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Do Soil and Water Conservation Practices Influence Crop Productivity and Household Welfare? Evidence from Rural Nigeria

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Abstract

One of the most serious challenges threatening Nigeria's agricultural sustainability is land degradation. Although this issue has received little attention in Nigeria, soil and water conservation practices have been identified as a possible pathway out of the potential problems posed by land degradation. Therefore, the central research question that this paper tries to address is the following: Do adoption of soil and water conservative (SWC) practices affect crop productivity and welfare? This paper used data collected by the International Institute of Tropical Agriculture (IITA) from maize farmers in rural Nigeria. We used the propensity score matching (PSM), inverse Probability Weighting Adjusted Regression model (IPWRA) approach and the linear regression with endogenous treatment effect (LRETE) model to incorporate the typologies of SWC practices, and then test how the model affects crop productivity and household welfare. Additionally, multinomial logit was used to estimate the factors influencing the decision to adopt single and multiple SWC practices. The estimates show that education, age of the household head, access to credit, experience of drought, soil fertility, and occupational stress contribute to the decision to adopt SWC practices. The casual effect estimates reveal that both single and multiple adoptions of SWC practices had a positive and significant relationship with the crop productivity and welfare of the adopters. Interestingly, our results show that the adoption of combined SWC practices has a higher impact on crop productivity and welfare than single SWC practices. For instance, the adoption of a combination of three SWC practices was found to increase crop productivity and welfare by 27.55% and 38.23%, respectively versus 13.91% and 15.11% in the case of single SWC practices.The study suggests that profile-raising agenda and efforts that focus on promoting the adoption of combination of SWC practices should be designed and implemented in order to enhance crop productivity and hence the welfare of the maize farming households in Nigeria.

Key words: Soil and water; yield; food security, poverty incidence; Nigeria

1. Introduction

The contribution of smallholder agriculture is not limited to the production of food but also extends to livelihood provision, particularly for rural population which constitutes approximately 75% of the world's poor (Raj et al., 2022; Tang et al., 2022). Though there are combination of factors affecting productivity and production of farming households.However, among other factors, the success of agricultural production, especially in Sub-Saharan Africa (SSA), is threatened by the harmful effect of climate crisis, soil fertility depletion as well as land degradation. According to Lobell *et al.* (2011), the global food system is experiencing unprecedented stresses largely due to climate change. Meanwhile, the rural regions of SSA countries are worst hit by the harmful effects of climate change manifestations with regards to reduction of agricultural production than other parts of the world (Shiferaw *et al.* 2014; Olagunju *et al.* 2019). For example, according to Palombi and Sessa (2013), the average maize yield in Africa has been consistently lesser compared with average global yield. Also, FAO (2019) reported the economic loss due to climate change to be approximately 9% of GDP of African countries.

In other to respond to these, policymakers in SSA have promoted the development, dissemination and adoption of different 'climate-smart' agricultural technologies, including soil and water conservation practices (SWC) as a policy initiative aimed at enhancing productivity and welfare of rural farming households as well as fostering farmers' resilience to climate change shocks (Brouder & Gomez-Macpherson 2014). As a means for sustainable agricultural intensification, the seminal paper of Brouder and Gomez-Macpherson (2014) highlighted three main practices upon which SWC farming is based, and these include crop rotation, minimum soil disturbance (otherwise known as minimum tillage), and crop residue retention. The objective of these practices is to raise agricultural output improvement in soil nutrients and fertility and lessen risks associated with weather shocks such as rainfall and drought shocks (Brouder & Gomez-Macpherson 2014).

Advocates of SWC claim that, besides increased yield and enhanced yield resilience, SWC has implications for positive environmental externalities on the soil by raising its organic carbon composition (Smith *et al.* 1998; Lal & Stewart 2010). Several SSA countries have keyed into encouraging SWC practices owing to the variability of rainfall patterns and projected high temperatures in these countries. For example, conservation farming is well supported by the government of Zambia, likewise Nigeria among other African countries (Haggblade & Tembo 2003; Oni 2011). In Nigeria, the promotion of agricultural practices based on SWC date back in the 1970s, and since then many non-governmental institutions have showed renewed interest in it because of the productivity and welfare gains associated with them. Recently, the Federal Government of Nigeria (FGN) launched a policy and strategy document entitled "The Agriculture Promotion Policy" (APP) in which SWC is incorporated as one of the agricultural policy targets for the country. However, despite these concerted efforts at promoting the adoption of the SWC, it seems that the rate of adoption is still low, and this has raised the question about whether rural farming households have taken advantage of the opportunities that are associated with the SWC (Oni 2011; Arslan *et al.* 2014; Ng'ombe *et al.* 2014). For example, 6% and 3.9% adoption rates of SWC practices in Zambia were reported by Ng'ombe *et al.* (2014) and Arslan *et al.* (2014), respectively.

Studies on the impacts of adoption of SWC on productivity and welfare outcomes are well established in the literature, albeit with differing conclusions. For example, Kassie *et al.* (2008) examined the impact of SWC on productivity in northern Ethiopia and found that adoption resulted in improved yield. The study conducted by Brouder and Gomez-Macpherson (2014) also highlighted that the adoption of SWC practices led to improved labour productivity by about 15% in Zambia. Similarly, Mango *et al.* (2017) found that adoption of SWC had positive impacts on key livelihood outcomes in Zimbabwe, Malawi, and Mozambique. In addition, studies such as Tesfayohannes et al. (2022) conducted for Ethiopia found that adoption of SWC positively impact crop income, Uddin and Dhar (2016) for Bangladesh and Koch *et al.* (2019) for Brazilian Amazon reported positive impacts of SWC practices on yield and farmers' welfare. In contrast, using a propensity score matching approach, Abebe and Bekele (2014) found that adoption of soil and water conservation program did not significantly improve household income, and crop yield in Ethiopia while Nkala *et al.* (2011a) argued that SWC practices are associated with labour intensive in Central Mozambique.

Likewise, Nkala *et al.* (2011b) concluded in their study in Mozambique that the returns from soil and water conservation practices are not immediate and may not benefit the very poor farmers. However, to the best of our knowledge, the literature on the impact of adoption of SWC practices, particularly on productivity and welfare outcomes from the Nigerian perspective still remains scarce. Our study aims at providing a detailed impacts of adoption of soil and water conservation practices among rural farmers in Nigeria. Specifically, the study seeks to provide answers to the following agricultural policy questions: What are the socio-economic factors influencing rural farmers' decision to adopt SWC practices as a bundle or in isolation? What is the welfare impact of adoption of SWC practices? And does the adoption of SWC practices increase yield of rural farmers? Hence, this study hypothesis that adoption of SWC practices will have positive impact on the productivity and welfare of the crop farmers. The SWC practices considered in this study are incorporation crop residue in the soil, crop rotation, and practicing minimum soil disturbance on the plot.

Our paper contributes to the empirical literature and policy debate in this area in three important ways. First, in the Nigeria context, this study is the first, to the best of our knowledge, to explicitly evaluate the impact of the adoption of SWC practices on productivity and welfare of farming households. Given that low productivity and poverty are still major challenges facing farmers in several developing countries, particularly in rural Nigeria, providing answers to the question of how adoption of SWC practices can help to address the agriculture productivity constraints while also improving welfare outcomes is hugely important for research and policy in this area. The second contribution of this paper is in the use of linear regression with endogenous treatment effect approach for obtaining unbiased and consistent estimates. This estimation approach can address possible endogeneity issues in order to estimate the true causal impacts of adoption on outcomes variables. Thirdly, this study will provide useful insights on the driving factors of enable adoption of SWC practices in bundle or individually in the Nigeria context by employing a multinomial logistic estimation technique. With the knowledge that SWC adoption rates in rural Nigeria and many other developing countries are still low compared to the rest of the world (Arslan *et al.* 2014; Brouder & Gomez-Macpherson 2014; Ng'ombe *et al.* 2014), highlighting the factors that influence adoption is relevant in providing policy direction on best practices that will facilitate appropriate dissemination strategies for extension purposes.

Our paper is structured into six parts. Section 2 provides related empirical literature followed by Section 3 which presents the data used for the study. We present the estimation strategies in Section 4 followed by the presentation of results and discussions in Section 5.The final section concludes the paper along with relevant policy recommendations emanating from our findings.

2. Review of relevant literature

Improved agricultural productivity has predominantly been associated with soil management practices and farming systems which emphasize water conservation. Despite the plethora of empirical studies demonstrating higher yields for adopters of SWC practices (Ellis-Jones & Tengberg 2000; Abebe & Bekele 2014; Uddin & Dhar 2016; Mango *et al.* 2017), adoption rate in Africa, Nigeria included, is rather low. Meanwhile, various studies (Kassie *et al.* 2008; Brouder & Gomez-Macpherson 2014; Ng'ombe *et al.* 2014; Mango *et al.* 2017) have associated the poor adoption rate to individual characteristics, household characteristics, plot-level characteristics, and institutional related characteristics. Additionally, rural farmers find it difficult to adjust to evolving farming systems and creasing intensity of land use, as evidenced in Kenya, Uganda and Tanzania (Ellis-Jones & Tengberg 2000). Due to this, some authors have suggested that eliciting farmers' participation in the design and implementation of SWC technologies could improve adoption rate (Bekele & Drake 2003; Manda *et al.* 2016).

Adoption of new technology can have different effects on both yield and crop income. In some cases, it results in an increase in output and invariably profits although at the expense of an increase in labor use, while in other cases, labor cost is saved but with no significant increase in output and unclear effects on income generation. Nevertheless, the potential for increasing rural incomes through the diffusion of modern farming techniques such as SWC practices remains substantial. However, technology is more likely to generate positive benefits for the poor where initial assets and income inequality are lower and related infrastructure and social services are well developed (Awotide *et al.* 2015). Studies (Wossen *et al.* 2015; Wossen *et al.* 2017a; Abdoulaye *et al.* 2018) have also suggested multiple pathways through which the adoption of agricultural innovation like SWC practices can improve crop productivity growth which converts to improved welfare through improved crop income changes. Explicitly, direct impacts of adoption of SWC practices could be observed through an increase in the crop yield per hectare.

Consequentially, an increase in crop yield will likely lead to an increase in revenue generated from the sales of crop, and thus, leading to increased crop income and purchasing power. Additionally, indirect impact could occur when an increase in agricultural production stimulates both food and non-food expenditure in the rural as a response to higher domestic crop production. Therefore, an improvement in the food and non-food expenditure of the farmers is evidence of improved wellbeing and reduction of poverty in rural households headcount (Wossen *et al.* 2017a; Abdoulaye *et al.* 2018). It can be concluded that the adoption of SWC practices will lead to increase in crop productivity measured as yield and crop income. Consequentially, improvement in productivity outcomes will lead to improving welfare and poverty reduction.

