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ESTIMATING THE IMPACT OF CONSERVATION AGRICULTURE ADOPTION ON CROP PRODUCTIVITY UNDER RAIN-FED SYSTEM (ETHIOPIA): A COUNTERFACTUAL APPROACH ANALYSIS

Mussie YM[1*]

Mussie Ybabe Mengistu

*Corresponding author email: mussieyba@gmail.com

[1]College of Social Science and Humanities, Geography and Environmental Studies, University of Gondar, Gondar, Ethiopia

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ABSTRACT

Few initiatives have been made to raise awareness of Conservation Agriculture (CA) and how it has improved the lives of smallholder farmers in sub-Saharan Africa, particularly in Ethiopia. This study seeks to analyze the crop productivity impact of CA in the Farta district of Ethiopia. Cross-sectional household data was collected in 2018/19 in the two agro-ecological zones of the study area. Mean comparison of CA farmers' characteristics with respect to count of adult males in family and number of farm plots fragmented; and educational attainment, differ statistically from their counterparts. The impact of CA adoption was estimated using counterfactual outcome approach by employing Propensity Score Matching (PSM) based on a sample of CA matched with the non-CA farmers. Initially a binary outcome variable indicating whether a farmer adopted CA was estimated as a primary outcome while crop productivity as a secondary outcome variable of interest measured in kg/hectare of farmland in logarithmic form. From a total of 322 subjects included 168 CA and 154 non-CA farmers, four treated cases (CA farmers) were discarded from the analysis using estimator of kernel matching with no bandwidth. The Average Treatment Effect on the Treated (ATT) was used as a relevant statistical measure. The advantage was taken by CA farmers as CA practice has brought increment in 1.08 kilogram of crop produced per hectare of farmland. Despite CA's practice found with small effect as observed at T-value of 1.65 at less than 1 percent level of significance. Possible reasons may include farmers' interest to increase production at the expense of cultivating large farmland size for crop production and the failure to implement the full practices necessary to improve crop productivity. The project's findings highlighted the need for policies that support and enable a more frequent and successfully established communication link between farmers with agricultural experts at the regional, zonal, and district levels, as well as agricultural extension personnel at the local level. There should be more attention to sustainable agricultural practices through adopting crop and soil management system on farmland, improving soil quality consistently for improved crop productivity.

Key words: Rainfed production, Conservation Agriculture, crop productivity, Propensity Score Matching, Ethiopia

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INTRODUCTION

Conservation Agriculture (CA) over the past three decades was tried to promote in Africa with many organizations working in research and rural development. Yet, the success observed in CA adoption on Africa farms remained inadequate [1]. The success with adopting of CA on farms in Africa remained inadequate despite many organizations working in research and rural development promoted Conservation Agriculture (CA) over the past three decades. This is mainly due to lack of incentives to smallholder farmers for engaging in optimal land management policies and speed up the need for technological change to overcome massive land degradation leading to low agricultural productivity. Added to this, smallholder farmers' interest to invest in improved CA agricultural technologies is becoming low as they become pessimistic of their future benefits and lack immediate increase in farm income from the adoption of CA.

The suitability in smallholder farming environments for CA continued to be a strong debate in the adoption of CA technologies and their impacts in sub-Saharan Africa (SSA) [2]. The benefits farmers gained in some areas of SSA from reducing tillage were unreliable in managing weeds. Changes in the weed population are understood better during conversion from frequently tilled land for maize/bean production with continuous intercropping to reduced or no-till CA practices. Farmers most often perceived practicing CA such as reduced tillage without using herbicides resulted in high densities of weed and low crop yields [3]. On the one hand, Velvet bean (Mucuna pruriens) is implemented successfully as a tropical legume in different parts of the world. This is to fix atmospheric Nitrogen and suppress weeds through the effects of leguminous cover crops among farmers become under question for the spread of weed species [4].

Soil erosion and degradation that leads to loss of soil organic matter and nutrient depletion remained to be an agro-ecological challenge in the highlands of Ethiopia. In response to these challenges, conservation Agriculture (CA) is projected as a key intervention to abate the current trend of physical and chemical soil erosion to improve soil quality and sustainably intensify crop production and crop yield [5].

