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Impact of the Adoption of Soil and Water Conservation Practices on Crop Production: Baseline Evidence of the Sub Saharan Africa Challenge Programme

[1]*Luke O. Olarinde,* [2]*Judith B. Oduol,* [1]*Joachim N. Binam,*
[3]*Aliou Diagne,* [4]*Jemimah Njuki and* [5]*A.A. Adekunle*

[1]Forum for Agricultural Research in Africa (FARA), sub-Saharan Africa Challenge Programme,
C/o Agric. Research Station, Institute for Agricultural Research, Ahmadu Bello University,
Sabo Bakin Zuwo Road, P.O. Box 1062, Kano, Nigeria
[2] Forum for Agricultural Research in Africa (FARA), sub-Saharan Africa Challenge Programme,
C/o Kachwekano Zonal Agricultural Research and Development Institute P.O. Box 421, Kabale, Uganda
[3]Africa Rice Centre, Cotonou, Benin Republic
[4]International Livestock Research Institute, Nairobi, Kenya
[5]Forum for Agricultural Research in Africa (FARA), sub-Saharan Africa Challenge 12,
Anmeda Street, Roman Ridge, PMB CT 173, Cantonments, Accra, Ghana

Abstract: As the population of many countries in the sub Saharan Africa (SSA) region continues to grow rapidly, the carrying capacity of its agricultural land is becoming lower, bringing closer the land frontier. Consequently, agricultural productivity and food security in SSA are being seriously threatened by the steady decline in soil fertility. The need therefore to economically examine the adoption of soil and water management technology (SWMT) options to improve agricultural production becomes imperative in order to evaluate the impact of their uptake by the resource-poor African farmers. Using the counterfactual outcomes framework to estimate the "Local Average Treatment Effect (LATE)" of SWMT adoption on households' crop production value, results indicate that the adoption of SWMT increases the value of total crop production by 17-24% per household. Furthermore, the impact could be higher to 22-33% within the population of the farmers who are involved in the SSA CP IAR4D's intervention programme. The findings indicate that there is scope for improving farmers' income from crop production through increased use of the SWMT. This also suggests that there is the need on the part of the stakeholders in the IAR4D's Innovation platforms to explore more avenues for providing adequate incentives, particularly technical assistance to the farmers to use a lot more of the SWMT options on their farms.

Key words: Integrated Agricultural Research for Development (IAR4D) · Innovation Platform (IP) · Soil and Water conservation · Local Average treatment effect (LATE) · sub-Saharan Africa Challenge Programme (SSA CP)

INTRODUCTION

Although 60 percent of the Sub-Saharan Africa (SSA) population depends on rain-based rural (mostly agricultural) economies, generating in the range of 30-40 percent of the countries' GDP [1], agriculture [2] is still the most important economic activity supporting over 67 percent of the population. As the region's population continue to grow rapidly (3% per annum), the carrying capacity of its agricultural land is becoming lower, bringing closer the land frontier. Extensification on the marginal and quality-poor lands has reached upper limits and, when farmers do intensify land use to meet increasing food and fibre needs they do it without proper management practices and with little or no external inputs. Resulting consequences are a lowering of soil organic

Corresponding Author: Luke O. Olarinde, Forum for Agricultural Research in Africa (FARA), sub-Saharan Africa Challenge Programme, C/o Agric. Research Station, Institute for Agricultural Research, Ahmadu Bello University, Sabo Bakin Zuwo Road, P.O. Box 1062, Kano, Nigeria.

matter in already poor soil, a depletion of nutrients that have contributed to a stagnation or decline of crop production in many African countries. In some cases the rate of nutrient depletion is so high that even drastic measures such as doubling the application of fertilizers or manure or halving erosion losses, would not be enough to offset nutrient deficits [3].