3. Data and Descriptive Statistics

The data used in this study is nationally representative. Household survey data collected by the International Institute of Tropical Agriculture (IITA) under the Drought Tolerant Maize Variety for Africa project in Nigeria between November 2014 and February 2015 was used for this study. In order to reduce sampling error, a stratified sampling approach was used to select a representative sample of crop farming households in major maize producing areas in Nigeria. The multi-stage stratified sampling proceeded in the first stage with the division of states in Nigeria into homogenous five sub-groups. The sub-groups were obtained based on the size of land devoted to maize cultivation by the farmers. Sixteen states were selected randomly from the sub-groups. The second stage was the selection of Enumeration Areas (EAs), proportional to the size of each Local Government Areas (LGA) and equally based on the recommendation of the National Bureau of Statistics (NBS) for obtaining a nationally representative data: two communities were randomly selected from the selected EAs. In the third stage, 10% of the LGAs were selected in each of the selected states, a total of 2334 farming households were randomly selected from the selected households.

In the survey, data were collected on detailed information on socioeconomic and demographic characteristics of the maize farmers and households, household expenditure on food and non-food items, information on adoption of soil and water conservative practices, outputs of maize, income from maize sold and other various sources. The treatment variables, adoption of soil and water conservative practices, were constructed using the following survey questions: "*Did you adopt any soil and water conservation practices?*" "*Did you incorporate crop residue in the soil*?" "*Did you rotate the planting of your crop?" "Did you practice minimum soil disturbance on your plot?"* Based on these questions, we constructed a dummy variable that took on the value of one if the farmer had used any of the aforementioned SWC practices and zero otherwise. However, we further lumped different SWC practices to construct two or three combinations of SWC practices. For instance, a farmer will get the value of one if she/he adopted the use of crop residue incorporation and minimum soil disturbance and zero otherwise hence, we tagged this variable as "MR-only". Also, if a farmer adopted the use of the three combinations i.e. crop residue incorporation, crop rotation, and minimum soil disturbance and zero otherwise we tagged the variable as "MRC-only".

The outcome indicators used for measuring the impact of SWC practices adoption are variables related to productivity and welfare. Firstly, following (Abebe & Bekele 2014; Arslan *et al.* 2014;

Wossen *et al.* 2017a), the productivity outcome-related variable is maize yield measured in kilogram per hectare. The decision to use maize yield was also informed by the fact that the data was primarily collected from maize farmers. Based on the summary statistics in our data, average maize yield was 1153.14 kg/ha. However, average maize yield for adopters of SWC practices (1283.45 kg/ha) is significantly higher than non-adopters (990.57 kg/ha) and the difference is statistically significant at 1% significance level (see Table 1). Our second productivity indicator is the per capita crop income measure in United States Dollars. This value was calculated using farmer estimates of the total harvest value for maize. The results show that the over mean crop income is 150 USD. Consistently, crop income of the adopter of SWC practices (165.898) is significantly higher than non-adopters of SWC practices.

In addition, we used three measures to capture the welfare of the maize farmers. Firstly, we used per capita expenditure. In principle, there is possibility of increase in expenditure (food and non-food) as a result of increase in income. Therefore, we followed (Awotide *et al.* 2015; Ogunniyi *et al.* 2017; Wossen *et al.* 2017a) to measure welfare using per capita expenditure. Secondly, we used per capita food expenditure as a measure of welfare. Many times, per capita food expenditure is used as a measure of food security. However, food security has been regarded as a good measure of welfare (Ogunniyi *et al.* 2017; Wossen *et al.* 2017a; Abdoulaye *et al.* 2018). Finally, following previous studies (Foster *et al.* 1984; Awotide *et al.* 2015) on poverty, we used the Foster-Greer-Thorbecke [FGT] of expenditure-based poverty measure to generate a poverty line that categorizes the poverty status of the farmers as poor and non-poor. A farmer is given the value of 1 implying poor if the mean per capita expenditure is less than two-thirds of the mean and zero otherwise.

The treatment variables shows that about 27.8% i.e 28% of the maize farming households adopted the combination of the three ("MRC-only") soil and water conservation (SWC) practices, 34.2% adopted the mixture of minimum soil disturbance and crop residue retention ("MR-only"), and 38 % adopted the mixture of minimum soil disturbance and crop rotation ("MC-only"). On the other hand, 71% adopted minimum soil disturbance ("M-only"), 45.7% adopted crop residue retention while 50.7 % adopted crop rotation.

Table 1: Summary Statistics of pooled, adopters and non-adopters of SWC practices

Variable	Description of variables	Pooled		Adopt
Controls		Mean	S.D	Mean
age_new	Age of household head (years)	47	14	47
marrital_s~2	Marital status (1 if married; 0 otherwise)	0.88	0.32	0.89
Sex	Gender of household head (1 if male; 0 otherwise)	0.82	0.18	0.82
Edy_yrsc	Education level of household head (years)	7.50	5.77	7.29
Fieldsizec	Total size of farm land owned by household head (hectare)	4.42	3.16	4.53
ever_willing	1 if household head is willing to risk adopting new maize variety; 0 otherwise	0.71	0.46	0.75
farmn_exp_~w	Experience of household head in farming activities (years)	25.49	16.28	26.08
house_owne~p	1 if household owned productive assets, 0 otherwise	0.87	0.34	0.88
main_occup	Main occupation of household head (1 if farming; 0 otherwise)	0.77	0.42	0.79
off_farm_o~p	1 if household head is non-farm employment; 0 otherwise	0.29	0.45	0.29
access_cre~t	1 if household head has access to credit; 0 otherwise	0.15	0.36	0.17

drought	1 if farming household ever experienced drought; 0 otherwise	0.18	0.39	0.20
mem_input_~s	1 if household head belong to any social group; 0 otherwise	0.62	0.48	0.66
Ever_usedf~t	1 if farming household ever used fertilizer during the cropping season; 0 otherwise.	0.68	0.47	0.70
agro_eco1	1 if Savannah, 0 otherwise	0.35	0.48	0.30
stress	1 if household head ever experience occupational stress; 0 otherwise.	0.65	0.48	0.67
poor_soil_~y	1 if farming household used land with poor soil fertility; 0 otherwise.	0.06	0.23	0.03
hhsize2	Number of people in the household	7	3.	7
Do_u_own	1 if household head own farm asset; 0 otherwise	0.95	0.23	0.96
access_exte	1 if household head has access to extension service; 0 otherwise	0.52	0.50	0.52
NWest	1 if household is resident in northwest geo-political zone; 0 otherwise	0.35	0.48	0.30
SSouth	1 if household is resident in south-south geo-political zone; 0 otherwise	0.05	0.21	0.05
SEast	1 if household is resident in south east geo-political zone; 0 otherwise	0.04	0.20	0.04
NCentral	1 if household is resident in north central geo-political zone; 0 otherwise	0.27	0.44	0.33
NEast	1 if household is resident in northeast geo-political zone; 0 otherwise	0.05	0.21	0.05
Outcome variables				
Maize income ($US)	Per capita maize income in US Dollars equivalent	150.11	12.88	165.90
Maize Yd (kg/ha)	Average maize yield measured in kilogram per hectare	1153.14	70.57	1283.44
Per_cap_($US)*	Per capita expenditure in US Dollars equivalent	131.52	14.44	143.78
Per_cap_Fd_($US)	Per capita food expenditure in US Dollars equivalent	110.62	7.09	123.89
Poverty count (%)	Poverty headcount measured as poverty incidence [percentage]	0.46	0.09	0.49
Treatment variables				
adoption_s~n	Adoption of at least one SWC practices; 0 otherwise	0.52	0.49	
min_soil_dis	Adoption of minimum soil disturbance; 0 otherwise	0.71	0.45	
crop_res_r~n	Adoption of crop residue retention; 0 otherwise	0.45	0.49	
crop_rotaion	Adoption of crop rotation; 0 otherwise	0.50	0.50	
MC	Adoption of minimum soil disturbance and crop rotation; 0 otherwise	0.38	0.48	
RC	Adoption of crop residue retention and crop rotation; 0 otherwise	0.23	0.42	
MR	Adoption of minimum soil disturbance and crop residue retention; 0 otherwise	0.34	0.47	
MRC	Adoption of the three SWC practices; 0 otherwise	0.278	0.383	
Total		2,334		1,2

*Note that the official exchange rate was (1 US$ = 280 Naira,) during the survey period

4. Empirical strategy

4.1 Multinomial logit model

To determine the factors influencing the choice of soil and water conservation (SWC) practices, we estimated a multinomial logit model based on the familiar random utility framework (Maddala 1986; Bezu & Holden 2014). The response probabilities for our multinomial logit model with seven alternatives can be given as:

$$\Pr_{(y=\frac{x}{j})} = \frac{exp\left[\beta_0 + \sum_{i+1}^{k} \beta_j X_{ij}\right]}{1 + exp\left[\beta_0 + \sum_{i=1}^{k} \beta_j X_{ij}\right]} \dots\dots\dots \text{j} = 1{,}2{,}3 \dots\dots\dots 7 \qquad (1)$$

where j denotes the alternative soil and water conservation (SWC) practices, that include: M-only", "R-only", "C-only", "RC-only" "MC-only", "RM-only" and "RCM-only". X is a vector that denotes factors that influence the choice of by the farmer. The coefficients on these explanatory variables differ for each alternative. The factors that are expected to influence choice of the farmers' soil and water conservation (SWC) practices include both individual-level factors and household level factors. The individual-level factors are characteristics of the farmers (such as age, gender, marital status), the endowment of the farmer and economic activities. The endowment of the farmer includes own human capital such as education as well as networks such as belonging to a social group (i.e. a proxy for social capital). Economic related variables include main occupation and engagement in off-farm occupation.The household factors include land holdings, size of the household and demographics. In addition, we included geopolitical zone dummies to control for regional variations. We also included institutional related variables such as access to credit and access to extension information. Therefore, the $\Pr_{(y=\frac{x}{j})}$ (dependent variable) are non-adoption=0, M-only" =1, "R-only" =2, "C-only =3, "RC-only" =4, "MC-only" =5, "RM-only" =6 and "RCM-only" =7) while the explanatory variables are listed in Table 1.

