Turkish Journal of Agriculture - Food Science and Technology, 10(8): 1611-1619, 2022
DOI: https://doi.org/10.24925/turjaf.v10i8.1611-1619.5157

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Is There A Synergy in Adoption of Climate Smart Agricultural Practices? Evidences from Ethiopia

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ARTICLE INFO

Research Article

Received : 09/03/2022
Accepted : 29/07/2022

Keywords:
Conservation tillage
Manure
Multivariate probit
Soil conservation
Government

ABSTRACT

This study assessed the intensity of adoption of climate-smart agricultural practices (CSA), identified determinants of the adoption, and examined adoption synergies and trade-offs among the practices in Ethiopia. The study used cross-sectional data collected by the Ethiopian Central Statistical Agency with the support of the World Bank in 2018/2019. The analysis was done using descriptive statistics and multivariate probit model. Widely promoted CSA technologies i.e. conservation tillage, manure, crop residues, compost, and soil and water conservation practices were considered in the study. The study found soil and water conservation practices were the most widely adopted technologies (77% of farmers) followed by manure application (56% of farmers), and residue cover (54% of farmers). Among the adopters, 43% and 13% of them used conservation tillage and applied compost on their farms respectively. Area-based intensity of adoption of soil and water conservation practices, residue cover, conservation tillage, manure, and compost were 63%, 25%, 18%, 14% and 3%, respectively. The study indicated improvements in government services such as extension, credit, market and watershed programs enhance adoption of CSA practices. Adoption of manure and compost, residue cover and compost, and residue cover and conservation tillage had a positive and significant correlation, implying that adopting one practice increases the likelihood of adoption of the other practice for the same farmer. In conclusion, the government needs to use the opportunity of complementarity effect among adoption decision of the practices and work on driving factors identified to enhance the adoption and build resilient agriculture.

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Introduction

Agriculture contributes 32.7% of GDP to Ethiopian economy (NBE, 2020). The sector accounts for 90% of exports, and 85% of employment (Bingxin, 2011).The total land cultivated for crop production was about 12.9 million hectares, of which cereals production covered 81.5%, pulses accounted for 12.2%, and oilseeds accounted for 6.4% (NBE, 2020). However, the performance of the agriculture sector in Ethiopia is highly dependent on the timely onset, duration, amount, and distribution of rainfall that makes the sector highly vulnerable to drought and other natural troubles (CSA, 2019). Climate change and low level of technology adoption are among the main problems in agriculture that decreases productivity. According to CIAT and USAID (2017), climate change may decrease GDP by 8–10% by 2050, but adaptation action in agriculture could cut climate shock-related losses by half.

Mitigation of climate change impacts through technological changes is the primary concern in agriculture to ensure the food security of the growing world population. Increasing the adoption of sustainable agricultural practices has become an important device to enhance agricultural productivity and alleviate the impact of climate variability. There is a growing interest among policymakers and development practitioners to get as many farmers, mainly small-scale farmers, as possible to embrace sustainable farming practices that will fortify agricultural and food systems (Victor et al., 2019).

Many approaches have been recommended to mitigate the impacts of climate change on agricultural production. Climate-smart agricultural (CSA) practices that integrate the benefits of a sustainable increase in agricultural productivity, the adaptation and building of resilient agricultural and food security systems have appeared to be very promising, particularly against high risk of climatic shocks (FAO,2013). Conservation agricultural practices including conservation tillage, crop residues, manure application, and crop rotation, have the potential to increase water infiltration and thereby reduce the risk of crop failure (Thierfelder and Wall, 2009).

CIAT and USAID (2017) indicate that, although widespread use of traditional production methods in Ethiopian agriculture, there is evidence of increased use of improved agricultural practices such as organic fertilizers, improved crop varieties with higher tolerance to drought, pests, and diseases, improved livestock feeding practices and soil and water conservation practices, as attempts to increase productivity and resilience.

Few studies investigated the simultaneous uptake of climate-smart agricultural practices in Ethiopia. In particular, Hailemariam et al. (2018) considered interdependency and tradeoff among these practices. However, the study was limited to the Nile basin and do not have wider coverage. To inform policymakers and increase the adoption of CSA practices, the trade-off and synergies among them need to be studied adequately. Therefore this study assessed the intensity of adoption of CSA practices, adoption synergies, and trade-offs among the CSA practices and identified adoption determinants in Ethiopia.

Methodology of the study

Study Area

This study was carried out in Ethiopia. Ethiopia is 12th world populous country found in the horn of Africa which has a total area of 1,100,000 square kilometers and is known for its agro-climatic, cultural and ethnic diversity. Agro-climatic classification of Ethiopia based on annual mean temperature includes Bereha (Desert), Kolla (Tropical), Woina Dega (Subtropical) and Dega (temperate), and Wurch (afro-alpine). Agriculture is the main stay that embraces 85% of labor force and the production season varies based on the climatic conditions. Cereals, pulses, oilseeds, vegetables, root crops, fruits, coffee, enset, chat, hops, sugarcane, cotton, tobacco, etc. have been produced for food, making drinks, stimulation, and making fabrics. Cereals accounted for 81% of the total area of production. Teff, maize, sorghum and wheat were among major cereal crops produced in the country which took 23% of the cereals area (CSA, 2019 and Wikipedia, 2022).

