopted Conservation Agriculture	$L_0R_0M_0$	8679.28 (410.38)	8206.11 (247.94)	473.17
	$L_0R_0M_0$	9592.64(527.78)	8206.11 (247.94)	1386.53***
	$L_0R_0M_0$	10872.19 (391.21)	8206.11 (247.94)	2666.08***
	$L_0R_0M_0$	8998.85 (316.42)	8206.11 (247.94)	792.74*
	$L_0R_0M_0$	9586.14(522.52)	8206.11 (247.94)	1380.03**
	$L_0R_0M_0$	10358.26 (490.12)	8206.11 (247.94)	2152.14***
	$L_0R_0M_0$	10212.08 (512.59)	8206.11 (247.94)	2005.97***
		BH_1	BH_0	TH
Transitional and Heterogeneity effects	$L_1R_0M_0$	206.51 (490.98)	-558.59(471.6)	352.08
	$L_0R_1M_0$	-913.42*(548.94)	2083.08*** (292.9)	-1169.67**
	$L_0R_0M_1$	-2871.08***(443.2)	-2655.5***(818.37)	5526.61***
	$L_1R_1M_0$	-15.68(365.10)	-489.00(396.95)	504.69
	$L_1R_0M_1$	60.78 (617.08)	-2614.4***(448.3)	2553.57***
	$L_0R_1M_1$	-1166.47**(536.08)	386.16(528.11)	780.3**
	$L_1R_1M_1$	-4447.86***(666.4)	-4294.4***(960.2)	8742.24***

Source: Author results (2023), Standard error in parenthesis; *, ** and *** mean significant at 10%, 5% and 1% probability level, respectively

a and b shows effect under actual case, while c and d shows the counterfactual case, for adopter and non-adopter, respectively.

ATT= treatment effect on treated (a-c), while ATU=treatment effect on untreated (d-b) which is adoption effect on non-adopters.

BH_1 is base heterogeneity effect for adopters (a-d) and BH_0 is base heterogeneity effect for non-adopter (c-b).TH is a transitional Heterogeneity effect which is the difference between TT and TU.

The impact of conservation agriculture on households' resilience to drought

The results in Table 10 revealed the impact of conservation agricultural practices adoption on households' resilience to drought in terms of drought resilience index (DRI). The resilience to drought was estimated as an index that constructed from consumption aspect of the society and income as indicators using the principal component analysis (PCA) method. So in this study to construct resilience to drought index(DRI), different variables including proportion of food consumed by households in droughts as compared to normal season, months of food scarcity, and consumed meals per day in times, and number of alternative sources of income and proportion of total income that is off-farm/non-farm were used.

The results in the Table 10 shows average treatment effects of adoption of a single and combination of different practices on household resilience to drought(DRI). The average treatment effect on the adopter shows that adoption of combination of crop-rotation and crop-residue retention or mulching ($L_0R_1M_1$) increased effect of treatment by 49.6 percent, followed by adopters of crop residue retention ($L_0R_0M_1$) which 47.6 percent, adoption legume-intercropping and residue retention on farm ($L_1R_0M_1$) increased by 45.9 percent and then followed by adoption of full combination of practices ($L_1R_1M_1$) which increased treatment effects by 44.3 percent compared to the non-adopters in terms resilience to drought index(DRI). Results shows that the average treatment effect on treated (ATT), for adopters who actually adopted conservation agricultural practices significantly would have been lower in terms of drought resilience index if they had not adopted.

The results from average treatment effect on the untreated (ATU) for non-adopter which is actually 3.56 in terms drought resilience index, would be increased by 12.0 percent, 10.6 percent and 9.9 percent if they had decided to adopt combination of crop rotation and crop-residue retention or mulching ($L_0R_1M_1$), adopt combination of legume-intercropping and crop-rotation ($L_1R_1M_0$), and followed by adoption of full combination of CA practices ($L_1R_1M_1$), respectively. This results consistent with [60] that shows adopting conservation agriculture means a more quality of soil and higher resistance to drought. The summary of adopter and non-adopter based on drought resilience index shows that, adoption increased resilience index of adopter by 29.85percent than non-adopters. Similarly, if non-adopter adopted, their current resilience index would be increased by 6.83percent more than their current.