4.2 Empirical methods for estimating the impact

In principle, in order to measure the accurate impacts of innovation or technologies, there is a need to control for both unobservable and observable characteristics through random assignment of individuals into treatments. Firstly, we fitted propensity score matching (PSM) to address this possible problem.The rudimentary mechanism behind the use of PSM is to match each adopting farmer with a similar non-adopting farmer and then estimate the average difference in the outcome variables (productivity and welfare) between the treated and untreated households. Following (Heckman & Navarro-Lozano 2004; Imbens & Wooldridge 2009; Cattaneo *et al.* 2013; Kassa *et al.* 2013; Uddin & Dhar 2016), the average treatment effect on the treated (ATT) is defined as:

$$ATT = E[Z(1) - Z(0)|Q = 1 \qquad (2)$$

where $Z(1)$ and $Z(0)$ are outcome indicators (productivity and welfare of the adopters and non-adopters, respectively). Q is a treatment indicator. However, we can only observe $E[Z(1)|Q = 1$ in our data set and $E[Z(0)|Q = 1$ is missing. In essence, we cannot observe the productivity and welfare of adopting farmers had they not adopted the SWC practices, once they are adopters. The magnitude of self-selection bias is formally presented as:

$$E[Z(1) - Z(0)|Q = 1 = ATT + E[Z(0)| = 1 - Z(0)|Q = 0] \qquad (3)$$

Once the treated (adopting) farmers have a comparison group (counterfactual), the build-up of PSM necessitates the reduction in the bias due to observables. Additionally, once the farmers are matched with observable "characteristics", PSM assumes that there are no systematic differences in unobservable characteristics between treated and untreated households. Given this assumption of conditional independence and the overlap conditions, ATT is computed as follows:

$$ATT = E[Z(1)Q = 1, p(x) - E[Y(0)|Q = 0, p(x)] \quad (4)$$

The presence of misspecification in the modeling of propensity score may result in ATT estimates from PSM which can still be biased. A prospective "therapy" for bias due to misspecification is the use of inverse probability weighted adjusted regression. Consistency in estimates from IPWRA, in the presence of misspecification, will likely be possible for treatment or outcome model, but not both. Consequently, the inverse probability weighted adjusted regression estimator has "double advantage" with the property of double robustness that guarantees dependable and consistent estimates. Suppose that the outcome model is represented by a linear regression function of the form $Z_i = \delta_i + \omega_i X_i + \varepsilon_i$ for i [0,1] and the propensity scores are given by $p = (x; \gamma)$. The first stage of the IPWRA is for us to generate the propensity scores using the observables as $p(x; \hat{y})$. The second stage is, therefore, to use linear regression model to estimate for non-adopters (δ_0, ω_0) and adopters (δ_1, ω_1) using inverse probability weighted least squares as:

$$\min_{\delta_0,\omega_0} \sum_i^N (Z_i - \delta_0 - \omega_0 X_i)/p(x; \hat{y}) \; if \; Q_i = 0 \quad (5)$$

$$\min_{\delta_1,\omega_1} \sum_i^N (Z_i - \delta_1 - \omega_1 X_i)/p(x; \hat{y}) \; if \; Q_i = 1 \quad (6)$$

The ATT is then computed as the difference between Eq. (5) and Eq. (6):

$$ATT = \frac{1}{N_W} \sum_i^{N_W} [(\widehat{\delta_1} - \widehat{\delta_0}) - (\widehat{\omega_1} - \widehat{\omega_0})X_i \quad (7)$$

where $(\widehat{\delta_1}\widehat{\omega_1})$ are estimated inverse probability weighted parameters for adopting farmers while $(\widehat{\delta_0}\widehat{\omega_0})$are estimated inverse probability weighted parameters for non-adopting farmers. Finally, Nw stands for the total number of farmers that adopted the SWC practices. In view of this, we have employed a linear regression with endogenous treatment effect (LRETE) model that accounts for endogeneity (Lewbel 2007; Awotide *et al.* 2015).

$$Y_1 = X_1\omega_1 + \alpha_1 \quad (8)$$
$$Y_0 = X_0\omega_0 + \alpha_0 \quad (9)$$

Equations (8) and (9) are the two potential outcomes equations in the two possible states (adopter non-adopter) of the farmers.

$$T^* = Z_T\psi_T + \alpha_T \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (10)$$

The estimate of productivity and welfare indicators is represented as T(Z); meanwhile observed treatment represents $T(Z) = 1$ depicting the adoption of SWC practices by the farmers and $T(Z) = 0$ reveals otherwise, the T^* is a latent variable which generates T (Z) thus:

$$T(Z) = 1\{T^*(Z) \geq 0\} = 1\{X_\varphi + \alpha_\rho\} \quad (11)$$

The (ATT), is the improved productivity and welfare for farmers that selects the adoption of SWC practices thus:

$$ATT = (x, z, T(z) = 1) = E(\aleph | X = x. Z = z, T(z) = 1)$$
(12)
$$= x_1(\omega_1 - \omega_0) + E(\alpha_1 - \alpha_0 | \alpha_T \geq z_1 \emptyset)$$

To achieve this, we used a relevant instrument. We used access to climatic information of the farmer. We assume that access to climate information may reduce ambiguity and can assist farmers in decision-making process especially on types of technologies to adopt as some measure adaptation strategies to climate change. Moreover, access to climate information has the prospect of improving agriculture resilience and tenacity to climatic shocks (Roudier 2012; Mabe *et al.* 2014). This instrument is correlated with SWC practices but with no correlation with productivity and welfare indicators (see validity test in appendix C). The instrument that we use is exogenous by definition. It is assumed that it is not directly related to productivity and welfare indicators other than through the decision to adopt SWC practices.

4.3 Foster, Greer and Theobecke (FGT) analysis

This paper used the standard FGT (Foster *et al.* 1984), to generate the poverty profile for the children across the geopolitical zones (GPZ's) in Nigeria. FGT takes the form:

$$P_\alpha(y, z) = \frac{1}{N} \sum_{i=1}^{n} \left(\frac{Z - Y_i}{Z} \right)^\alpha \qquad (12)$$

Z = the relative poverty line

n= number of the maize farmers below the poverty line

N = Total number of maize farmers sampled

Y_i = estimated per capita expenditure scale (of the i^{th} household

Z-Y_i = poverty gap of the i^{th} household

$\frac{Z - Y_i}{Z}$ = poverty gap ratio

α = poverty aversion parameter, with values: 0, 1, 2

α = 0, equation (1) gives the poverty headcount

α =1, equation (1) gives the poverty depth

α =2, equation (1) gives the poverty severity index

5. Results and Discussion

5.1 Socio-Economic and Institutional Characteristics

Table 1 presents the summary statistics of the key variables of interest in the present study. The data show that about 52% of farmers have adopted at least one of the soil and water conservation (SWC) practices. Hence, the disaggregation between adopters and non-adopters was based on the adoption of at least one of the soil and water conservation (SWC) practices. The average household size is about 6.8 i.e 7 members and a mean of 47.45 years of age. In addition, the majority of the participants rrecorded a mean of 7.5 years educational attainment. The study further shows that 81% male headed households while 88% are married. The study shows that only 15% of the responsdent had access to credit facilities with the slight difference between the access level of adopter (17%) versus non-adopters (14%). This result suggests that access to credit may give an edge to the adopters over the non-adopters. Membership of an association is critical social capital that is key for improving livelihoods of farming households. The study shows that 66% percent of the adopters belong to at least one social group while 59% of the non-adopters belong to a social group.

5.2 Factors influencing the adoption of SWC practices: Multinomial Logit Regression (MNL)

The results from the Multinomial Logit Regression model used to examine factors influencing the adoption of dynamics of soil and water conservative (SWC) practices are presented in Table 2. The base category to which we compare the results is non-adopters of any of the SWC practices. We checked for multicollinearity for the variance inflation factor (VIF) and contingency coefficients (CC). The results from the VIF values (see Appendix) have shown that variance inflation factors (1.84) for all variables are less than 10 and none of the tolerance values were below 0.40, which indicates all the continuous explanatory variables have no serious multicollinearity concerns. Correspondingly, the values recorded for the contingency coefficients show that no multicollinearity concerns among dichotomous variables used in the MNL model. Based on the collinearity diagnostics, the continuous and dummy variables hypothesized were retained in the model. Preceding the MNL model, we used the Hausman test and the seemingly unrelated post-estimation procedure (SUEST) to test for the validity of the independence of the irrelevant alternatives (IIA) assumptions.

The results of the tests show that both tests failed to reject the null hypothesis of independence of the soil and water conservation practices, suggesting that the multinomial logit (MNL) specification is appropriate to model soil and water conservation practices of smallholder farmers. The model considerably justifies its use as it shows perfect goodness of fit in relation to variables and data. The Wald test rejects the null hypothesis that all coefficients are jointly equal to zero [LR chi2(203) = 1175.75; p = 0.000]. In principle, the coefficients in multinomial regression models are often calculated and conveyed in respect to the base outcome and they might not easy to interpret in a direct form as compared to other linear models (Wooldridge 2010). However, the signs of the coefficients are informative and, in addition, the prediction of the average marginal effects, which also provide useful insights into the relationship between the independent and dependent variables.

In all the options of SWC practices considered, the age of the household head has consistent positive and statistically significant correlation with choice of conservative farming adopted by the farmers. This finding indicates that the likelihood of adoption of SWC practices increases as the farmer gets older which implies that the adoption of SWC is more preferred among older farmers than among the younger ones. The probable reason for this may be associated with the premise that older farmers could adopt SWC practices because they have more years of farming experience that helps them to quickly recognize erosion problems (Amsalu & De Graaff 2007) and adequate amassed social and physical capital to satisfy their demands (Manda *et al.* 2016).

The probabilities of adopting SWC practices were found to be positive and significant for a household headed by a male. However, in previous studies (Asfaw & Admassie 2004; Bayard *et al.* 2007; Temesgen *et al.* 2014) found a mixed relationship (positive or negative) has been found regarding the association of gender of the household head with the adoption of SWC practices. In this study, our positive relationship can be explained by the fact that male farmers are considered to have access to pool of productivity-enhancing information owing to social capital and culture of male-inclusive system in rural Nigeria. Additionally, as compared to their female counterparts, male farmers are high business risk-takers. Our finding is consistent with the findings of Danso-Abbeam, (2022) which noted that male-headed households have more access to information about new technologies and ready to take the risk of adoption than female-headed households.

In line with *a priori* expectations and previous literature (Bayard *et al.* 2007; Shiferaw *et al.* 2014; Temesgen *et al.* 2014; Manda *et al.* 2016; Ogunniyi *et al.* 2017), education positively influences the decision to adopt SWC practices by the farmers. Interestingly, the result reveals that the probability of adopting more than one SWC practices increase with education. For instance, education increases the adoption of "M-only" with 21 % while adoption of the three SWC practices together ("RCM-only") was increased by 23%. Studies (Sidibé 2005; Kassa *et al.* 2013; Ogunniyi *et al.* 2017) have noted that education coupled with higher years of farming experience increases farmers' chance to have access and utilize useful information relevant to farming activities. Additionally, education improves farmer's willingness to participate and awareness of probable positive feedbacks from local natural resource management and conservation activities.

In relation to access to credit, we found a positive and significant association with the adoption of SWC practices. However, the extent differs between single and joint SWC practices. With the exception "M-only", the probabilities of adopting SWC practices is higher among single adopters ("R-only" and C-only") than the combination of SWC practices (RC-only, MC-only, RM-only, and RCM-only). The probable reason for this outcome may be associated with higher investment needed to combine SWC practices than single SWC practices. Studies (Kandlikar & Risbey 2000; Gbetibouo 2009; Temesgen *et al.* 2014) have ascertained that farmers with more financial and other productivity-enhancing resources at their disposal are able to invest in the use of SWC practices.