Type and Source of Data

The study employed cross-sectional data collected by the Ethiopian Central Statistical Agency with the support of the World Bank Living Standards Measurement Study-Integrated Surveys of Agriculture (LSMS-ISA) project carried out in 2018/2019 (World bank, 2021).A two-stage probability sampling technique was used to collect the data. The first stage of sampling entailed selection of enumeration areas (i.e. the primary sampling units) using simple random sampling (SRS) from the sample of the enumeration areas (EAs). The second stage of sampling was the selection of households to be interviewed in each EA. Finally, a total of 3239 households were selected randomly from 316 rural EAs. For this study we used 2199 households excluding households who did not cultivate crops (holds only livestock) and those with a missing data.

Figure 1. Map of the study area
Source: (WorldAtlas.com, 2022)

Method of Data Analysis

Descriptive Statistics

Descriptive statistics like mean, frequency and percentage, tabular and graphical presentation, which mostly used to examine the socio economic and farming characteristics of households employed along with appropriate statistical tests.

Econometric Analysis

This study relied on multivariate probit model for empirical analysis. The observed choice between two technologies reveal which one provides greater utility. Accordingly, the rational farmer adopts a given new technology if the expected utility obtained from the new technology is higher than that of the previous one.

Following Arun and Yeo (2020) the general specification for the multivariate probit model (MVP) is given as follows:

$$y^*_m = x'_{m\beta_m} + \varepsilon_m, y_m = 1 \quad (1)$$
i$y^*_m > 0$, 0 otherwise, m=1,……M f
$E[\varepsilon_m | x_1, \ldots, x_m] = 0$; $Var[\varepsilon_m | x_1, \ldots, x_m] = 1$
$cov[\varepsilon_j \varepsilon_m | x_1, \ldots, x_m] = \rho_{jm}$; $\varepsilon_1 \ldots\ldots, \varepsilon_m \sim N_M(0, \Omega)$

Where x is a matrix of covariates, consisting of any independent variables, β is a matrix of unknown regression coefficients and ε_m is residual error. Ω is the variance-covariance matrix. The off-diagonal elements in the correlation matrix ρ_{jm} represent the unobserved correlation between the stochastic component of the j^{th} and m^{th} options.

In this model with the possibility of adopting multiple CSA practices, the error terms jointly follow a multivariate normal distribution (MVN) with zero conditional mean and variance normalized to unity (Aryal et al., 2018). The adoption of several technologies is better analyzed with a multivariate probit model rather than using separate univariate probit models, because the former can account for correlations between the disturbance terms (Sodjinou and Henningsen, 2012). The pair wise correlation coefficient of the error terms corresponding to any two CSA practices in the off-diagonal elements in the covariance matrix become non-zero justifies a multivariate probit model (Aryal et al., 2018).

This study focused on the adoption of CSA technologies; i.e. conservation tillage: as indicated in FAO, (1993) there are five types of conservation tillage systems: i.e. no-tillage, mulch tillage, strip tillage, ridge till (including no-till on ridges) and reduced or minimum tillage. Accordingly, in this study adoption of conservation tillage refers to adoption of at least either of minimum tillage or zero tillage. use of manure, retaining crop residues (Crop residue retention refers whether the land is covered at least 30%) use of compost, and soil and water conservation practices. The unit of analysis was the farmer that decided to engage or not in CSA practices.

Results and Discussion

Description of Explanatory Variables

Of the total sample farmers, 21% were female headed households. The number of male headed households that adopted manure and compost was significantly higher than the number of female headed household adopters. Different to manure and compost the number of male headed household adopters of conservation tillage were significantly lower than female headed household adopters. Age of farmers could be used as a proxy variable for experiences in agriculture. Average age of sample farmers was 45 years and the average age of adopters of manure, compost, conservation tillage and soil and water conservation was found higher compared to average age of non-adopters. Education is assumed to enhance the level of technology adoption and it was considered as dummy variable, literate versus illiterate. The study revealed only 14% of the farmers were literate and the number of literate farmers that adopted conservation tillage was more than illiterate ones. The household size was measured using adult equivalent in the study. The average household size was 4 adult equivalent and the farmers who adopted manure, compost and residue cover had more adult equivalent compared to non-adopters.

Of the farmers 41% of them owned mobile phones and 6% of them participated in off-farm activities. Participation of farmers in government extension programs and watershed activities was measured as dummy variable of participation. The number of sample farmers who participated in extension program and watershed activities were significantly higher for adopters of manure, compost, residue cover and soil and water conservation compared to non-adopters (Table 1).