The splitting up of land into smaller entities among siblings upon inheritance forced them to use fertilizer per hectare at an increasing rate. Increased input use, however, stayed with no increase in yields and result in a decline in income at the farm level [6]. The weed infestation and interference of changes in large-scale traditional mixed farming livestock systems forced farmers to plow fields numerous times and leave crop residues in the field for 40–50 percent to feed their livestock [7].

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Minimal ability was observed in attempt to design a conservation strategy in Ethiopia in 1989 and introduce CA practice in smallholder agriculture through studying natural resources, environmental imperatives and development demands. Consequently, promoting CA adoption in traditional agriculture is bringing a small return resulting very low living standard of the majority of the people [8].

Efforts by the Agricultural Transformation Agency (ATA) of Ethiopia to promote CA practices in 2014 in many parts of the country such as Oromia, Amhara and Tigray regions have contributed to improved yield per unit area of land [9]. However, core principles of CA were not permanently implemented. This is partly associated with a lack of practical skills of extension workers in various parts of the country. In due course, this has created weak integration in the existing extension services such as making the CA practice participatory and offering more services to those farmers who show interest in the program together [10].

Natural resource deterioration observed in the study area in the last few decades has created considerable stress on the land and vegetation resources [11]. The study hypothesized that CA such as appropriate cropping systems, crop rotations, and intercropping generally results in improved crop yield over conventional agriculture given CA contribution. Community watershed rehabilitation assessment and conservation practice were investigated in the Farta district, though it lacks investigating the impact of CA on crop productivity at the household level [12]. This study, therefore, aimed to evaluate the impact of CA adoption on crop productivity while simultaneously examining the characteristics of adopters and non-adopters of CA practices in North Western Ethiopia.

Previous findings on the impacts of Conservation Agriculture practices

The CA adoption in central Mozambique has brought gain in smallholder farmers crop productivity and yields while household incomes and food security indirectly correlated with CA adoption. The data was subjected to analysis using semi-parametric propensity score matching methods with consistent estimates of ATT. Based on the results obtained; CA was suggested to systematically be a practice by integrating it into the rural development policy framework [13].

In nine countries of SSA which includes Ghana and Nigeria (West Africa); Ethiopia, Kenya, Tanzania and Uganda (East Africa); and Malawi, Mozambique and Zambia (Southern Africa), the survey was made on maize-growing households to evaluate the welfare impacts of implementing the three components of CA at individual and in combination. The result of this study as analysed based on multiple treatment estimators using techniques of inverse-probability-weighting regression-adjustment and Propensity Score Matching shows significant increment in income per consuming adult equivalent unit and total household income, respectively. The largest income gain was observed to those households who have jointly adopted the three core practices of CA [5].

The impact of CA adoption estimated using Propensity Score Matching (PSM) based on observable covariates offering consistent estimates of ATT using survey data of Rural Agricultural Livelihood in 2012 shows a small but positive impact on crop productivity and income. The authors suggested the necessity of encouraging CA adoption with the required extension services promoting CA practices and assisting farmers to generate means of their livelihood in Luapula Province, Zambia [14].

Data taken on Conservation agriculture in Eastern Uganda and Western Kenya among 800 smallholder farming households who adopt and didn't adopt and analysed its yield impact using matching estimators of Kernel and Nearest Neighbor Matching showed significant improvement in over 1000 kg of maize per hectare of farm plots. This showed CA's great potential to increase farm productivity and profitability. Whilst CA's adoption correlation with the cost of inorganic fertilizers and family labor days used per hectare of farmland found indirect as compared to households not adopting CA in maize production [15].

DATA AND METHODS

Description of the study area

The study was carried out in Farta district located in the northwestern part of Ethiopia. It lies between 11°32' to 12°03'N Latitude and 37°31' to 38°43' E Longitude covering an estimated area of 1,118 km^2. Altitudes vary between 1,900 and 4,035 m above mean sea level [16]. The population living in the district predicted in the year 2011 is about 281,280 [16].

Nearly about 71 percent of households are food insecure [17]. In terms of topography, 45 percent of the total area is a gentle slope, while flat and steep slope lands account for 29 and 26 percent, respectively. The soil characteristics, coupled with sloping terrain and intense rain events, make the woreda very susceptible to watershed degradation. The landscape nearly about seventy percent is gently inclined hills with gully formation [18].