Additionally, credit availability can increase the chance of switching or combining SWC practices to suit the forecasted climate change related to the farming areas (Shiferaw *et al.* 2014; Ogunniyi *et al.* 2017). We assessed the relationship of drought experienced by farmers in the last five years in relation to adoption of SWC practices. The results show that the experience of drought is positive and significantly influences the decision of farmers to adopt options related to minimum soil disturbance ("M-only", "MC-only", "RM-only" and "RCM-only") as a measure of SWC practices. The study by Moraru and Rusu (2010) has argued that higher soil water retention using minimal soil disturbance is a way of reducing and alleviating drought. This further suggests that drought as an indicator of climate change is a key driver of adopting SWC practices.

The influence of occupational stress (farming) was estimated in relation to the adoption of SWC practices. The results show that stress from farming activities is capable of reducing the probability of farmers adopting any of the SWC practices. It is well known in the relevant literature (Gidron *et al.* 2012; Starcke & Brand 2012; Pabst *et al.* 2013) that stress influences decision-making process, however the magnitude and direction of influence is, in most cases, context-dependent. Studies (Myers *et al.* 1992; Baradell & Klein 1993) have shown that occupational stress prevents farmers from taking necessary safety precautions even when they are cognizant of how dangerous is it not to adopt SWC practices. Meanwhile, the use of SWC practices has been identified as a pathway out of the cycle of poor soil fertility. The results show that poor soil fertility increases the probability in all the SWC practices considered. The highest probabilities were recorded in the adoption of minimum soil disturbance related options ("M-only", "MC-only", "RM-only" and "RCM-only") as compared to other options. Similar findings were found in the study of (Gidoi *et al.* 2013; Kpadonou *et al.* 2017), namely that poor soil fertility positively influences decision to adopt SWC practices.

The size of the household has both positive and negative relationships with the adoption of SWC practices. The results show that an increase in the size of household will increase the probabilities of the SWC practices such "M-only", "R-only", "C-only", "RC-only", "MC-only". The possible reason for this may be that larger household size relaxes the anxiety of farmers to take up labor-intensive adaptation strategies like SWC practices and the use of irrigation that demand high labor especially during the peak period in the production season. The negative relationship with the adoption of "RM-only" and "RCM-only" may be associated with the fact that farmers with large household size might involuntarily divert proportion of their labor force into non-farm activities to generate additional income to complement farm income and reduce consumption demands (Shiferaw *et al.* 2014).

Institutional variables such as extension services are essential sources of information especially on agronomic practices as well as on climate. Our results show that access to extension services positively and significantly influences the adoption of SWC practices. Studies (Bekele & Drake 2003; Asrat *et al.* 2004) have shown that an increase in access, and frequency of access to extension services and information, have increased the use of specific SWC practices and irrigation. The pathway of influence was identified that access to extension services increases the understanding of farmers on land degradation problems and soil conservation practices and hence may perceive SWC practices to be a pathway out of the possible adverse effect.

The regional dummies of the northern region of Nigeria show a positive relationship with adoption of all the categories of soil and conservation practices considered. The northern region of Nigeria is typically known as a dry area with fewer rainfall periods as compared to the southern region. Expectedly, both North East and North West positively drives the decision of farmers to adopt SWC practices. This is consistent with the findings of (Shiferaw *et al.* 2014) that found that northern Nigeria is likely to adopt or use SWC practices and irrigation technologies. Summarily, the likelihood of adopting SWC practices, either single or joint ones, is consistently and significantly influenced by individual characteristics, household characteristics, demographic and institutional variables, agro-ecological location and several miscellaneous factors. However, their relationship on the decision making process of adoption of SWC practices varies, depending on how SWC practices are combined.

Table 2: Factor influencing adoption of SWC practices

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	M-only	R-only	C-only	RC-only	MC-only	RM-only	RCM-only
age_new	0.32***	0.18***	0.15***	0.29***	0.12***	0.22***	0.12***
	(0.01)	(0.02)	(0.09)	(0.08)	(0.01)	(0.08)	(0.04)
age_square	-0.10***	-0.23***	-0.13***	-0.12***	-0.29***	-0.12***	-0.30***
	(0.08)	(0.03)	(0.01)	(0.02)	(0.10)	(0.03)	(0.05)
Sex(male)	0.02**	0.06***	0.05**	0.04**	0.02**	0.02**	0.02**
	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
marrital_status2	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01
	(0.02)	(0.04)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)
Edy_yrsc	0.01***	0.02***	0.22***	0.10***	0.20***	0.20***	0.23***
	(0.02)	(0.02)	(0.02)	(0.01)	(0.04)	(0.02)	(0.02)
Fieldsizec	0.01	0.01	0.01	0.03	0.02	0.04	0.02
	(0.01)	(0.02)	(0.02)	(0.07)	(0.05)	(0.09)	(0.01)
ever_willing	0.03	-0.01	-0.02	-0.02	0.02	-0.03	-0.04
	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
house_ownershp	0.01	-0.01	-0.00	-0.00	0.00	0.00	0.00
	(0.02)	(0.03)	(0.03)	(0.02)	(0.01)	(0.01)	(0.01)
main_occup	-0.00	-0.01	-0.01	-0.01	-0.00	-0.00	-0.00
	(0.02)	(0.03)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
off_farm_occup	0.00	0.01	0.01	0.01	0.00	0.01	0.00
	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
access_credit	0.09***	0.24***	0.34***	0.04**	0.12***	0.13***	0.12***
	(0.02)	(0.03)	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)
Drought	0.05***	0.07***	0.20***	0.11***	0.10***	0.10***	0.22***
	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
Healthy	0.02*	0.03*	0.03*	0.03*	0.02*	0.02*	0.02*
	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
mem_input_supply_grps	0.00	0.01	0.01	0.01	0.00	0.00	0.00

	(0.04)	(0.06)	(0.06)	(0.05)	(0.03)	(0.03)	(0.03)
Stress	-0.02**	-0.06**	-0.05**	-0.04**	-0.02**	-0.02**	-0.02**
	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
poor_soil_fertility	0.32***	0.23***	0.28***	0.24***	0.29***	0.29***	0.33***
	(0.06)	(0.05)	(0.06)	(0.05)	(0.06)	(0.06)	(0.05)
hhsize2	-0.04***	-0.01**	-0.21***	-0.01***	-0.00**	-0.03***	-0.03***
	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)
Accesss_extension	0.23***	0.25***	0.24***	0.24***	0.23***	0.33***	0.32***
	(0.02)	(0.07)	(0.07)	(0.06)	(0.04)	(0.04)	(0.03)
Do_u_own	0.04	0.11*	0.09	0.08	0.03	0.04	0.03
	(0.04)	(0.07)	(0.06)	(0.05)	(0.03)	(0.03)	(0.03)
access_imp_mz_seed	0.03***	0.04**	0.04**	0.04**	0.02**	0.03***	0.02***
	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
NEast	0.14***	0.19**	0.19**	0.18**	0.14**	0.13**	0.13**
	(0.06)	(0.08)	(0.08)	(0.07)	(0.06)	(0.05)	(0.05)
SSouth	-0.03	-0.06	-0.05	-0.04	-0.02	-0.03	-0.02
	(0.02)	(0.04)	(0.04)	(0.03)	(0.02)	(0.02)	(0.02)
SEast	-0.01	-0.05	-0.03	-0.03	-0.01	-0.01	-0.01
	(0.03)	(0.04)	(0.05)	(0.04)	(0.03)	(0.03)	(0.02)
NCentral	0.13***	0.13***	0.14***	0.12***	0.11***	0.11***	0.11***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
NWest	0.03	0.04	0.04	0.04	0.02	0.03	0.02
	(0.02)	(0.04)	(0.04)	(0.03)	(0.02)	(0.02)	(0.02)
Observations	2,247	2,247	2,247	2,247	2,247	2,247	2,247

M-only" - Adoption of minimum soil disturbance; 0 otherwise, "R-only" - Adoption of crop residue retention; 0 otherwise, "C-only - Adoption of crop rotation; 0 otherwise, MC-Adoption of minimum soil disturbance and crop rotation; 0 otherwise, RC- Adoption of crop residue retention and crop rotation; 0 otherwise, MR - Adoption of minimum soil disturbance and crop residue retention; 0 otherwise, MRC - Adoption of the three SWC practices; 0 otherwise

5.3 Impact of SWC Practices Adoption on Crop Productivity and Welfare: PSM and IPRWA

5.3.1 Preliminary Findings

In principle, the reliability and validation of PSM and IPWRA result strongly rest on the quality of matching procedures. Table 3 presents the magnitude of the inclusive covariate balancing showing the pseudo R^2 (before and after matching), LRchi^2 p-value (before and after matching), median (before and after matching), mean standardized bias (before and after matching) and mean propensity score. Additionally, visual representation of the overlap over the common support is another channel for validating the quality of our match. The overall covariate balancing test shows that the standardized mean difference for all covariates used in the PSM reduces from 18.44% pre-matching to 5.48% post-matching for adoption at least one of the SWC practices. Similarly, the mean standardized bias reduces from 15.89% to 5.90% for adoption of "MRC".

Table 3 Propensity score matching quality test

Matching quality indicators	At least one SWC practices	Adoption of "MRC"
Pseudo R2 before matching	0.023	0.056
Pseudo R2 after matching	0.002	0.005
LRchi^2 (p-value) before matching	102.98 (p>chi^2 =0.000)	234.77 (p>chi^2 =0.000)
LRchi^2 p-value after matching	12.78 (p>chi^2 =0.680)	8.67 (p>chi^2 =0.309)
Median standardized bias before matching	9.14	7.89
Median standardized bias after matching	4.22	3.30
Mean standardized bias before matching	18.44	15.89
Mean standardized bias after matching	5.48	5.90
Mean propensity score	0.67	0.78

Moreover, the joint significance of all covariates was never rejected before matching for the adoption of "at least one of the SWC practices" and adoption of "MRC" only (p>chi^2 =0.000). However, the likelihood ratio tests indicate that the joint significance of all covariates can be rejected after matching (p>chi^2 =0.680 for adoption at least one of the SWC practices and p>chi^2 =0.309 for the adoption of "MRC"). The low mean standardized bias and joint insignificance of the covariates are indicative of successful balancing of the distribution of covariates between treated and untreated maize farming households. Additionally, we present in Figure 1 and Figure 2 the common support region adoption of at least one of the SWC practices and adoption of "MRC" respectively. A visual inspection of the distribution of the estimated propensity scores for households with and without treatment indicates that the common support condition is satisfied. A larger proportion of overlap implies a good match of treated and control cases (Rajeev & Wahba 1999; Dehejia & Wahba 2002). As indicated in Figure 1, there is a considerable overlap of propensity scores between the treated and control cases, this implies that the match is good and balanced.