Farmers were considered adopters of improved seed if they used improved seed for at least one of the crop that they planted in the survey year. The number of improved seed users that adopted manure, compost and water conservation was significantly higher compared to non-adopters. The number of adopters of conservation tillage that used improved seed was significantly lower than non-adopters.

Farmers those hold large cultivated land size is assumed to have better opportunity to try new agricultural technologies. Adopters of manure and soil and water conservation had larger cultivated land compared to non-adopters and the average cultivated land size of farmers was 0.98 hectare. About 9% of farmers had an access to credit and the number of adopters of soil and water conservation who had credit access was significantly higher than non-adopters. Livestock holding was significantly higher for adopters of manure and soil and water conservation compared to non-adopters and the average livestock holding of sample farmers was 3.9 TLU. Annual expenditure that a farmer has could be used as proxy variable to level of income of the household. Accordingly, average household annual expenditure was 47,700 birr and the expenditure was found higher for adopters of manure, compost and residue cover as compared to their counterpart non-adopters.

Average distance to main market (zonal market) that the farmer had from his residential house was 61 km. Non-adopters of manure and soil and water conservation were found to travel longer distance to main market compared to adopters of the technologies.11% of farmers had an access to irrigation water and the number of adopters of soil and water conservation with access to irrigation water was significantly higher compared to non-adopters (Table 1).

In conclusion, preliminary descriptive statistics pointed out a greater likelihood of adoption of CSA practices among relatively better off farmers with high access to government services (such as extension and credit) as well as markets.

Intensity of Adoption

The farmer that adopted the considered technologies at least on one of his farm was considered as adopter of the technology and not otherwise. Soil and water conservation practices were widely adopted (77%) climate smart agricultural technology. The result matches with effort that has been made by governmental and non-governmental organizations to insure soil and water conservation in the country. Manure application and residue cover was adopted by more than half of the farmers. Conservation tillage and compost application were adopted by 43% and 13% of the farmers respectively (Figure 1).

Number of farmers who adopted manure, compost, residue cover, conservation tillage and soil and water conservation practices (SWCP) significantly varied across regional state of the country. Manure was largely adopted in Southern Nation Nationalities Peoples (77%), Ahmara (73%) and Oromia (60%) regional states respectively and had lower adoption level in Somali and Gambela regional states.

Table 1. Definition and description of independent variables across adoption of climate smart technologies

Variables	Manure			Compost			Residue cover		
	MA1	MN2	MT3	CA1	CN2	CT3	RA1	RN2	RT3
Sex (% male)	81	76	79***	86	78	79***	81	78	79
Age (years)	46	44	45***	47	44	45***	45	45	45
Education (% Literate)	14	14	14	15	13	14	14	13	14
Household size (AE)	4.1	3.8	3.9***	4.2	3.9	4**	4.1	3.9	4.0***
Mobile owner (% yes)	41	41	41	36	42	41*	39	43	41
Off-farm (% yes)	5	7	6*	7	6	6	6	6	6
Extension (% yes)	50	34	43***	60	40	43***	47	40	44***
Watershed activities(% yes)	68	49	60***	72	58	60***	62	59	61
Credit access (% yes)	11	6	9***	10	9	9	9	10	9
Type of seed(%improved)	34	22	29***	40	27	29***	29	30	29
Cultivated land size (ha)	1.1	0.87	0.98***	1	0.98	0.98	0.98	1	1
Livestock (TLU)	4.4	3.4	3.9***	3.8	3.9	3.9	4	4	4
Distance to market (km)	59	63	61*	65	60	61	61	60	60
Expenditure (1000 Birr)	49.9	44.6	47.7**	57.9	46.1	47.7***	50.3	45.4	47.9**
Irrigation (% yes)	12	9	11**	12	11	11	11	10	11

MA1: Adopters N=1,241; MN2: Non adopters N=958; MT3: Total N=2199; CA1: Adopters N=289; CN2: Non adopters N=1910; CT3: Total N=2199; RA1: Adopters N=1144; RN2: Non adopters N=989; RT3: Total N=2133

Variables	Conservation tillage			Soil and water conservation		
	COA1	CON2	COT3	SA1	SN2	ST3
Sex (% male)	79	82	81*	81	74	79***
Age (years)	46	44	45**	45	43	45***
Education (% Literate)	12	15	14**	14	13	14
Household size (AE)	4.1	4.0	4.1	4.0	3.8	4.0*
Mobile owner (% yes)	36	46	41***	41	41	41
Off-farm (% yes)	6	6	6	6	4	6
Extension (% yes)	37	49	44***	49	22	43***
Watershed activities(% yes)	62	61	61	64	45	60***
Credit access (% yes)	8	10	9**	11	3	9***
Type of seed(%improved)	23	34	30***	32	18	29***
Cultivated land size (ha)	1.1	1.0	1.0	1	0.69	0.98***
Livestock (TLU)	4.2	4.0	4.1	4.2	3	3.9***
Distance to market (km)	61.2	60.0	60.0	59	66	61***
Expenditure (1000 Birr)	49.2	49.3	49.3	47.6	48.0	47.7
Irrigation (% yes)	11	10	11	13	4	11***