Furthermore, agricultural productivity and food security in SSA are being seriously threatened by the steady decline in soil fertility [3]. Declining soil fertility jeopardizes the sustainability of farming systems in SSA, especially in arid and semi-arid areas that are ecologically fragile. Highly variable and declining rainfall patterns observed since the 1970s compound the ecological fragility of these regions which account for half of the cultivable land in SSA [4]. In a report compiled by [3], [5] had estimated only 12 percent of African soils to be "moderately fertile, well-drained soils" compared to 33 percent in Asia. The extent of soil degradation problem had also been highlighted by [3] to include the one reported by [6] that degraded soils amount to about 494 Million hectares in Africa. It is also estimated that 65percent of SSA's agricultural land is degraded because of water and soil erosion, chemical and physical degradation [7]; [8]. Forms of degradation vary with the causative movement or over blowing (water and wind erosion), loss of nutrient and organic matter, salinization/ alkanization, acidification, pollution (chemical deterioration), compacting/crusting, water logging and subsidence of organic area (physical deterioration). There is also human-induced soil degradation through overgrazing, deforestation and inappropriate agricultural activities. This also poses a serious threat to land productivity. Response to declining land productivity has been abandonment of existing degraded pasture and crop land and the move to new land for grazing and cultivation. Unless there are investments in soil conservation, the process will repeat itself in a vicious cycle with overgrazing and cultivation causing land degradation and then the search for new pasture and cropland [9]. Considering the background problem enumerated above on soil and water management in SSA, proper soil conservation becomes imperative when considering issues regarding soil fertility improvement in SSA. This becomes evident to the effect that the lives of a greater percentage of the populace in the region are directly connected to agriculture and agricultural based industries [10]. As pointed out by [11] however, whether soil and moisture (water) conservation technologies increase crop yields may depend on the agro-ecology and technology in question. This is an indication that agro-ecological conditions may be a particularly important determinant of the profitability of soil and water management practices. In effect, there is the need for economic research which will explicitly incorporate these and to an appreciable extent, some social and economic issues that can impact on agricultural productivity as a result of the adoption of the soil and water conservation practices in SSA.

Among the soil and water management options which have been practised by some farmers in Africa are: mulching, water harvesting, trenches/terraces, irrigation and conservation tillage. These practices constitute some options among a couple of the "soil conservation and other land management options" that some of the farmers enlisted in the Sub-Saharan African Challenge Programme (SSA CP) have adopted in some past intervention programmes. This study is in effect motivated by the need to investigate the baseline situation of farmers' use of soil and water management options in the three pilot learning sites (PLSs) of the SSA CP and to also analyse the impact of these on crop production. This is important for the programme as it will lead to the knowledge of the impact of these technologies on crop production as a result of some past interventions and also to project the expected impact of the increased adoption of these technologies as they will be influenced by the Integrated Agricultural Research for Development (IAR4D) and for adequate planning for the scaling up and out of the programme.

The Sub-Saharan Africa Challenge Program (SSA CP) was initiated in 2004, as a response to the need for increased impact from agricultural research and development efforts on the agrarian livelihoods and quality of life throughout Sub-Saharan Africa (SSA) [12]. It also aims to reverse the declining trend in agricultural productivity. Its central goal is to contribute to improved rural livelihood, increased food security and sustainable natural resource management throughout SSA, by adopting and promoting an appropriate agricultural research for development approach. The SSA CP proposes a new research approach called *Integrated Agricultural for Development* (IAR4D).

This study focuses on the pilot learning sites of the SSA CP, where the IAR4D is currently being implemented using the innovation Platform (IP) system. The 3 PLSs are (i) the Kano-Katsina-Maradi (KKM) PLS in West Africa (Nigeria and Niger Republic; (ii) the Lake Kivu (LKPLS) in East/ Central Africa (Rwanda, Uganda and DRC) and the (iii) Zimbabwe-Malawi-Mozambique (ZMM PLS) in the Southern Africa.

The remaining part of this paper is arranged as follows: section two presents the literature review and theoretical framework for assessing the impact of technology adoption. Section 3 is on the econometric framework, which discusses the analytical procedures applied to the data set. Section 4 describes the sampling, data sources and types. The fifth section describes both the descriptive and the empirical results and discusses the findings while the last section (section 6) concludes by discussing the implication of the findings.