The mean annual rainfall recorded during the survey time was 1,651mm with a mean monthly minimum and maximum temperature of 18.4 and 4.9^{0}C, respectively. The area is characterized by irregular rainfall pattern with prevalences of hail damage, soil fertility depletion, and recurrence of livestock diseases and pest infestations. Shortages of potable water, food, fuel and construction wood, and animal forage are the major challenges to livelihoods in the area [19].

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During the survey time, a total of 1,235 farm plots were used by sampled households for cultivation of crops (Table 1). From these, the proportion of farmland allocated to finger millet, sorghum, teff and maize was respectively 43, 21, 15 and 13 percent. Farmland allocated to crops like beans and sunflowers together accounted for 8 percent. Dual CA farming techniques were in practice in 9.5 percent of the farm plots. The full CA principle was applied in 1.6 percent of the farm plots. Most smallholders practiced crop diversity in sequence, rotation or association with annuals and perennials including legumes followed by minimum soil disturbance.

Sampling Procedure and Sample Size Determination

A multistage sampling procedure was employed to select the study district, kebeles, and farmers. Initially, Farta district was purposively selected as an ideal place to study the impact of CA adoption. This pertains to the two agro-ecological regions of this area, which could lead to variations in the growing conditions and drivers of CA adoption and the degradation of natural resources consequential to the present depletion of soil fertility [20].

One basic question the study brings out is defining what is meant by an “adopter” of a CA. The definition of adopter varied across different studies. What exactly is an adopter? This proves to be a complicated question with no obvious, correct answer. For realization of the study, adopter is once farm households adopt a conservation technology and decides to continue and has adopted a component or more of a conservation technology for a minimum of five years with non-stop. In a nutshell, CA adopters among households are those who adopted at least one of the three CA principles, non-adopters are those who didn’t adopt CA [21].

Four rural kebeles, namely *Buro_Teraroch* and *Girbi* situated in *dega* (midland), and *Awzet_Azawur* and *Debelima* located in *woina dega* (highland) agro-ecology sampled for it accentuates widely varying bio-diversity, socio-economic conditions, and asset ownership [22]. For instance, crop residue retention in *woina dega* (midlands) sites as evidenced during the survey time, adopted in 0.6 hectares (5 percent of their cropped land) of their farmland is much less than cropped land allocated in *Dega* (highlands) agro-ecological site while few farmers in *dega* zone practiced minimum tillage of about 0.4 hectares of cropped land.

In these four kebeles who inhabited in the two agro-ecological zones, study population (N=964) included 502 CA and 462 non-CA farmers were identified to select sampled household heads (n=322). As a final point, the household sampled was selected by systematic random sampling using the random start and sampling interval at every K_{th} individual, where K refers to the sampling interval.

Data Collection techniques

Secondary data was gathered through reviewing published and unpublished sources prior to the field visit period for a clear understanding of the purpose of the research properly guide the collection of the accurate data, choosing the best source and method of data analysis. At the time of the field work, previous work experience related to the research's purpose was collected from reports and records of concerned office maintained at Development Agent's center simultaneously with discussion with the knowledgeable local people.

A household survey questionnaire was developed initially in English, translated into the local language (Amharic) and translated back into English to ensure correct translation. The questionnaire was composed of 58 structured questions, most of which were multiple-choice questions. A preliminary survey was made with eight farmers together with four technical assistants in companion with information obtained in discussions with key informants and focus group discussants to have background information of the issue under study. Based on the insights obtained from the preliminary survey, questions were pretested and revised. Questions' relevance and validity too were checked, and necessary modifications were made. Results of descriptive analysis and Propensity Score Matching performed using Stata 14 is stated in the next section.

RESULTS AND DISCUSSION

Description of baseline characteristics

This section presented simple descriptive statistics of 15 confounding variables that may affect treatment status and/or outcome. However, it has no direct bearing on a household choice of conservation agriculture practices. Description of the entire sampled household was made using percentages and frequencies whilst comparison of means of selected variables between CA and non-CA farmers, respectively, using paired t-test and Pearson chi-square. Overall, 322 households were included, of which 168 (52.2%) and 154 (47.8%) farmers were identified as CA and non-CA farmers, respectively.