COA1: Adopters N=810; CON2: Non adopters N=1084; COT3: Total N=1894; SA1: Adopters N=1690; SN2: Non adopters N=509; ST3: Total N=2199

*** P<0.01, ** P<0.05, * P<0.1; AE: Adult equivalent; TLU: tropical livestock unit

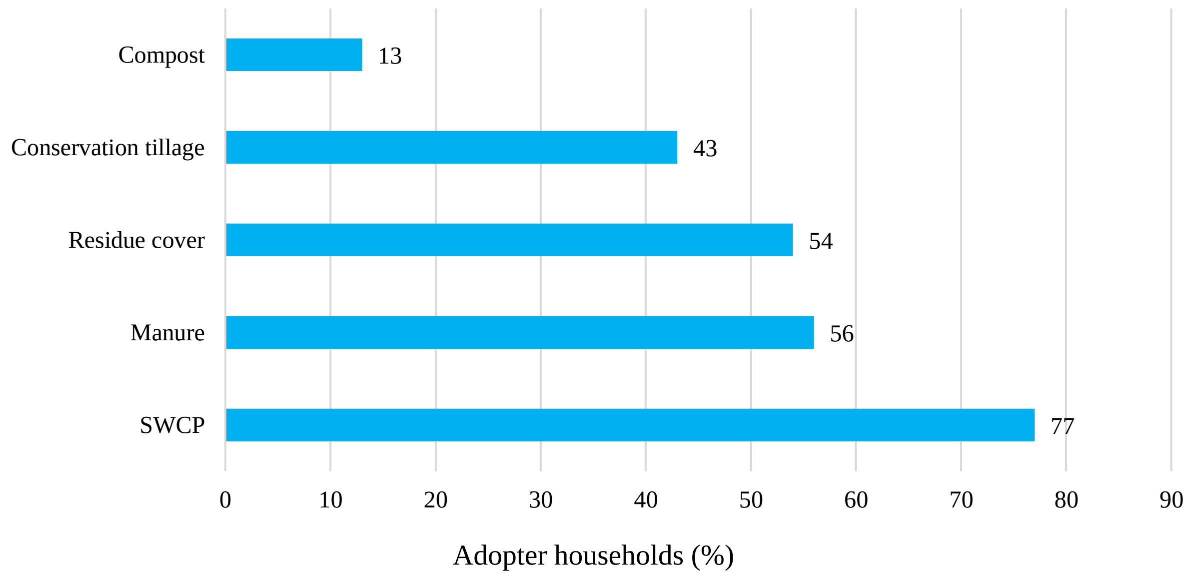

Figure 2. Level of adoption of the technologies based on number of farmers used the practice

The highest adoption rate of residue cover was found in Benishan-Gulgumuz regional states (90%) followed by SNNPR (79%), Harari (73%) and Gambela (68%) regional states. Conservation tillage was widely adopted in Somali (100%), Dire Dewa (82%) and Benishan-Gulgumuz (62%) whereas the lowest level of adoption was found in Tigray (29%) regional state. Compared to other climate smart agricultural technologies soil and water conservation practices were better adopted in many of the regional states. The highest level of adoption of SWCP was found in Ahmara (96%) regional state whereas the lowest adoption was found in Gambela (19%) regional state (Table 2).

Plot level coverage of the technologies adoption also varied across regional states. Soil and water conservation practices which had highest plot coverage (57% farm plots) were widely adopted in Dire Dewa, Harari, Tigray, Ahmara and Afar regional states. Soil and water conservation practices were adopted on 63% of the area of 12.5 million hectares of farm land. Residue cover was found to have 2nd largest coverage and was applied on 36% of the plots and 25% of farm areas. The study revealed that manure application and conservation tillage were practiced on 31% and 26% of total farm plots respectively. The adoption result obtained for conservation tillage was virtually consistent with the finding of Marenya et al. (2017) which showed a 30% adoption of minimum tillage in Ethiopia. The total area in which manure was applied and conservation tillage was practiced accounted for 14% and 18% out of 9.9 million hectares of farm land respectively. Compost application took the least adoption intensity in terms of both number of plots (5%) and area coverage (3%) (Table 2 and Figure 2).

Soil fertility status of farm plots was rated into good, fair and poor based on the farmers perception. Most of the plots that climate smart agricultural technologies were applied on were plots that were rated as fair soil fertility. Out of the total plots on which CSA practices were adopted on, 70% manure, 65% of compost, 57% of residue cover, 52% of conservation tillage and 58% of SWCP were adopted on plots that had fair soil fertility status.