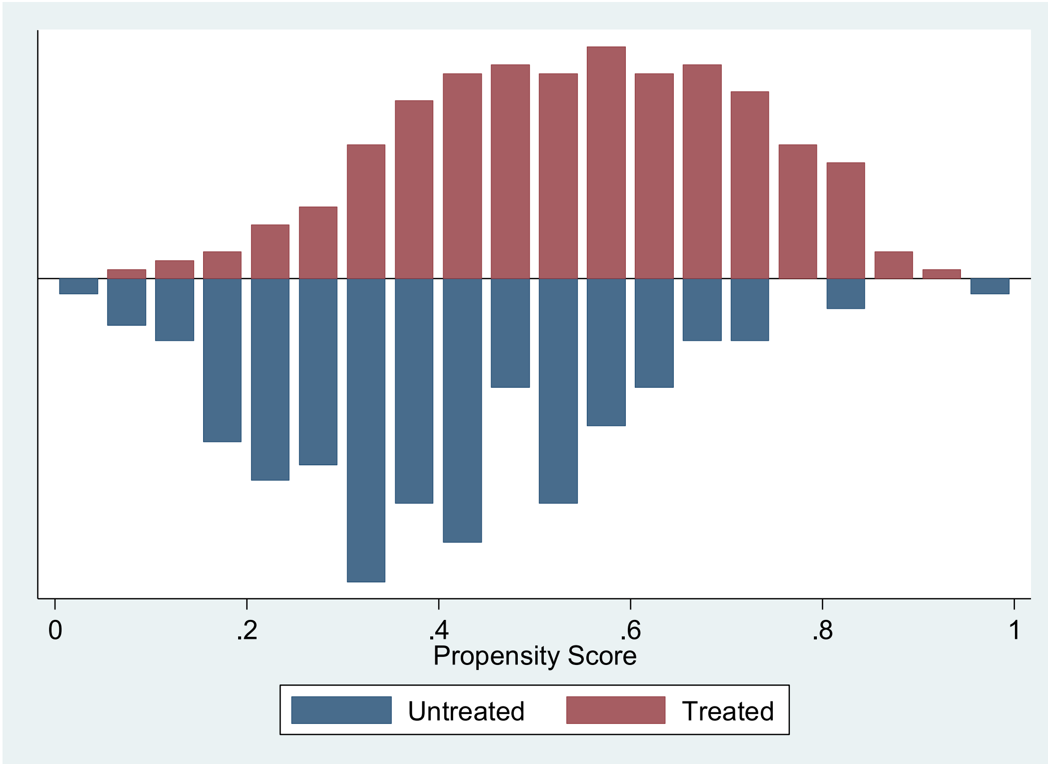

Figure 1. Distribution of propensity scores and common support region for adoption of at lease one SWC practices.

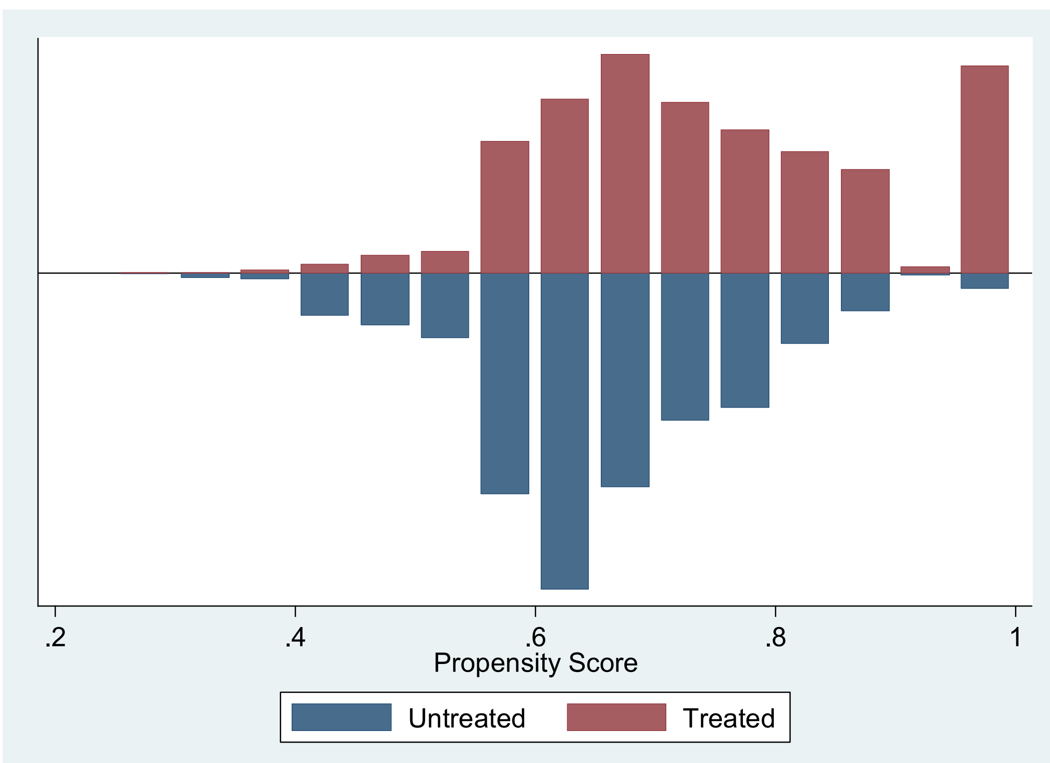

Figure 2. Distribution of propensity scores and common support region for adoption of "MRC".

5.3.2. Key findings

The treatment effect estimates regarding the impact of SWC practices adoption on crop productivity and welfare using alternative estimation techniques are reported in Table 4. The first two columns measure crop productivity (yield and per capita crop income) and the last three column measures welfare (per capita expenditure, poverty headcount and per capita food expenditure). Each indicator of crop productivity and welfare were estimated using PSM, IPWRA and, our preferred specification, LRETE. The discussion of the average treatment effects on treated (ATTs) will be principally based on the estimates of LRETE. However, the magnitude of the effect, particularly on productivity, was smaller. This result suggests that failure to account for unobserved heterogeneity leads to biased estimates that guarantee overestimation and underestimation of the effect of adoption of SWC practices in PSM and IPRWA (hence the use of linear regression with endogenous treatment effect is more appropriate). In general, the reported effects of SWC practices adoption are robust across all estimation strategies, showing the important role of SWC practices adoption on crop productivity and welfare outcome indicators.

In order to understand the dynamics of the role SWC practices, we singly and jointly assessed the treatment effects of the SWC practices productivity and welfare outcome indicators. Therefore, we assessed the impact of "M-only", "R-only", "C-only", "RC-only", "MC-only", "RM-only" and "RCM-only". Additionally, we assessed the impact of adopting at least one of the SWC practices on the outcome variables. The results show that the adoption of SWC practices significantly increases the yield of maize farmers. In particular, we found that the adoption of at least one of the SWC practices will increase maize yield by 24.90% and 22.09% using PSM and IPWRA, respectively. In our LRETE model, where we accounted for both observable and unobservable sources of bias, the effect of adopting at least one SWC practices is 15.56%. Furthermore, we found that ATT of the combination of SWC practices tends to have a higher impact on productivity than single SWC practices. The results show that except "MR-only", all other combinations have a higher impact than sole SWC practices. Interestingly, the combination of the three SWC practices ("MRC") has the highest effect on the yield of the maize farmers. The estimates show that the adoption of the three SWC practices leads to an increase of 27.55% on the adopters'maize yield.

The results underscore that farm investment that aims at improving awareness, accessibility, and adoption of improved soil and water conservative practices can have a significant positive effect on maize productivity. This may be related to the complementarity role between the three SWC practices. The findings are consistent with previous studies (Smith *et al.* 1998; Teklewold *et al.* 2013; Ng'ombe *et al.* 2017) that showed that adoption of one or more SWC practices has a positive and significant relationship of crop yield. Using per capita crop income as the second productivity measure, the results show that the adoption of SWC practices has a positive and significant impact on per capita crop income in all the typologies of SWC practices except "M-only". Although the adoption of "M-only" increases per capita crop income by 21.4% using PSM, the credibility of this estimate may be questionable owing to cited reasons for hidden bias. In theory, all other factors controlled, the significant increase in the yield of maize farmers as a result of adopting SWC practices will most likely translate into increased crop income. Hence, as the yield of the maize increases in kg/ha couples with effective market access, maize income generated by maize farming households increases which in turn leads to per capita crop income in the household. For instance, the adoption of at least one of the SWC practices, "C-only" and "MRC" will lead to an increase in per capita crop income by 22.20%, 6.92% and 29.65%, respectively. It was noticed that there is consistency on the impact of adopting “C-only” on yield and per capita crop income.

The impact on yield was the lowest and so also the per capita crop income (Table 3). In a similar trend, the joint adoption of SWC practices increases per capita income more than the singular adoption of SWC practices. This finding is also supported by the studies of Kassa *et al.* (2013) in Zambia, Wossen *et al.* (2015) in Ethiopia and Kassie *et al.* (2008) in Northern Ethiopia which suggests that the adoption of SWC practices is key for enhancing crop revenue. The second part of the estimation focuses on the welfare effects of adopting SWC practices. As earlier mentioned, following (Shiferaw *et al.* 2014; Wossen *et al.* 2017a; Wossen *et al.* 2017b; Abdoulaye *et al.* 2018) the present study captures welfare using three indicators namely, per capita expenditure, poverty headcount ratio and per capita food expenditure. Firstly, we estimated the effect of adopting SWC practices on per capita food expenditure. It may be appropriate to assume that an increase in maize income will likely lead to increase in expenditure (food or non-food). We estimated the average treatment effects of adoption of SWC practices on per capita food expenditure which is a measure of food security (an indicator of welfare). The study shows that food security of the participants has been positively affected as a result of adopting SWC practices. For instance, the adoption of the combination of three SWC practices (“MRC-only”) shows that it has increased the per capita food expenditure of the adopters by 23.2% more than the non-adopters of SWC practices.

Secondly, we estimated the effect of adoption of SWC practices on a relative measure of welfare using the per capita expenditure. The per capita expenditure comprises both food and non-food expenditure of the maize farmers. The results show that the adoption of SWC practices is significant and positively associated with the per capita expenditure of the adopters than non-adopters. For instance, although with a small magnitude effect in PSM and IPWRA, the adoption of MC-only”, “MR-only” and “MRC-only” increases the per capita expenditure of adopters of SWC practices by 13.12%, 23.12%, and 33.22%, respectively as compared to the non-adopters in the LRETE model. This finding suggests that the adoption of SWC practices has welfare improving effects on the adopters as compared to non-adopters. The estimated impact of adoption of SWC practices on the poverty headcount ratio shows a negative and significant relationship with poverty headcount. This implies that adoption of the SWC practices reduces the probability of being poor. In particular, in our LRETE model, the adoption of at least one of the SWC practices and combination of “MRC” shows that poverty of the maize farmers will be reduced by 16.90% and 35.23%, respectively. Again, the result reveals that the combination of SWC practices has a higher impact versus single practices. Furthermore, since FGT approach of poverty profiling uses the per capita expenditure measure to generate poverty status, it is unsurprising that the adoption of SWC practices reduces the probability of being poor. Earlier, the study shows that there is increase in per capita expenditure, therefore it is rather clear that poverty headcount ratio was reduced as a result of adoption of the SWC practices as compared to the non-adopters of SWC practices. These consistent, significant and positive impacts of SWC practices adoption on alternative welfare indicators imply that addressing output, input, and inefficiencies through technology adoption can improve the wellbeing of rural poor farmers (Wossen *et al.* 2017b).