Literature Review and Theoretical Framework: Several factors have been found to be influencing adoption and in effect, the impact of soil and water management technologies where they have been adopted. The study by [13] dealt extensively on soil and water conservation practices in SSA using Tanzania and Uganda as case studies. In their study, investigations were extended to livelihood approaches to soil and water conservation. Issues that have to do with farming systems, access to assets, transformation of structures and processes, institutions and policies were clearly highlighted in their findings. Bayard *et al*. [14] studied the adoption and management of soil conservation practices in Haiti. In this study, they identified and analysed factors influencing farmers' decisions to adopt rock walls and they also examined the factors which played a significant role in the management of this land improvement technology. In their findings, it was discovered that age, education, group membership and per capita income negatively influence the ability to manage the rock walls, while age^2 and the interaction between age and per capita income positively influenced the management. They asserted that factors influencing management of rock walls may be different for each farmer or group of farmers depending upon the constraints they faced. Another related study which dwelled on adoption levels and sources of soil management practices in low-input agriculture [15] revealed that arable farming was dominated by relatively young and educated people who can enhance adoption and soil management technological transfer. The results in this study also indicated that farmers were exposed to a wide range of impersonal sources of soil information and have potentials of disseminating such soil information to neighbouring farmers. The study in question also found out that age, education and income dictate the adoption status in the study area. Quite a number of other studies have investigated the adoption and in rare cases, the effect of different soil and water (or soil conservation practices) management technologies where they have been adopted. Few of these studies include [16]; [17]; [18]. According to [11], studies which have however proceeded to assess the economic impact of soil conservation and water management related technologies abound. Some of these include [19]; [20]; [21]; [22]; [23]; [24]; [25]; [26]; [27]; [28]. According to [11], these studies have used econometric and cross-sectional data to directly examine the impacts of conservation measures on mean yield in developing countries, but however, they suffered from a number of methodological problems that may have led to under-or over-estimation of the productivity impacts of the analysed technologies. This assertion was based on the fact that first, some of the comparisons were not based on comparable observations, which could yield biased estimates [29], that all of the prior studies assumed a single equation model in which technology had only intercept effects and the same set of variables was taken as equally affecting both technology adopters and non-adopters [11]. Some of these studies are also believed not to have accounted for endogeneity of the technology and self-selection problem. None of the studies were also said to have accounted for unobserved heterogeneity, which might have affected their findings.

To avoid the estimation problems enumerated above and other commonly encountered estimation inadequacies that are related to these types of studies, we tried to adopt a couple of other methods which have been proposed in the statistics and econometric literature. These methods, according to [30], to a large extent, takes care of some of the estimation problems which also removes (or at least minimizes) the effects of overt and hidden biases and deal with the problem of non-compliance or endogenous treatment variable which are part of the estimation problems (see [30]). The difficulty to assess productivity gains from soil conservation based on non-experimental observation because the counterfactual outcome of what production would have been without conservation or conserved plots is ‘‘not observed” has been proved [3]. This difficulty, as they affect crop technology adoption has also been alluded to severally by [31], [32] and [33]. In experimental studies [11], this problem is addressed by randomly assigning plots to treatment and control status, which assures that the outcomes observed on the control plots without conservation are statistically representative of what would have occurred without conservation on the treatment plots. In real farming situations however, farmers and plots are not randomly assigned to the two groups (adopters and non-adopters), but rather make their own adoption choices, or are systematically selected by development agencies based on their propensity to participate in technology adoption. Failure to account for this potential selection bias could lead to inconsistent estimation of the impact of technology adoption.