Table 2. Intensity of adoption across regional states (%)

Regional states	Manure		Compost		Residue cover		Conservation tillage		Soil and water conservation	
	MH	MP	CH	CP	RH	RP	COH	COP	SH	SP
Tigray	46	27	11	6	29	24	29	21	89	78
Afar	10	7	0	0	39	34	30	28	74	65
Amhara	73	25	20	5	34	14	46	17	96	71
Oromia	60	30	13	6	38	25	34	17	76	54
Somali	0	0	29	29	60	60	100	100	43	50
Benishangul gumuz	47	20	18	5	90	75	62	39	82	55
SNNP	77	45	15	5	79	53	47	25	63	40
Gambela	7	8	3	1	68	57	35	70	19	8
Harari	58	44	11	4	73	60	34	22	93	80
Dire Dawa	52	40	0	0	63	56	82	65	90	85
Total	56	31	13	5	54	36	43	26	77	57

MH: HH (N=2199); MP: Plots(N=13377); CH: HH (N=2199); CP: Plots (N=13377); RH: HH (N=2199); RP: Plots (N=10160); COH: HH (N=2199); COP: Plots (N=8432); SH: HH (N=2199); SP: Plots (N=15636)

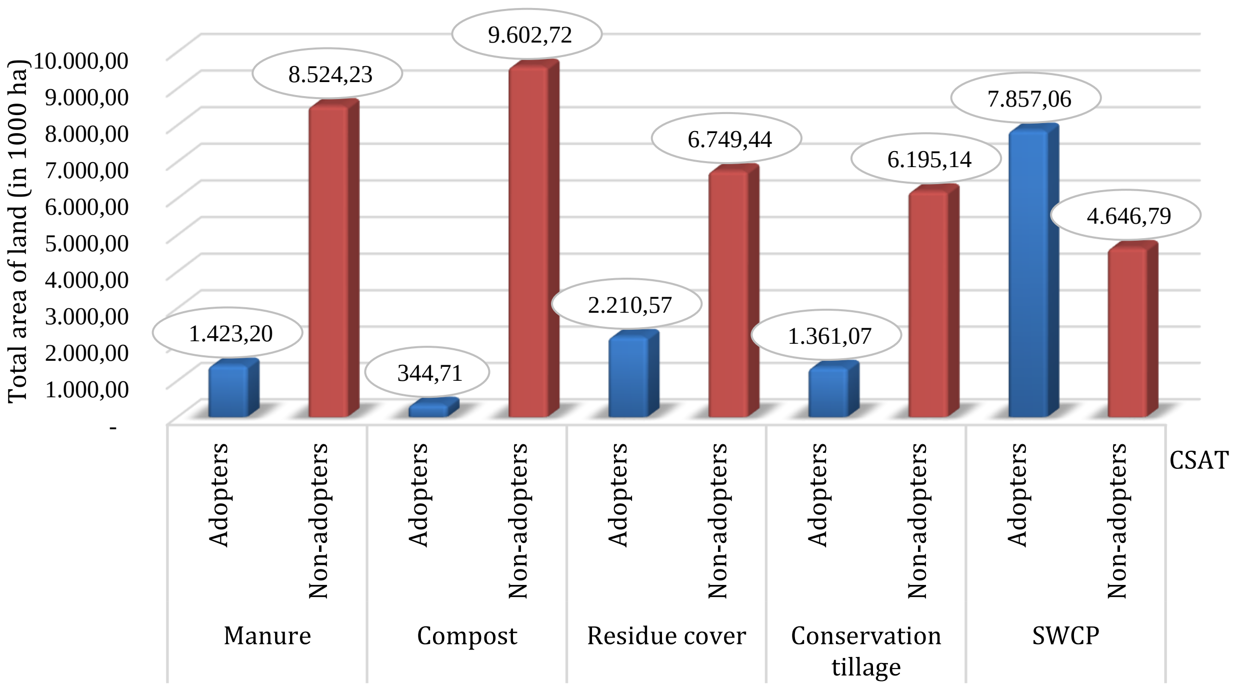

Figure 3. Intensity of adoption of climate smart technologies based on the total area covered across the country

Table 3. Intensity of adoption across perceived soil fertility of farm plots

Technologies	Soil fertility of farm plots (No. Plots)			Chi-square value
	Good	Fair	Poor	
Manure	134 (24)	395 (70)	37 (6)	43.555***
Compost	43 (33)	85 (65)	2 (2)	10.134***
Residue Cover	405 (34)	679 (57)	104 (9)	2.507
Conservation tillage	221 (34)	335 (52)	92 (14)	23.873***
SWCP	1000 (31)	1864 (58)	364 (11)	18.206***

Percent of plots in parentheses, *** P<0.01

This might be related to farmers' perception that plots that have fair level of soil fertility needs to be maintained using CSA practices so that its fertility would not be declined and become poor soil. Plots with good soil fertility might also be taught not in the level that CSA technologies were practiced on as they give good production. CSA technologies were less adopted on poor fertility plots compared to good and fair soil fertility plots. Farmers also tended to allocate farm plots that were perceived to have poor fertility for pasture, homestead, and forest or allowed it to be fallow. About 57% poor soil fertility plots were not used for crop production. Generally, adoption of CSA practices was higher on fertile farm plots, possibly to maintain fertility rather than increasing fertility of poor farm plots.