During the survey time, 4,990 kilograms of crop was produced on average per hectare of farmland. The productivity of CA farmers reported with a mean score of about 5,273 kg/hectare statistically and inversely distinct from their counterpart (p value= 0.003). Proportion (%) of farmland allocated for crop planting/cultivation and dependency exists on average in an individual household reported by about 55 and 11 percent, respectively. Nearly all households (98%) owned livestock with no clear difference between the two groups of the household. About 58 percent of surveyed farmers' age spent on farming activities. Farmers on average earned 673.7 ETB from non-farming and/or off-farming activities. A farmer on average owned 0.19

hectares of irrigated land as reported by surveyed households during the survey time. While no clear difference was observed between the two groups of the household. An individual farmer's own family labor measured in terms of Man Equivalent unit (ME) described on average of 2.74. Family labor owned on average by adopters of conservation agriculture is 2.88. This figure, as shown in Table 2, is differing significantly from their counterparts (non-adopters) who counted family labour of 2.58 as observed statistically at less than 5 percent level (P= 0.03).

The average household size of the sampled household was computed at 8. The average age of household head in years computed after transforming it into linear form (Age squared =1,685.2), is about 41 years. Adult males members count on average as reported by the surveyed households during the survey time was 3.4 people. Amongst, CA farmers on average reported 3.19 adult males which varied statistically and inversely from their counterparts in the traditional channel (P-value = 0.00). With regard to education, twenty one percent of the surveyed household head attained formal school education. Amongst the households, CA farmers' education attainment statistically and indirectly differ from their counterparts (P-value =0.00).

Overall, surveyed farmers on average owned 1.31 hectares of farmland. This is comparable to the national average of 1.38 hectares [23]. The entire sampled household was visited on average by Development Agent 3.3 times per month, whilst CA farmers are not significantly distinguishable in terms of connectivity to Development Agents. On average the number of fragmented farm plots of CA farmers is 3.77. This is statistically and positively varied from farm plots of non-CA farmers fragmented at less than 1 percent level of significance. Distance CA farmers traveled to their farm plots is statistically and positively varied from non-CA farmers at less than 1 percent level of significance.

Results of Propensity Score matching analysis

To estimate how best the conservation program improved farmer crop productivity, the author employed the counterfactual approach that one ideally observes CA adopter with had he/she not had adopted with different attributes to CA and the concept of a non-adopter of CA relevant to it. A rigorous statistical analysis was employed to estimate the impact of CA adoption using an initially binary outcome variable indicating whether a farmer adopted CA as a primary outcome and crop productivity measured in kg/hectare of farmland in logarithmic form, as our secondary outcome variable of interest. Propensity Score Matching technique was employed to construct a statistical comparison group based on matched observed characteristics of the two groups of farmers (CA adopters and non-adopters) based on their propensity scores in the region of common support [24].

Cross-sectional data problems such as multicollinearity of continuous and discrete explanatory variables were tested before estimating the binary logit model [24]. In estimating the model, the dependent variable takes a value of 1 for households who adopted CA; and 0 otherwise. Respondent's pre-treatment characteristics composed of mainly demographic, socio-economic, and institutional factors. The variance inflation factor (VIF) was measured to identify the existence of collinearity in the variables of multivariable logistic regression analysis. Collinearities were not observed among variables (VIF < 2.58). Discrete variables regressed in the model tested with a Contingency Coefficient of 0.045 and 0.049, implying the absence of an association problem.

Propensity score (PS), the probability of an observation receiving the conservation program given a vector of covariates as a function of individual characteristics estimated using binary logit model is indicated in Table 3, by the variable, Proportion (percentage) of cropped land (Proprcrla). This variable is a significant correlate of CA adoption indicating the higher the proportion of the cultivated land the higher the likelihood of the household adopt CA (P<0.1). The variable is used as a balancing score for confounding treated individuals to an untreated individual matched.

Once the propensity scores have been obtained, kernel matching with no bandwidth is selected as the best matching estimator for its lowest pseudo-R^2, insignificant likelihood ratio, and low mean bias. This implies that both groups have the same distribution in covariates, Xs, after matching. The reduction in mean bias indicated in Table 4 by shaded row with a value of 4.5 after matching in Figure 1, is less than 5 percent. This is sufficient as supported by Smith & Todd [19] to assess marginal distributions distance in the covariate.