Econometric Framework: Modelling the impact of soil and water management practices on crop production in the SSA CP: Following the need to address the estimation problem discussed in the latter part of the section (2.0) above, the econometric (analytical) and estimation frameworks adapted in this study is based on the ‘‘potential outcome framework” developed by Rubin [34] and adopted by [30]. Under this framework [34]; each farm household has ex-ante two potential outcomes: an outcome when adopting a soil and water management practice (SWMT)[1] that is denoted by y_1 and outcome when not adopting SWMT that we denoted by y_0. Letting the binary outcome variable stand for SWMT adoption status, with $d=1$ meaning adoption and $d=0$ non-adoption, the *observed* outcome y of any farm household can be written as a function of the two potential outcomes: $y=dy_1 + (1-dy_0)$. For any household, the causal effect of the adoption on its observed outcome y is simply the difference between its two potential outcomes: y_1-y_0. But, because the realization of the two potential outcomes are mutually exclusive for any household (i.e. only one of the two can be observed ex-post), it is impossible to measure the individual effect of adoption on any given household. One can however estimate the mean effect of adoption on a population of households: E (y_1-y_0), where E is the mathematical expectation operator. Such a population parameters is called the average treatment effect (ATE) in the literature. The mean effect of adoption on the sub-population of adopters can also be estimated: $E\ (y\text{-}y_0/d=1)$, which is called the average treatment effect on the treated and is usually denoted by ATE1 (or ATT). The average treatment effect on the untreated: $E\ (y_1\text{-}y_0/d=0)$ denoted by ATE0 is also another population parameter that can be defined and estimated.

The estimation methods of these parameters can be classified under two broad categories based on the types of assumptions they require to arrive at consistent estimators of causal effects [35]. More and detailed explanations are found in: [34]; [36]; [37]; [38]; [35]. For the sake of brevity, however, we shall adapt from these literatures, some of the statistical derivations which make use of the econometric conditions and further assumptions under which estimations can progress. This leads to the following equations:

$$A\hat{T}E0 = \frac{1}{1-n_i}\sum_{i=1}^{n} \frac{\left(d_i - \hat{p}(x_i)\right)y_i}{\hat{p}(x_i)\left(1-\hat{p}(x_i)\right)} \quad (1)$$

$$A\hat{T}E1 = \frac{1}{n_1}\sum_{i=1}^{n} \frac{\left(d_i - \hat{p}(x_i)\right)y_i}{\hat{p}(x_i)\left(1-\hat{p}(x_i)\right)} \quad (2)$$

$$A\hat{T}E0 = \frac{1}{1-n_i}\sum_{i=1}^{n} \frac{\left(d_i - \hat{p}(x_i)\right)y_i}{\hat{p}(x_i)\left(1-\hat{p}(x_i)\right)} \quad (3)$$

Where n is the sample size, $n_1 = \sum_{i=1}^{n} d_i$ is the number of treated (i.e. the number of SWMT adopters) and $\hat{p}(x)$ is a consistent estimate of the propensity score evaluated at x. Use is made of the probit specification to estimate the propensity score. Then, there are the *instrumental variables* (IV)-based methods [39]; [35]; [40]; [41] which are designed to remove both overt and hidden biases and deal with the problem of endogenous treatment. The IV-based methods assume the existence of at least one variable z called the *instrument* that explains treatment status but is redundant in explaining the outcomes y_1 and y_0, once the effects of the covariates x are controlled for. Different IV-based estimators abound and this is dependent on functional form assumptions regarding the instrument and the unobserved heterogeneities.

In this paper, we use two IV-based estimators to estimate the LATE of adoption of SWMT on value of total crop production[2]. The first one is the simple non-parametric Wald estimator proposed by [41] and which requires only the observed outcome variable y, the treatment status variable d and an instrument z. The second IV-based estimator is the generalization by [40] of the LATE estimator of [41] to cases where the instrument z is not totally independent of the potential outcomes y_1 and y_0; but will become so conditional on some vector of covariates x that determine the observed outcome y. To give the expressions of the [41] LATE estimator and that of [40], we note that the binary variable denoting the farmers’ exposure status to the SWMT options (i.e. its awareness of the existence of the SWMT options) is a “natural” instrument for the SWMT adoption status variable (which is the treatment variable here). Indeed, firstly one cannot adopt or practice SWMT without being aware of it and we do observe some farmers adopting SWMT (i.e. awareness does cause adoption).