Econometric Analysis

Model diagnosis

The model fit analysis, Wald test, for multivariate probit model confirmed the adequacy of the model for the analysis. The hypothesis that coefficients in each equation are jointly equal to zero was rejected suggesting the variations in the dependent variables were explained by the specified model (independent variables). Likelihood ratio test of the null hypothesis that the covariance of the error terms across equations are not correlated was also rejected, which supports estimations of MVP model. Therefore, likelihood ratio test also confirm that adoption of climate smart agricultural technologies were interdependent and need joint analysis. Pearson's correlation coefficient was used to check whether there was serious multicollinearity among independent variables. Some variables were transformed to solve multicollinearity problem and to maintain normal distribution assumption. Size of cultivated land, livestock, household size and distance to market were transformed into their natural logarithm.

Factors affecting adoption of climate smart agricultural technologies

Manure is assumed to enhance the level of soil fertility and there by decrease the need for chemical fertilizers. Adoption of manure positively and significantly associated with extension program participation, watershed activities participation, credit access and number of livestock owned by the farmers. Extension system is assumed to play crucial role in technology and information delivery for farmers. The study indicated that participation in extension program significantly (P<0.01) increased the likelihood of manure adoption. Watershed activities have been done through campaign which enable farmers to share experiences and knowledge. Additionally awareness have been created particularly about importance of soil and water conservation using the opportunity of the large farmers` gathering. Farmers possibly use credit money to buy livestock and resale after they fattened for more price; doing this the farmer also get animal manure to apply on their farm land. Cultivated land size (P<0.01) and distance to market (P<0.01) had negative and significant association with adoption of manure. Market areas has multiple functions for farmers; they use it to sell their outputs, buy inputs and share important information about the performance of their farms, market situation, new knowledge and technology they apply, climate change and natural disasters and so on. Therefore as distance to main market increase, exposure that a farmer has to information decrease thereby the likelihood for technology adoption also decrease. On the other side as distance to main market increases farmers opportunity of selling to potential traders and buying important farm inputs decrease; this may discourage farmers to produce surplus using improved way of doing and improved technologies.

Compost is organic fertilizer prepared from organic matters like animal dung, stalk, straw, and leaf of different plants etc and helps to improve productivity of crops. The study pointed out that age of the household head (P<0.1), participation of farmers in extension program (P<0.01), watershed activities (P<0.1) and annual expenditure (P<0.05) of the household significantly and positively associated with the adoption of compost. As age of farmers increase they able to get lots of practical experience and it increases the likelihood of technology adoption as it was exhibited for compost adoption. Participation of farmers in extension program and watershed activities facilitate information flow and knowledge transfer and perhaps increase the likelihood of adoption of compost.

Residue of crops covered on farm land facilitates infiltration of water in soil, reduce soil erosion and maintain soil moisture. The study showed owning of mobile phone negatively associated with adoption of residue cover. Beside this, distance to market had significant and positive correlation with adoption of residue cover; which indicated as distance to market increased from the residence of farmers the likelihood of adoption of residue cover increased. These two variables differently associated with adoption of residue cover than expected and the reason for this might be related to market price of crop residue. Price of crop residue had become increasing with an increase of demand associated with expansion of dairy farms and fattening that were located in urban and semi-urban areas nearby the market areas. Short distance to market and having mobile phone may facilitates flow of market information and thus farmers may prefer to sell their crop residue than using it on their farm. Urban dairy and fattening farms also tend to use more crop residue to feed their animals as it is relatively cheaper than other manufactured type of feeds which attract farmers to sell their crop residue as market distance becomes shorter. Like other climate smart agricultural technologies adoption of residue cover was associated significantly and positively with participation of farmers in extension program (P<0.01) and watershed activities (P<0.01).

Conservation tillage improves soil structure and rapid infiltration of water in soil (Rusu et.al, 2009). The study showed age of the head, cultivated land size and irrigation access positively and significantly associated with adoption of conservation tillage whereas extension, improved seed and household annual expenditure negatively and significantly associated with it. Adoption of conservation tillage increased with the increased of age of the household head. Cultivated land size and irrigation availability positively and significantly associated with adoption of conservation tillage. Large cultivated land size (Musafiri et al., 2021) and availability of irrigation water increase the level of confidence for farmers to try conservation tillage as these could be used as assurance in case of crop failure due to use of the new technology. The negative and significant relationship between extension and adoption of conservation tillage, and use of improved seed and adoption of conservation tillage was unexpected; however, this possibly elated to the focus that conservation tillage had got in the extension programs and technology development. Training shave been given to farmers at the beginning of production seasons to make farmers ready to prepare their farm plowing frequently before the planting time and this was sometimes done in the form of campaign in Ethiopia. Agricultural technology packages including improved seeds give little consideration for conservation tillage to be included as alternative agricultural technology package and thus missed in extension programs.