Table 10 Average Treatment Effects of Adoption on resilience to drought(DRI)

		Farmers decision		
Sub-sample	Packages	To adopt	Not to Adopt	Treatment Effect
		a	c	ATT
For household that adopted Conservation Agriculture	$L_1R_0M_0$	2.04(.14)	1.84(.09)	0.20
	$L_0R_1M_0$	4.38(.05)	4.01(.10)	0.37^{***}
	$L_0R_0M_1$	3.09(.20)	1.61(.37)	1.47^{***}
	$L_1R_1M_0$	2.20(.016)	1.88(.05)	0.32^{***}
	$L_1R_0M_1$	1.94(.07)	1.06(.16)	0.89^{***}
	$L_0R_1M_1$	2.62(.10)	1.33(.22)	1.30^{***}
	$L_1R_1M_1$	2.12(.049)	1.19(.11)	0.94^{***}
		d	b	ATU
For household that do not adopted Conservation Agriculture	$L_0R_0M_0$	3.59(.09)	3.56(.07)	0.032
	$L_0R_0M_0$	3.54(.07)	3.56(.07)	0.0195
	$L_0R_0M_0$	3.68(.12)	3.56(.07)	0.1209
	$L_0R_0M_0$	3.98(.05)	3.56(.07)	0.4207^{***}
	$L_0R_0M_0$	3.92(.09)	3.56(.07)	0.358^{***}
	$L_0R_0M_0$	4.04(.12)	3.56(.07)	0.483^{***}
	$L_0R_0M_0$	3.95(.07)	3.56(.07)	0.39^{***}
		BH_1	BH_0	TH
	$L_1R_0M_0$	1.55^{***}(.13)	-1.72^{***}(.15)	0.17
	$L_0R_1M_0$	-0.83^{***}(.09)	$.44^{***}$(.12)	0.35

Transitional and Heterogeneity effects	$L_0R_0M_1$	0.60***(.24)	-1.95***(.38)	1.35
	$L_1R_1M_0$	1.78***(.05)	-1.68***(.09)	-0.10
	$L_1R_0M_1$	1.98***(.11)	- 2.51***(.17)	0.53
	$L_0R_1M_1$	1.42***(.16)	-2.24***(.24)	0.82
	$L_1R_1M_1$	1.83***(.09)	-2.37***(.13)	0.55

Source; Author results(2023), Standard error in parenthesis;*, **and *** mean significant at 10%, 5% and 1% probability level, respectively

4 CONCLUSION AND RECOMMENDATION

The study was undertaken in Eastern Ethiopia where mostly affected by drought & erratic rainfall, hence, need adaptation strategy. The aims of this study is to analysis adoption and impacts of conservation agricultural practices on poverty reduction and resilience to drought in moisture stress area of Eastern Ethiopia. The core point of poverty analysis is lays on the determination of poverty line since it used for estimate extent or poverty level of the households. Using the cost of basic need (CBN) approach, the absolute total poverty line was found to be 8620.70ETB per AE per year based on food poverty line of 6582.7ETB and 2038.04ETB of non-food poverty line at average local market price. Households' drought resilience index was constructed using principal component analysis and used in impact analysis. Farm experience, education, climatic-socks experience, access to climate information, extension, number of oxen, farm size, labor force, livestock and distance to market are some of important variables that influences adoption in single and combination practices. Most of these variable have positive and significant relation with adoption. The overall comparison of adopter and non-adopter shows that, adoption improved expenditure of adopter by 36.34 percent than non-adopter. Similarly, if non-adopter adopted, their expenditure would be increased by 15.90 percent than their current consumption.

The summary of adoption based on drought resilience index shows that, adoption increased resilience index of adopter by 29.85percent than non-adopters. Similarly, if non-adopter adopted the conservation practices, their current resilience index would be increased more than their current resilience index. Adopting CA practices significantly increases the consumption and drought resilience index than non-adopters. The finding provide that combining CA practices increase consumption expenditure per AE at much higher value than single practices of adoption. It shows that farmers who adopt one CA practice are more likely to adopt additional practices than those who do not adopt. Policies that try to reduce poverty and improve resilience to drought while also improving soil fertility could first target the 10.5 percent of non-adopter and then 27 percent of single CA practices adopter to increase adoption impact.

Generally, the results endorses that adoption of conservation agricultural practices have positive and significant impacts on the households' resilience to drought (DRI) and annual consumption expenditure per AE. The study shows that extension worker can play an important role in adoption of CA through creating awareness, distributing information for the farmers. The policy implication for these results is that there is a need to encourage extension service to promote the adoption of CA practices, particularly in its combination, given its significant impact on households' poverty and resilience to drought.

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Author's contribution

I declare that we all are the authors of this research article. Regarding the Author's contribution JM: prepared the proposal, collected the data, analyzed, interpreted the data, and wrote the paper. JH, MJ and KJ provide advisory services and commented on the manuscript from data analyzing, interpreting and writing up of the final report. Finally, all authors read and approved the final manuscript.

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Data availability statement

The author confirms that the data that support the findings of this study are available based on the request from the corresponding authors.

Declarations

Competing Interests: The authors declare that they have no competing interests related to the publication of this research manuscript.

Ethics approval
This study involved a questionnaire-based survey of farmers and No human or animal tissues were used. The study procedure was assessed and approved by Fadis Agricultural Research Center under Oromia Agricultural Research Institute. Participants provided their verbal informed consent for the survey questions.

Consent to participate:
Informed consent was obtained from all individual participants included in the study.

Consent for publication
Not applicable

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