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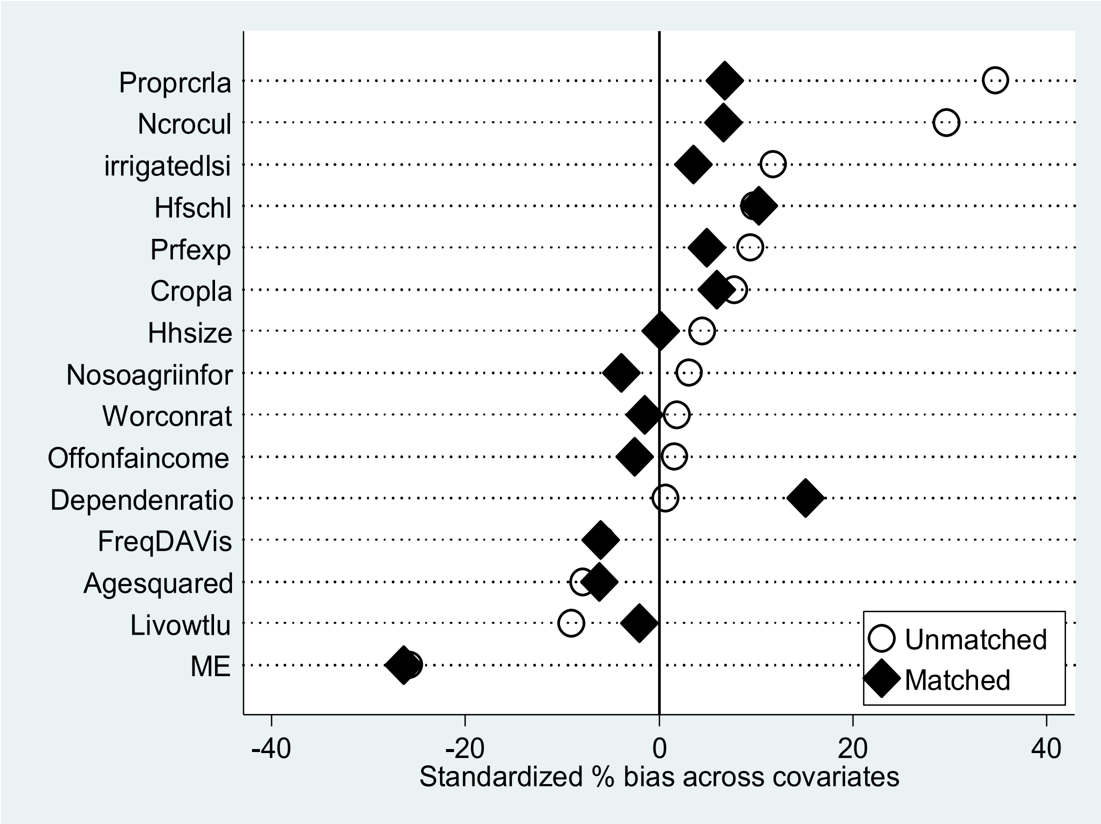

Figure 1: Standardized % bias across covariates before and after matching

The observations in the adoption group who have and do not have a suitable comparison is depicted in Figure 2 by "treated: on support" and "Treated: off support", respectively. Propensity score distributions of treated cases are shown in chocolate on top and control cases in grey on the bottom. CA and non-CA's farmer groups' PS distribution is slightly skewed to the right and left, respectively, bringing distribution nearer to normal.