The study also revealed that age of the household head, education, participation in extension programs and watershed activities, access to credit, cultivated land size and access to irrigation positively and significantly associated with adoption of soil and water conservation practices whereas adult equivalent and distance to market negatively and significantly associated with adoption of the technology (Table 4). The result revealed extension and education enhanced adoption of soil and water conservation practices. The positive association between extension and SWCP is consistent with the finding of Musafiri et al. (2021). Extension and education are means of technology and knowledge transfer that is assumed to support the adoption of new technologies. Access to credit (P<0.05) and cultivated land size (P<0.01) had significant and positive relationship with adoption of soil and water conservation practices.

Table 4. Factors affecting adoption of climate smart agricultural technologies

Variables	Manure (1)	Compost (2)	Residue cover (3)	Conservation tillage (4)	SWCP (5)
Sex[male]	0.017 (0.112)	0.038 (0.139)	-0.094 (0.115)	-0.095 (0.113)	0.181 (0.129)
Age[years]	0.002 (0.003)	0.006* (0.003)	-0.003 (0.003)	0.009*** (0.003)	0.007* (0.004)
Education[literate]	0.108 (0.125)	-0.027 (0.135)	-0.022 (0.114)	0.075 (0.116)	0.295** (0.145)
Mobile[yes]	-0.077 (0.093)	-0.127 (0.103)	-0.178** (0.086)	-0.138 (0.087)	-0.020 (0.106)
Household size[AE]	0.176* (0.102)	0.063 (0.119)	0.090 (0.097)	0.143 (0.099)	-0.201* (0.112)
Off-farm[yes]	-0.307* (0.171)	0.153 (0.191)	-0.183 (0.175)	-0.038 (0.179)	0.059 (0.190)
Extension[yes]	0.258*** (0.092)	0.312*** (0.103)	0.246*** (0.086)	-0.314*** (0.087)	0.351*** (0.105)
Watershed activities[yes]	0.270*** (0.101)	0.206* (0.122)	0.431*** (0.096)	0.045 (0.097)	0.187* (0.111)
Credit access[yes]	0.290** (0.146)	-0.064 (0.143)	-0.106 (0.126)	-0.094 (0.130)	0.470*** (0.180)
Type of seed[improved]	0.075 (0.095)	0.077 (0.107)	-0.076 (0.088)	-0.291*** (0.090)	-0.208* (0.110)
Cultivated land size[ha]	-0.179*** (0.044)	-0.068 (0.051)	-0.034 (0.041)	0.122*** (0.043)	0.238*** (0.047)
Livestock[TLU]	0.270*** (0.052)	0.021 (0.061)	-0.021 (0.049)	-0.036 (0.048)	0.080 (0.055)
Distance to market[km]	-0.122** (0.055)	0.079 (0.063)	0.397*** (0.055)	-0.035 (0.050)	-0.330*** (0.067)
Annual Expenditure[birr]	0.070 (0.066)	0.166** (0.074)	0.034 (0.066)	-0.114* (0.065)	-0.049 (0.078)
Irrigation[yes]	0.246 (0.157)	-0.191 (0.174)	-0.103 (0.144)	0.295** (0.143)	1.309*** (0.249)
Constant	-0.928 (0.732)	-3.789*** (0.864)	-2.221*** (0.723)	0.919 (0.720)	2.219** (0.915)

Wald chi2 (75)=495.70; Log pseudo likelihood = -24462100; Prob > chi2=0.0000; Number of observations= 1,724
Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0:
Chi2 (10) = $4.9e^{+07}$, prob > chi2 = 0.0000

Robust standard errors in parentheses; *** P<0.01, ** P<0.05, * P<0.1

Table 5. Synergy and trade off among climate smart agricultural technologies

Pair of CSA practices	Relationship	Coefficient	Standard error	Z
Compost and Manure	ρ 21	0.339***	0.061	5.53
Residue cover and Manure	ρ 31	-0.013	0.052	-0.26
Conservation tillage and Manure	ρ 41	-0.061	0.054	-1.14
Soil and water conservation and Manure	ρ 51	0.102	0.063	1.63
Residue cover and compost	ρ 32	0.245***	0.058	4.26
Conservation tillage and compost	ρ 42	-0.019	0.059	-0.33
Soil and water conservation and compost	ρ 52	0.042	0.073	0.57
Conservation tillage and residue cover	ρ 43	0.090*	0.050	1.78
Soil and water conservation and residue cover	ρ 53	-0.214***	0.058	-3.69
Soil and water conservation and conservation tillage	ρ 54	-0.049	0.059	-0.82

*** P<0.01, ** P<0.05, * P<0.1; Note: 1= Manure, 2=compost, 3=Residue cover, 4=Conservation tillage and 5=soil and water conservation practice,

The reason for this possibly be the autonomy of technology use that the farmers could get from the assets. In addition to this, as cultivated land size increases the confidence of a farmer to try new practices and technology possibly increases and the result was consistent with the finding of Hailemariam et al. (2018). Adult equivalent (P<0.05) had significant and negative relationship with adoption of soil and water conservation practices. In most of rural community as children get old enough for work parents should give them farm land to be cultivated by themselves and this increases fragmentation of cultivated land in the household which in perhaps leads to fear of technology adoption having small plots of cultivated land. The negative relationship between distance to market and adoption of soil and water conservation practices was similarly reported by Hailemariam et al. (2018).