Table 4: Estimation of the Impact of SWC Practices Adoption on Crop Productivity and Welfare: PSM, IPRWA and LRETE

SWC Practices		Productivity				Welfare					
		Yield [kg/ha]	% Change	Crop Income (in USD)	% Change	PCE (in USD)	% Change	Poverty headcount (%)	% Change	PC FE (in USD)	% Change
M-only	PSM	1078.89***	20.67	167.45***	21.4	107.34***	12.91	-0.041**	37.90	85.87***	34.90
		(60.75)		(15.89)		(12.45)		(0.0238)		(5.98)	
	IPWRA	1007.168***	19.81	169.44	19.08	84.56***	8.90	-0.040	26.01	83.89***	20.90
		(47.830)		(169.23)		12.88		(0.022)		(6.89)	
	LRETE	398.22***	13.91	135.99	16.90	71.78***	5.66	-0.09***	14.90	63.89***	15.11
		(23.891)		(122.98)		8.90		(0.002)		4.89	
R-only	PSM	1134.557***	34.89	85.90**	16.89	66.56***	28.23	-0.010***	22.32	45.78***	21.09
		(54.16)		(9.56)		(4.56)		(0.001)		(4.90)	
	IPWRA	1172.007***	32.90	78.90***	14.01	65.90***	27.01	-0.021	21.44	55.78***	23.22
		(37.169)		(4.09)		(12.03)		(0.021)		(1.90)	
	LRETE	378.45***	14.44	50.89***	10.55	46.89***	11.67	-0.12***	12.56	34.23***	15.99
		(22.90)		(1.80)		(2.90)		(0.03)		(3.90)	
C-only	PSM	1074.75***	23.90	134.90***	15.90	103.90***	23.89	-0.098	21.90	34.89***	20.90
		(54.161)		(19.99)		(5.87)		(0.100)		(2.89)	
	IPWRA	1049.564***	18.89	104.67***	12.77	101.67	23.96	-0.092***	15.90	89.78***	16.00
		(35.808)		(2.5		(100.89)		(0.014)		(5.90	
	LRETE	334.02***	12.09	67.90***	6.92	55.23***	15.90	-0.11***	11.45	34.89***	14.07
		(12.93)		(3.90)		(3.44)		(0.01)		(2.22)	
MC-only	PSM	1343.86***	23.90	100.23***	33.32	98.89***	34.89	-0.145***	32.09	45.01***	23.90
		(213.89)		(3.6)		(4.33)		(0.09)		(6.9)	
	IPWRA	1030.403***	19.30	123.89***	28.89	103.56***	30.90	-0.029	21.09	55.90***	18.09
		(31.97)		(23.90)		(4.34)		0.021		(3.33)	
	LRETE	401.89***	15.21	90.89***	24.45	87.89***	23.89	-0.13***	15.01	65.89***	13.12
		(22.01)		(3.45)		(2.78)		(0.002)		(3.89)	
RC-only	PSM	1253.56***	38.90	189.80	23.09	167.90***	36.10	-0.167***	34.90	122.45***	56.09
		(290.09)		(178.09)		(34.09)		(0.02)		(0.99)	
	IPWRA	1114.671***	27.85	178.89***	22.22	156.12*	32.90	-0.053**	32.90	133.24***	45.09
		(29.71)		(34.94)		(8.67)		(0.024)		(6.61)	

	LRETE	549.89***	19.23	167.33***	18.91	109.74***	28.09	-0.11***	18.08	89.34***	19.89
		(23.90)		(3.90)		(0.45)		(0.01)		(7.7)	
MR-only	PSM	1169.09***	24.90	209.11***	31.90	189.90***	34.87	-0.275***	23.84	54.33**	44.90
		(56.90)		(23.44)		(23.45)		(0.03)		(3.45)	
	IPWRA	1146.609***	14.90	211.66***	29.12	180.67**	24.88	-0.036*	19.78	67.09***	34.76
		(32.985)		(6.88)		(3.67)		0.021		(11.73)	
	LRETE	478.90***	12.87	190.89***	19.07	154.88***	20.12	-0.11***	13.33	100.85***	23.12
		(22.89)		(22.90)		(6.99)		(0.01)		(4.89)	
MRC-only	PSM	1329.82***	45.90	250.67***	33.23	200.89**	48.45	-0.309***	45.45	156.01***	54.67
		(607.78)		(12.90)		(10.45)		(0.03)		(6.99)	
	IPWRA	1110.595***	34.50	209.89	30.34	199.09***	45.89	-0.077***	39.45	176.00***	45.89
		(28.761)		(8.44)		(40.45)		0.026		(19.20)	
	LRETE	509.34***	27.55	186.03***	29.54	145.88***	38.23	-0.23***	35.23	132.45***	33.22
		(23.89)		(23.09)		(34.90)		(0.09)		(22.81)	
At least one	PSM	1286.28	24.90	200.80***	38.65	189.89**	34.90	-0.039***	28.45	171.33***	27.90
		(58.17)		(22.34)		(11.55)		(0.02)		(8.23)	
	IPWRA	1272.507***	22.09	188.99***	29.34	145.23***	28.90	-0.441***	22.78	129.23***	23.90
		(40.075)		(11.43)		(11.55)		(0.015)		(4.56)	
	LRETE	444.90***	15.56	167.54***	22.09	145.90***	16.50	-0.21***	16.90	109.90	20.90
		(23.89)		(5.89)		(34.90)		(0.08)		(112.45)	

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

M-only" - Adoption of minimum soil disturbance; 0 otherwise, "R-only" - Adoption of crop residue retention; 0 otherwise, "C-only - Adoption of crop rotation; 0 otherwise, MC-Adoption of minimum soil disturbance and crop rotation; 0 otherwise, RC- Adoption of crop residue retention and crop rotation; 0 otherwise, MR - Adoption of minimum soil disturbance and crop residue retention; 0 otherwise, MRC - Adoption of the three SWC practices; 0 otherwise

6. Concluding remarks

This study has contributed to the dearth of knowledge on the overall nexus between the adoption of SWC practices, crop productivity, and household welfare, using nationally representative data of 2334 households. Despite numerous years of creating awareness and promoting SWC practices in Nigeria, the rates of adoption remain relatively low. The econometric analysis of the determinants of SWC practices adoption shows mixed findings on the role of individual characteristics, household characteristics, demographic and institutional variables, agro-ecological location and several miscellaneous factors and the role played in a household's decision to adopt SWC practices. Our findings indicate that education, age of the household head, access to credit, experience of drought, soil fertility, occupational stress are key drivers of adopting SWC practices.

Using PSM and IPWRA, we estimated the impact of adoption of the SWC practices on crop productivity captured as yield in kg/ha and crop income in per capita income. Also, we estimated the impact on welfare outcomes captured as per capita expenditure (relative welfare), per capita food expenditure (food security) and poverty headcount (poverty status). In general, our results seem to suggest that the adoption of SWC practices positively and significantly improve the crop productivity and welfare of the adopters of SWC practices as compared to those who have not adopted these practices.

A number of policy recommendations seem to emanate from the above empirical findings. First, the estimation of the drivers of adoption shows that education of farm households is key to enhancing adoption of SWC practices. Formal education where proficiency can be thought may be incorporated into already existing intervention programmes with the view of normalizing the decision-making process of the crop farmers. Additionally, public education relating to farm management practices (including soil and water conservative practices) can also be intensified through radio jingles, mobile phone inclusion, and any available platform that is capable of re-enforcing farmers' knowledge on adoption of improved agricultural technologies. Access to information remains a critical component in achieving broad-based adoption of improved agricultural technologies. Studies have shown that areas where farmers had access to free information on the benefits and the knowledge of implementing SWC practices, adoption rates were higher. Therefore, in Nigeria, there is need to enhance extension services nationwide in order for farmers to maximize the potential embedded in the adoption of SWC practices.

With regards to the findings emerging from the causal relationship of adoption of SWC practices and outcomes of interest, the following policy options can also be drawn. Firstly, the adoption of SWC practices should be encouraged. The reason for this recommendation emerges from the results of the casual effects which show that all possible typologies result in significant, consistent and positive effects on crop productivity and welfare indicators. Secondly, profile-raising agenda and efforts that focus on promoting the adoption of combination of SWC practices should be designed and implemented. As revealed by the present study, multiple adoption of SWC practices lead to higher average treatment effects (ATTs) on crop productivity and welfare outcomes as compared to single SWC practices. Finally, looking at the effects of the various typologies of adoption of SWC practices, irrespective of unobserved and observed effects, the adoption of 'M-only" and "R-only" resulted in highest crop productivity and welfare outcomes. Which seems to suggest that in situations where the farmer, due to credit constraints, can only adopt two typologies of SWC practices, the focus should be on combining adoption of minimum soil disturbance and crop residue retention for maximum returns on the investment.

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Availability of data and materials The data that support the findings of this study are available on reasonable request from the authors.

Declarations

Ethics approval and consent to participate IITA Research Ethics committee granted the research approval. Participation was voluntary and participants gave informed consents.

Consent for publication Not applicable

Competing interests The authors declare that they have no competing interests.

References

Abdoulaye, T., Wossen, T., Awotide, B., 2018. Impacts of improved maize varieties in Nigeria: ex-post assessment of productivity and welfare outcomes. Food security 10, 369-379

Abebe, Y., Bekele, A., 2014. The impact of soil and water conservation program on the income and productivity of farm households in Adama District, Ethiopia. Science, Technology and Arts Research Journal 3, 198-203

Amsalu, A., De Graaff, J., 2007. Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed. Ecological economics 61, 294-302

Arslan, A., McCarthy, N., Lipper, L., Asfaw, S., Cattaneo, A., 2014. Adoption and intensity of adoption of conservation farming practices in Zambia. Agriculture, ecosystems & environment 187, 72-86

Asfaw, A., Admassie, A., 2004. The role of education on the adoption of chemical fertiliser under different socioeconomic environments in Ethiopia. Agricultural economics 30, 215-228

Asrat, P., Belay, K., Hamito, D., 2004. Determinants of farmers' willingness to pay for soil conservation practices in the southeastern highlands of Ethiopia. Land Degradation & Development 15, 423-438

Awotide, B.A., Alene, A.D., Abdoulaye, T., Manyong, V.M., 2015. Impact of agricultural technology adoption on asset ownership: the case of improved cassava varieties in Nigeria. Food Security 7, 1239-1258

Baradell, J.G., Klein, K., 1993. Relationship of life stress and body consciousness to hypervigilant decision making. Journal of Personality and Social psychology 64, 267

Bayard, B., Jolly, C.M., Shannon, D.A., 2007. The economics of adoption and management of alley cropping in Haiti. Journal of environmental management 84, 62-70

Bekele, W., Drake, L., 2003. Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area. Ecological economics 46, 437-451

Bezu, S., Holden, S., 2014. Are rural youth in Ethiopia abandoning agriculture? World Development 64, 259-272

Brouder, S.M., Gomez-Macpherson, H., 2014. The impact of conservation agriculture on smallholder agricultural yields: A scoping review of the evidence. Agriculture, ecosystems & environment 187, 11-32

Cattaneo, M.D., Drukker, D.M., Holland, A.D., 2013. Estimation of multivalued treatment effects under conditional independence. The Stata Journal 13, 407-450

Danso-Abbeam, G. (2022). Do agricultural extension services promote adoption of soil and water conservation practices? Evidence from Northern Ghana. *Journal of Agriculture and Food Research*, *10*, 100381.