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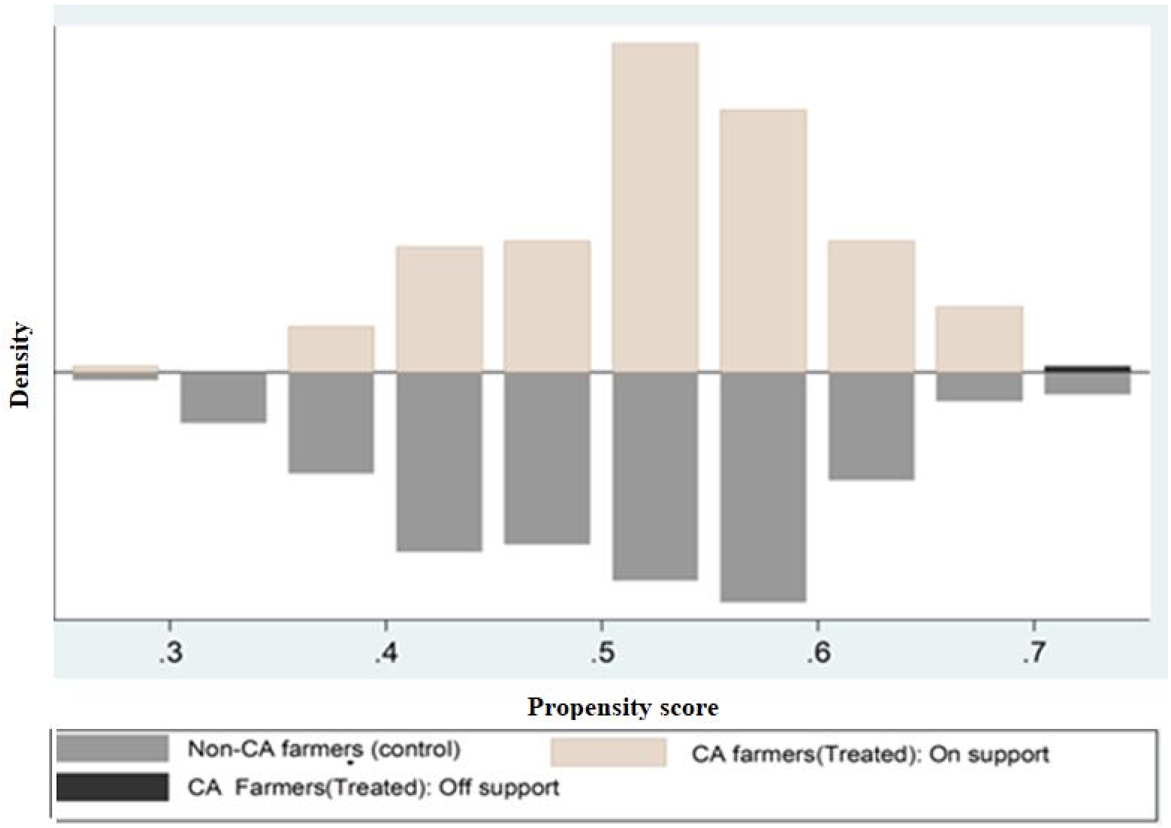

Figure 2: Graphical depiction of the Propensity score distribution

From a total of 322 subjects including 168 CA and 154 non-CA farmers, four treated cases (CA farmers) were discarded from the analysis using a matching estimator of kernel matching with no bandwidth. Before estimating the average effect of CA adoption, the sensitivity of the result in terms of unobserved covariates that could affect both adoption decision and outcome variables was checked using the logarithm of odds of differential assignment computed using p-critical values at the various critical level of e^{γ}. The test confirmed that CA adoption impact is not changing though CA and non-CA farmers allowed differing in their odds of being treated in terms of unobserved covariates.

Finally, the relationship between CA adoption and crop productivity was estimated with linear regression based on the matched sample of households using the average effect of CA adoption on the outcome variable (ATT) as a relevant statistical measure (see Table 5). Computation was performed using Stata's multi-purpose statistical package using the psmatch2 procedure [25]. Accordingly, the ATT estimates from kernel matching (Normal) with no bandwidth relative to non-adoption of a CA results in a change in crop productivity measured in kilograms per hectare of farmland calculated within the range of 3.658 to 3.692 (logarithm form). This has brought an average difference of 0.034 though not statistically observed at a significant level. This implies a positive association between farm household CA adoption and crop productivity though the benefit gained is quite small. The result is found in agreement with the study of Nkhoma et al. [26] analyzed using covariates of CA farmers and conventional farmers and reported the small and positive effects of CA adoption on crop productivity and income in Luapula Province, Zambia.

A similar result also prevailed in the study of Mango et al. [27] which confirmed the insignificant effect of CA adoption on Malawi and Zimbabwe farmers in terms of Food Consumption Score when studied using the counterfactual outcome approach. Implementing CA principles in isolation was suggested as a failure to secure yield benefit from CA adoption.