Generally, the result denoted that improvements in government services such as extension, credit, market and watershed programs would enhance adoption of CSA practices.

Adoption trade-off and synergies among climate smart agricultural technologies

Adoption of manure and compost had positive and significant relationship implying that the adoption of manure increased the likelihood of adoption of compost for the same farmer (Table 5). The study showed that adoption of manure and compost supplemented each other i.e. adoption of one of the technology augmented the adoption of the other. There was also a positive and significant relationship between adoption of residue cover and compost which indicated adoption of one of the practice enhanced the likelihood of adoption of the other practice keeping other factors constant. Farmers who adopted crop residue more likely applied compost on their farm land and vice versa. Positive and significant relationship was found between adoption of residue cover and conservation tillage indicating the complementarity effect between the two technologies. Adoption of conservation tillage increased the adoption likelihood of residue cover. Both conservation tillage and residue cover are conservation agriculture practices which have been promoted to improve soil properties, preserve and increase soil organic matter, and hence reduce soil erosion for sustained crop production (FAO, 2013). Adoption of residue cover was found to have substitutability effect on adoption of soil and water conservation practices. Farmers who adopted soil and water conservation practices such as stone bund, terracing and soil bund may think it was not essential to cover the soil using crop residue as both soil and water conservation practices, and residue cover used to prevent soil erosion. In conclusion, adoption decision among CSA practices were interdependent, and adoption of one of the practice enhanced the likelihood of adoption of the other in most of the cases.

Conclusion

The study indicated soil and water conservation practices were the most widely adopted (77% of farmers) climate smart agricultural technologies in Ethiopia. Manure application and residue cover were adopted by more than half of the farmers. Adoption of conservation tillage and compost application was accounted for 43% and 13% of the farmers respectively. Although the climate smart agricultural technologies were adopted by considerable number of the farmers, it was quite low in terms of area coverage for most of the technologies. Area based adoption intensity of the technologies was found 63% for SWCP, 25% for residue cover, 18% for conservation tillage, 14% for manure and 3% for compost. Climate smart agricultural technologies tend to be applied on plots that were fertile compared to the poor ones. Among the total number of plots on which CSA practices were adopted, about 70% manure, 65% of compost, 57% of residue cover, 52% of conservation tillage and 58% of SWCP were accounted for plots that have fair level of soil fertility.

Adoption of manure was positively and significantly associated with extension program participation, watershed activities, credit access and number of livestock owned by the farmers. Age of the head, participation of farmers in extension program, watershed activities and annual expenditure of the household had significant and positive relationship with adoption of compost. Owning of mobile phone had negative relationship with adoption of residue cover whereas participation in extension, watershed activities and distance to market were associated with adoption of residue cover positively. Adoption of conservation tillage was found to have positive and significant relationship with age of the head, cultivated land size and irrigation access whereas extension, improved seed and household annual expenditure had negative relationship with it. Age of the head, education, participation in extension programs and watershed activities, access to credit, cultivated land size and irrigation access were the factors that positively associated with adoption of soil and water conservation practices whereas adult equivalent and distance to market had negative relationship with adoption of SWCP.

The study indicated adoption decision of climate smart agricultural technologies were interdependent. Supplementary effect in adoption decision was witnessed between manure and compost, residue cover and compost, conservation tillage and residue cover. Thus, the result disclosed adoption of one of technology helped to enhance adoption of the other technology keeping the other factors constant. Adoption of soil and water conservation activities and residue cover showed substitutability effect as farmers might think both technologies had the same function that is prevention of soil erosion and water conservation.

Adoption intensity of the technologies were low that needs more effort from the government particularly through its extension system, watershed programs and improving market access to farmers. It is also important to use the advantage of complementarity effect among climate smart agricultural technologies to promote and enhance adoption of the technologies in combination. The government has to give due focus for climate smart agricultural technologies in extension packages to strongly promote and demonstrate the technologies for farmers so as to boost the adoption on all category of soil fertility status.

Acknowledgement

This research is supported by the CGIAR Standing Panel on Impact Assessment (SPIA) under its program of work 2019-2021. I cordially express my gratitude for the support given by EIAR and my staff particularly Tesfaye Solomon in reviewing the manuscript.

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