Dehejia, R.H., Wahba, S., 2002. Propensity score-matching methods for nonexperimental causal studies. Review of Economics and statistics 84, 151-161

Ellis-Jones, J., Tengberg, A., 2000. The impact of indigenous soil and water conservation practices on soil productivity: examples from Kenya, Tanzania and Uganda. Land Degradation & Development 11, 19-36

FAO, 2019. Annual Statistical Publication. Food and Agricultural Organization. Food and Agricultural Organization, Rome, Italy

Foster, J., Greer, J., Thorbecke, E., 1984. A class of decomposable poverty measures. Econometrica: journal of the econometric society, 761-766

Gbetibouo, G.A., 2009. Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa. Intl Food Policy Res Inst.

Gidoi, R., Mugagga, F., Buyinza, M., Wagoire, W., 2013. Implications of market access on soil and water conservation investment in Sebei sub region of eastern Uganda. African Crop Science Journal 21, 771-780

Gidron, Y., Giangreco, A., Vanuxem, C., Leboucher, O., 2012. The relationship between stress, hemispheric preference and decision making among managers. Anxiety, Stress & Coping 25, 219-228

Haggblade, S., Tembo, G., 2003. Conservation farming in Zambia. Intl Food Policy Res Inst.

Heckman, J., Navarro-Lozano, S., 2004. Using matching, instrumental variables, and control functions to estimate economic choice models. Review of Economics and statistics 86, 30-57

Imbens, G.W., Wooldridge, J.M., 2009. Recent developments in the econometrics of program evaluation. Journal of economic literature 47, 5-86

Kandlikar, M., Risbey, J., 2000. Agricultural impacts of climate change: if adaptation is the answer, what is the question? Climatic change 45, 529

Kassa, Y., Beyene, F., Haji, J., Legesse, B., 2013. Impact of integrated soil and water conservation program on crop production and income in West Harerghe Zone, Ethiopia. Studies 14, 15

Kassie, M., Pender, J., Yesuf, M., Kohlin, G., Bluffstone, R., Mulugeta, E., 2008. Estimating returns to soil conservation adoption in the northern Ethiopian highlands. Agricultural economics 38, 213-232

Koch, N., zu Ermgassen, E.K., Wehkamp, J., Oliveira Filho, F.J., Schwerhoff, G., 2019. Agricultural productivity and forest conservation: evidence from the Brazilian Amazon. American Journal of Agricultural Economics 101, 919-940

Kpadonou, R.A.B., Owiyo, T., Barbier, B., Denton, F., Rutabingwa, F., Kiema, A., 2017. Advancing climate-smart-agriculture in developing drylands: Joint analysis of the adoption of multiple on-farm soil and water conservation technologies in West African Sahel. Land Use Policy 61, 196-207

Lal, R., Stewart, B.A., 2010. Food security and soil quality. CRC Press.

Lewbel, A., 2007. Endogenous selection or treatment model estimation. Journal of Econometrics 141, 777-806

Lobell, D.B., Schlenker, W., Costa-Roberts, J., 2011. Climate trends and global crop production since 1980. Science 333, 616-620

Mabe, F.N., Nketiah, P., Darko, D., 2014. Farmers' willingness to pay for weather forecast information in savelugu-nanton municipality of the northern region. Russian Journal of Agricultural and Socio-Economic Sciences 36

Maddala, G.S., 1986. Limited-dependent and qualitative variables in econometrics. Cambridge university press.

Manda, J., Alene, A.D., Gardebroek, C., Kassie, M., Tembo, G., 2016. Adoption and impacts of sustainable agricultural practices on maize yields and incomes: Evidence from rural Zambia. Journal of Agricultural Economics 67, 130-153

Mango, N., Siziba, S., Makate, C., 2017. The impact of adoption of conservation agriculture on smallholder farmers' food security in semi-arid zones of southern Africa. Agriculture & Food Security 6, 32

Moraru, P.I., Rusu, T., 2010. Soil tillage conservation and its effect on soil organic matter, water management and carbon sequestration. Journal of Food, Agriculture & Environment 8, 309-312

Myers, M., Herrick, R., Olenchock, S., Myers, J., Parker, J., Hard, D., Wilson, K., 1992. Papers and Proceedings of the Surgeon General's Conference on Agricultural Health and Safety. Cincinnatti, Ohio: US Department of Health and Human Services, Public Health …

Ng'ombe, J., Kalinda, T., Tembo, G., Kuntashula, E., 2014. Econometric analysis of the factors that affect adoption of conservation farming practices by smallholder farmers in Zambia. Journal of Sustainable Development 7, 124

Ng'ombe, J.N., Kalinda, T.H., Tembo, G., 2017. Does adoption of conservation farming practices result in increased crop revenue? Evidence from Zambia. Agrekon 56, 205-221

Nkala, P., Mango, N., Zikhali, P., 2011a. Conservation agriculture and livelihoods of smallholder farmers in Central Mozambique. Journal of Sustainable Agriculture 35, 757-779

Nkala, P., Mango, N.A., Corbeels, M., Veldwisch, G.J.A., Huising, E.J., 2011b. The conundrum of conservation agriculture and livelihoods in Southern Africa. African Journal of Agricultural Research 6, 5520-5528

Ogunniyi, A., Oluseyi, O.K., Adeyemi, O., Kabir, S.K., Philips, F., 2017. Scaling up agricultural innovation for inclusive livelihood and productivity outcomes in sub-Saharan Africa: The case of Nigeria. African Development Review 29, 121-134

Olagunju, K.O., Ogunniyi, A.I., Awotide, B.A., Adenuga, A.H., Ashagidigbi, W.M., 2019. Evaluating the distributional impacts of drought-tolerant maize varieties on productivity and welfare outcomes: an instrumental variable quantile treatment effects approach. Climate and Development, 1-11

Olawuyi, S. O., & Mushunje, A. (2019). Determinants of adoption and use-intensity of soil and water conservation practices among smallholder farmers in Nigeria. *African Journal of Food, Agriculture, Nutrition and Development*, *19*(3), 14571-14586.

Oni, K., 2011. Tillage in Nigerian agriculture. In: Nigerian Branch of International Soil Tillage Research Organisation (ISTRO) Symposium, pp. 12-26

Pabst, S., Brand, M., Wolf, O.T., 2013. Stress and decision making: a few minutes make all the difference. Behavioural brain research 250, 39-45

Palombi, L., Sessa, R., 2013. Climate-smart agriculture: sourcebook. Climate-smart agriculture: sourcebook.

Raj, S., Roodbar, S., Brinkley, C., & Wolfe, D. W. (2022). Food Security and climate change: Differences in impacts and adaptation strategies for rural communities in the Global South and North. *Frontiers in Sustainable Food Systems*, *5*.

Rajeev, D., Wahba, S., 1999. Casual Effects in Non-Experimental Studies: Re-Evaluating the Evaluation of Training Programs. Journal of the American Statistical Association 94, 1053

Roudier, P., 2012. Climat et agriculture en Afrique de l'Ouest: Quantification de l'impact du changement climatique sur les rendements et évaluation de l'utilité des prévisions saisonnières.

Sen, A., 1976. Poverty: An ordinal approach to measurement. Econometrica: Journal of the Econometric Society, 219-231

Shiferaw, B., Tesfaye, K., Kassie, M., Abate, T., Prasanna, B., Menkir, A., 2014. Managing vulnerability to drought and enhancing livelihood resilience in sub-Saharan Africa: Technological, institutional and policy options. Weather and Climate Extremes 3, 67-79

Sidibé, A., 2005. Farm-level adoption of soil and water conservation techniques in northern Burkina Faso. Agricultural water management 71, 211-224

Smith, P., Powlson, D.S., Glendining, M.J., Smith, J.U., 1998. Preliminary estimates of the potential for carbon mitigation in European soils through no-till farming. Global Change Biology 4, 679-685

Starcke, K., Brand, M., 2012. Decision making under stress: a selective review. Neuroscience & Biobehavioral Reviews 36, 1228-1248

Tang, J., Gong, J., & Ma, W. (2022). Narrowing urban–rural income gap in China: The role of the targeted poverty alleviation program. *Economic Analysis and Policy*, *75*, 74-90.

Tesfayohannes, S., Kassa, G., & Mulat, Y. (2022). Impact of soil and water conservation practices on crop income in tembaro district, southern Ethiopia. *Heliyon*, *8*(8), e10126.

Teklewold, H., Kassie, M., Shiferaw, B., Köhlin, G., 2013. Cropping system diversification, conservation tillage and modern seed adoption in Ethiopia: Impacts on household income, agrochemical use and demand for labor. Ecological Economics 93, 85-93

Temesgen, D., Yehualashet, H., Rajan, D., 2014. Climate change adaptations of smallholder farmers in South Eastern Ethiopia. Journal of Agricultural Extension and Rural Development 6, 354-366

Uddin, M., Dhar, A., 2016. Conservation agriculture practice and its impact on farmers livelihood status in Bangladesh. SAARC Journal of Agriculture 14, 119-140

Wooldridge, J.M., 2010. Econometric analysis of cross section and panel data. MIT press.