The result of the present study diverges from the study of Ndlovu; Mazvimavi *et al*. [28] which endorsed strong improvement in farmers' crop productivity and yields as analyzed using matched observations of CA farmers and non-CA farmers in central Mozambique. In the same vein, the result of the study was inconsistent with the findings of Tambo & Mockshell [5] that have proven the direct effect of CA adoption impact on income as investigated using household survey data subjected to inverse-probability-weighting regression-adjustment and PSM.

It also deviates from the finding of Mango *et al.* [27] confirming that the significance of CA adoption on food consumption score of farmers in Mozambique is investigated using the counterfactual outcome approach. Implementing weeding timely and improved seed varieties in conjunction with CA is mentioned as a necessary precondition for acquiring the expected benefits from CA adoption.

Keeping in mind the potential effect with the result of the present study_the benefit that the previous studies highlight from CA adoption pinpoint the necessity of implementing core principles of CA in combination to the country's specific context to enhance crop productivity. Given these discussions in relation to previous studies, the study has some limitations for relying on cross- sectional data that could not allow examining the changing aspects and short-term benefits of CA adoption. Furthermore, the present study analysis is based on small observations that were very few farmers experience CA components in combination with a very small fraction of their farmland. However, the level of benefits that can be achieved with CA adhered to the practice of the three core principles in combination [29,30]. This implies the necessity of conducting the study at broader regional and national levels inclusive to address the limitation of this study for follow-up studies.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

The study used cross-sectional data collected from a survey of 322 people in an effort to empirically investigate the hypothetical effect of CA adoption on crop productivity farmers in the Farta district of North-Western Ethiopia. Structured questionnaires were used to collect primary data from household surveys. Mean differences of count of farm plots fragmented, family labor measured in terms of Man Equivalent, formal education attainment of household head, and count of adult males in the household were significant between the CA farmers and non-CA farmers.

The crop productivity based on the estimates ATT from kernel matching (Normal) with no bandwidth using the psmatch2 procedure computed on crop productivity data measured in kilogram per hectare of farmland in logarithm form in the range of 3.658 to 3.692 gives an average difference of 0.034. In other words, 1.08 kilogram of crop was produced per hectare of farmland as compared to the productivity secured by non-CA farmers. Despite the crop productivity gain following practicing conservation agriculture is quite small as observed statistically at T-value of 1.65 at less than 1 percent level of significance. From a policy perspective, this indicates the necessity to put key CA adoption principles in practice along with better cropping management practices such as timely weeding and improved seed varieties in addition to closer visits of extension agents to maximize gains in crop productivity.

The author does not deny the limitation of the study as cross-sectional data may create gaps to inform the results showing aspects of CA adoption changing with respect to different agro-ecological, socio-economic and institutional settings since the technologies introduced.

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Table 1: The Descriptive statistics of conservation agriculture components according to Distribution in farm plots

Component	% of farm plots (n = 1,235)	Mean area (Ha)
No CA components	45	0.65
Crop rotation alone	29.2	0.48
Crop rotation with minimum soil disturbance	12	0.15
Minimum soil disturbance and permanent ground cover	6.5	0.14
Permanent ground cover alone	3	0.1
Minimum soil disturbance alone	2.7	0.2
All CA principles	1.6	0.25
All plots		0.26