Wossen, T., Abdoulaye, T., Alene, A., Feleke, S., Ricker-Gilbert, J., Manyong, V., Awotide, B.A., 2017a. Productivity and welfare effects of Nigeria's e-voucher-based input subsidy program. World development 97, 251-265

Wossen, T., Abdoulaye, T., Alene, A., Haile, M.G., Feleke, S., Olanrewaju, A., Manyong, V., 2017b. Impacts of extension access and cooperative membership on technology adoption and household welfare. Journal of rural studies 54, 223-233

Wossen, T., Berger, T., Di Falco, S., 2015. Social capital, risk preference and adoption of improved farm land management practices in Ethiopia. Agricultural Economics 46, 81-97

Appendix A: Summary statistics: Disaggregated by adopters and Non-adopters of each SWC practices

	M-only				R-only				C-only				RC-only			
	Adopters		Non-Adopters		Adopters		Non-Adopters		Adopters		Non-Adopters		Adopters		Non-Adopters	
	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev
age new	47.451	14.055	47.535	14.221	47.556	14.319	47.402	13.903	48.371	13.431	46.516	14.723	48.23	13.05	46.996	14.707
marrital status2	0.912	0.284	0.872	0.334	0.895	0.306	0.906	0.292	0.918	0.274	0.882	0.323	0.931	0.253	0.882	0.323
Gender	0.898	0.303	0.885	0.319	0.892	0.31	0.896	0.306	0.899	0.301	0.889	0.315	0.902	0.297	0.889	0.314
Edy yrsc	7.316	5.751	7.946	5.876	6.809	5.651	8.102	5.849	7.683	5.75	7.288	5.831	7.663	5.794	7.384	5.789
fieldsizec	4.5	3.225	4.126	3.044	4.5	3.189	4.303	3.169	4.435	3.223	4.354	3.133	4.464	3.214	4.353	3.158
ever willing	0.694	0.461	0.772	0.42	0.747	0.435	0.687	0.464	0.692	0.462	0.741	0.438	0.67	0.47	0.744	0.436
farmn exp New	25.606	16.007	26.578	16.221	25.945	16.242	25.816	15.921	26.926	15.993	24.755	16.082	26.768	15.642	25.313	16.315
house ownershp	0.875	0.33	0.895	0.307	0.898	0.303	0.865	0.342	0.882	0.323	0.879	0.326	0.876	0.33	0.884	0.321
main occup	0.79	0.408	0.775	0.418	0.789	0.408	0.783	0.413	0.799	0.401	0.771	0.421	0.804	0.397	0.774	0.418
off farm occup	0.287	0.453	0.304	0.46	0.241	0.428	0.338	0.473	0.318	0.466	0.264	0.441	0.321	0.467	0.273	0.446
access credit	0.133	0.339	0.208	0.406	0.124	0.329	0.18	0.385	0.164	0.37	0.143	0.35	0.14	0.347	0.162	0.369
drought	0.186	0.389	0.182	0.386	0.149	0.356	0.217	0.412	0.195	0.396	0.174	0.379	0.202	0.402	0.174	0.379
mem input suppl	0.627	0.484	0.639	0.481	0.594	0.491	0.663	0.473	0.665	0.472	0.594	0.491	0.664	0.473	0.61	0.488
Ever usedfert	0.687	0.464	0.706	0.456	0.683	0.466	0.7	0.458	0.681	0.466	0.703	0.457	0.672	0.47	0.705	0.456
agro eco1	0.397	0.489	0.233	0.423	0.343	0.475	0.358	0.48	0.373	0.484	0.328	0.47	0.431	0.495	0.301	0.459
Stress	0.636	0.481	0.703	0.457	0.673	0.469	0.639	0.481	0.672	0.47	0.636	0.481	0.644	0.479	0.661	0.473
poor soil fertility	0.004	0.066	0.147	0.354	0.036	0.186	0.051	0.221	0.028	0.166	0.061	0.239	0.005	0.068	0.069	0.254
hhsize2	7.022	3.044	6.607	2.772	6.893	2.795	6.918	3.13	7.121	2.978	6.677	2.957	7.246	3.035	6.692	2.919
Do u own	0.963	0.189	0.962	0.192	0.973	0.163	0.954	0.21	0.976	0.153	0.948	0.221	0.972	0.164	0.956	0.204
access_exte	0.569	0.495	0.439	0.497	0.555	0.497	0.513	0.5	0.554	0.497	0.51	0.5	0.577	0.494	0.504	0.5
NWest	0.397	0.489	0.233	0.423	0.343	0.475	0.358	0.48	0.373	0.484	0.328	0.47	0.431	0.495	0.301	0.459
SSouth	0.052	0.222	0.043	0.203	0.053	0.224	0.046	0.21	0.053	0.225	0.045	0.208	0.052	0.221	0.048	0.214
SEast	0.041	0.198	0.051	0.22	0.069	0.253	0.021	0.144	0.055	0.228	0.031	0.174	0.054	0.226	0.037	0.189
NCentral	0.195	0.396	0.454	0.498	0.251	0.434	0.281	0.45	0.241	0.428	0.295	0.456	0.175	0.38	0.326	0.469
NEast	0.044	0.206	0.056	0.23	0.037	0.188	0.057	0.232	0.029	0.169	0.067	0.251	0.024	0.153	0.063	0.242
Maize income ($US)	323.00	12.600	320.000	14.600	406.40	14.40	315.700	14.200	392.500	14.400	326.00	14.30	417.5400	21.400	398.450	14.500
Maize Yd (kg/ha)	1201.089	9.332	1024.13	81.125	1134.10	73.242	1070.38	68.439	1252.44	47.109	1044.66	72.346	1343.38	79.148	1030.823	79.986
Per_cap_($US)*	281.18	76.87	226.04	34.34	352.33	21.81	256.73	20.35	354.86	3.51	280.43	14.76	396.06	17.42	25785.1	20201.98
Per_cap_Fd_($US)	225.367	36.741	210.693	80.838	256.748	30.375	205.005	31.908	320.952	10.972	262.371	8.059	301.507	15.06	4417.119	3482.118
Poverty count (%)	0.465	0.019	0.438	0.097	0.457	0.048	0.457	0.018	0.46	0.049	0.454	0.038	0.468	0.049	0.450	0.008

Appendix B: Summary statistics: Disaggregated by adopters and Non-Adopters of each SWC practices

	MC-only				RM-only				RCM-only			
	Adopters		**Non-Adopters**		**Adopters**		**Non-Adopters**		**Adopters**		**Non-Adopters**	
	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev
age new	48.692	13.428	47.087	14.287	47.258	14.551	47.593	13.848	48.316	13.144	47.284	14.301
marrital status2	.923	.268	.894	.308	.892	.311	.906	.292	.93	.256	.894	.308
Gender	.906	.292	.89	.313	.892	.311	.895	.306	.911	.286	.89	.313
Edy yrsc	7.073	5.708	7.625	5.813	6.501	5.455	8.034	5.899	6.903	5.621	7.625	5.822
Fieldsizec	4.247	3.07	4.443	3.213	4.64	3.26	4.262	3.127	4.261	3.048	4.427	3.208
ever willing	.729	.445	.711	.453	.723	.448	.711	.453	.7	.459	.719	.45
farmn exp New	26.915	16.215	25.547	16.014	25.527	16.451	26.068	15.859	26.894	16.023	25.647	16.075
house ownership	0.889	0.314	0.878	0.327	0.883	0.322	0.879	0.326	0.877	0.329	0.882	0.323
main occup	0.782	0.413	0.787	0.41	0.78	0.415	0.789	0.408	0.785	0.411	0.786	0.411
off farm occup	0.258	0.438	0.303	0.46	0.215	0.411	0.334	0.472	0.249	0.433	0.302	0.459
access credit	0.148	0.355	0.155	0.362	0.116	0.32	0.174	0.379	0.143	0.35	0.156	0.363
Drought	0.153	0.36	0.195	0.396	0.136	0.343	0.211	0.408	0.15	0.357	0.193	0.394
mem input supply	0.651	0.477	0.624	0.485	0.571	0.495	0.663	0.473	0.633	0.483	0.63	0.483
Ever usedfert	0.648	0.478	0.706	0.456	0.682	0.466	0.698	0.459	0.638	0.481	0.704	0.456
agro eco1	0.332	0.471	0.357	0.479	0.397	0.49	0.326	0.469	0.399	0.49	0.34	0.474
Stress	0.692	0.462	0.643	0.479	0.636	0.481	0.665	0.472	0.662	0.474	0.653	0.476
poor soil fertility	0.028	0.164	0.049	0.216	0.006	0.079	0.065	0.246	0.007	0.085	0.052	0.223
hhsize2	7.09	2.886	6.848	3.002	6.93	2.912	6.894	3.011	7.22	2.981	6.836	2.971
Do u own	0.978	0.147	0.958	0.201	0.969	0.175	0.959	0.198	0.978	0.146	0.959	0.198
access imp mz seed	0.565	0.496	0.523	0.5	0.59	0.492	0.501	0.5	0.592	0.492	0.519	0.5
NWest	0.332	0.471	0.357	0.479	0.397	0.49	0.326	0.469	0.399	0.49	0.34	0.474
SSouth	0.048	0.214	0.05	0.218	0.055	0.229	0.046	0.21	0.048	0.215	0.05	0.217
SEast	0.096	0.295	0.027	0.162	0.062	0.241	0.034	0.181	0.092	0.289	0.033	0.178
NCentral	0.216	0.412	0.283	0.451	0.181	0.385	0.314	0.464	0.143	0.35	0.295	0.456
NEast	0.02	0.141	0.056	0.231	0.035	0.184	0.054	0.227	0.017	0.129	0.055	0.227
Maize incom($US)	490.50	14.400	420.100	14.310	470.890	14.800	418.330	14.300	560.500	40.560	523.980	14.300
Maize Yd (kg/ha)	1253.340	151.941	1120.972	42.022	1167.34	107.598	1145.269	49.962	1328.976	84.256	1113.146	40.192
Per_cap_($US)*	341.420	18.380	393.99	31.17	361.42	45.29	362.17	19.79	398.69	78.41	366.46	18.75
Per_cap_Fd_($US)	301.946	47.821	379.792	35.776	320.69	21.471	269.081	35.779	330.163	64.972	306.195	43.995
Poverty count (%)	0.489	0.020	0.447	0.097	0.472	0.05	0.449	0.098	0.512	0.02	0.445	0.097

Appendix C: Test for validity of instruments

Instrumental variable	Treatment variables								Outcome variables				
	Soil and water conservation practices								Welfare			Productivity	
	M-only	R-only	C-only	MC-only	RC-only	MR-only	MRC-only	At least one	Poverty headcount	PCE	PC FE	Crop income	Yield
Access to climatic information	0.699***	0.577***	0.864***	0.698***	0.199*	0.762***	0.265***	0.456***	0.0443	0.0644	0.0104	0.0067	0.0601

Appendix D: Collinearity diagnostics

Variable	VIF	Tolerance (1/VIF)
multi_class	1.13	0.88
age_new	1.84	0.54
marrital_s~2	1.42	0.70
No_yrs_villg	2.11	0.47
Edy_yrsc	1.58	0.63
Fieldsizec	1.11	0.90
ever_willing	1.16	0.86
Illiterate	1.53	0.65
house_owne~p	1.17	0.85
main_occup	1.37	0.72
off_farm_o~p	1.15	0.87
access_cre~t	1.11	0.90
Drought	1.06	0.94
Healthy	1.10	0.90
mem_input_~s	1.64	0.13
Stress	1.22	0.82
poor_soil_~y	1.08	0.92
hhsize2	1.22	0.81
Do_u_own	1.07	0.93
access_imp~d	1.11	0.91
NEast	1.23	0.81
SSouth	1.28	0.78
SEast	1.21	0.82
NCentral	1.86	0.53
NWest	2.62	0.38
Mean VIF	**1.84**	