Source: Field survey data, 2018/19

Table 2: Description and Mean of Variables used in the Econometric Analysis

Variables Descriptions	Full sample	CA Farmer	Non-CA Farmer	T test// chi2	p-value
Dependent variables					
If household (HH) adopted CA, 1 if yes	0.59	0.509	0 .48		
Crop produced in in kilogram(kg) per /hectare of farmland	4,990	5273	4682	-2.72	0.003
Independent variables					
Count of people in family cooking in the same pot	7.46	7.50	7.43	-0.40	0.35
Square of household age in years	1,685	1647.5	1726.3	0.701	0.24
Farmland size in hectare	1.311	1.33	1.29	-0.69	0.25
Number of farm plots fragmented	3.43	3.77	3.06	-4.28	0.00
Proportion (%) of cropped land size	54.50	55.62	53.27	-0.73	0.23
Dependency ratio	0.11	0.11	0.11	-0.06	0.48
Household own livestock, 1 if yes	0.98	0.99	0.98	0.255	0.61
Household head formal schooling status,1if yes	0.21	0.12	0.31	19.23	0.00
Proportion (%) of farming experience to age equivalent	57.96	58.48	57.38	-0.843	0.20
income earned in birr in on/off farm activities	673.7	686.2	660.07	125.74	0.44
Family labor in Man Equivalent unit (ME)	2.74	2.88	2.58	-1.89	0.03
Frequency of Development Agents (DA) Visit per month	3.313	3.29	3.34	0.296	0.54
Irrigated land size in hectare	0.19	0.20	0.18	-1.06	0.16
Number of adult males	3.41	3.19	3.67	4.89	0.00
Ratio of proportion of Privately land to rented in land	1.064	1.07	1.05	-0.16	0.44
Number of Observations = 322, CA farmers =168, Non-CA farmers =154					

Note: * is a discrete variable

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Table 3: Binary logit estimates for conservation agriculture adoption

Covariates	Coefficient	Robust S.E	z-value
Constant	-0.471	0.755	-0.62
Square of household head's age in years	0.000	0.000	-0.52
Household size	-0.043	0.061	-0.71
Proportion of farming experience to respondent's age	0.006	0.006	0.93
Number of adult males	-0.119	0.088	-1.35
Farmland Size in Hectare	0.247	0.164	1.51
Proportion (percentage) of cropped land	0.005*	0.003	1.73
Count of family labour in Man Equivalent Units (ME)	0.113	0.083	1.36
Ratio of proportion of Privately land to rented in land	-0.014	0.071	-0.2
Irrigated land size in hectare	0.327	0.285	1.15
Dependency ratio	-0.159	0.727	-0.22
Livestock owned in Total Livestock unit	-0.018	0.038	-0.48
Household head formal schooling status	0.112	0.179	0.63
Off and on-farm income	0.000	0.000	0.36
Frequency of DA Visit per month	-0.143	0.113	-1.26
Number of farm plots fragmented	0.103	0.057	1.81
Number of observations=322; Wald chi2(16) =213.62; Log LL = 3.338; Prob > chi2= 0.000			

Note: * indicate statistical level of significance at or less than 10 percent

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Table 4: Performance of Matching Estimators

Matching Estimators	Balance test	LR chi2	Pseudo R^2	$p>chi^2$	Mean Bias	Off-support (discarded)	Matched sample size (on-support)
Nearest Neighbor Matching by replacing with	5	113.2	0.254	0.000	26.3	0	322
1 neighbor	5	113.2	0.254	0.000	26.3	0	322
2 neighbors	8	61.50	0.132	0.000	16.9	0	322
3 neighbors	9	39.52	0.085	0.001	14.4	0	322
4 neighbors	11	32.55	0.070	0.005	12.0	0	322
Radius Caliper With no Band Width (BW)	5	113.2	0.254	0.000	26.3	0	322
With BW 0.01	6	112.4	0.274	0.000	28.2	13 treated	309
0.05	7	112.4	0.274	0.000	28.2	13 treated	309
0.1	6	112.4	0.274	0.000	28.2	13 treated	309
0.25	6	112.4	0.274	0.000	28.2	13 treated	309
0.5	6	112.4	0.274	0.000	28.2	13 treated	309
Kernel Matching With no BW (Normal)	**15**	**5.19**	**0.011**	**0.990**	**4.5**	**4 treated**	**318**
With no BW epan	15	7.14	0.017	0.954	5.9	13 treated	309
With BW (epan) 0.08	15	7.14	0.017	0.954	5.9	13 treated	309
0.1	15	6.30	0.014	0.954	5.0	0	322
0.25	15	6.30	0.014	0.974	5.9	0	322
0.5	15	7.14	0.017	0.954	5.9	13 treated	309

Table 5: Average treatment effect on Treated from Normal Kernel type propensity score matching

Variable Sample		CA farmer	Non-CA farmer	Difference	S.E.	T-stat
Crop produced in kg/hectare in logged form						
	Unmatched	3.691	3.642	0.049	0.018	2.72
Average Effect/ATT/	Marched	3.692	3.658	0.034	0.020	1.65

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