[1]We denote "Soil and water management practices" by SWMT

[2]The outcome that we investigate in this paper is the value of total crop production, computed as the value of the crops grown on plots where the SWGMT options are applied.

Secondly, it is natural to assume that exposure to SWMT affects the overall household production outcome indicators such as total production and the value thereof only through adoption (i.e. the mere awareness of the existence a SWMT option without adopting it does not affect production outcome indicators of a farmer). Hence, the two requirements for the SWMT exposure status variable to be valid instrument for the SWMT adoption status variable are met. Now, let z be a binary outcome variable taking the value 1 when a farmer is exposed to the SWMT and the value 0 otherwise. Let d_1 and d_0 be the binary variables designating the two potential adoption outcomes status of the farmer with and without exposure to the SWMT options respectively (with 1 indicating adoption and 0 otherwise). Because one cannot adopt a SWMT without being exposed to it, we have $d_0=0$ for all farmers and the observed adoption outcome is given by $d\text{-}zd_1$. Thus, the sub-population of potential adopters is described by the condition $d_1=1$ and that of actual adopters is described by the condition $d=1$ (which is equivalent to the condition $z=1$ and $d_1=1$). Now, if we assume that z is independent of the potential outcomes d_1, y_1 and y_0 (an assumption equivalent to assuming that exposure to SWMT is random in the population), then the mean impact of SWMT adoption on crop production outcome of the sub-population of SWMT potential adopters (i.e. the LATE) is given by [41]; [42] as:

$$E(y_1\text{-}y_1|\ d_1=1) = E(y|z=1)\text{-}E(y|z=0) \qquad (4)$$
$$E(d|z=1)\text{-}E(d|z=0)$$

The right hand side of (4) can be estimated by its sample analogue:

$$\frac{\left[\sum_{i=1}^{n} yizi - \sum_{i-1}^{n} yi(1-zi)\right]\left[\sum_{i=1}^{n} yizi - \sum_{i-1}^{n} yi(1-zi)\right]^{-1}}{\left[\sum_{i=1}^{n} yizi - \sum_{i-1}^{n} (1-zi)\right]\left[\sum_{i=1}^{n} yizi - \sum_{i-1}^{n} (1-zi)\right]} \qquad (5)$$

which is the well known *Wald* estimator.

The assumption that exposure to the SWMT options is random in the population is, however, unrealistic. We therefore use the LATE estimator of [40] which does not require the assumption but instead requires the conditional independence assumption: The instrument z is independent of the potential outcomes d_1, y_1 and y_0 conditional on a vector of covariates x determining the observed outcome y. With these assumptions, the following results can be shown to hold for the conditional mean outcome response function for potential adopters $f(x, d) = E(y|x,d;d_1=1)$ and any function g of (y,x,d):

$$f(x,1)\text{-}f(x,0) = E(y_1\text{-}y_0|x,\ d_1=1) \qquad (6)$$

$$E(g(y,d,x)|d_1=1) = \frac{1}{P(d_1=1)} E(k.\ g(y,d,x)) \qquad (7)$$

Where $k = \frac{z}{P(z=1|x}$ (1-d) is a weight function that takes the value 1 for a potential adopter and a negative value otherwise. The function $f(x,d)$ is called a *local average response function (LARF)* by [40]. Estimation proceeds by a parameterization of the LARF $f(\theta;x,d)=E(y|x,d;d_1=1)$. Then, using equation 2 with $g(y,d,x) = (y\text{-}f(\theta;x,d)^2$, the parameter θ is estimated by a weighted least squares scheme that minimizes the sample analogue of $E\{k(y\text{-}f(\theta;x,d))^2\}$.

Data and Sampling: The data used for this paper were excised from a cross-sectional Baseline survey data. The surveys were conducted in 2008 covering a total of 5400 households and 600 from 540 villages in 3 pilot learning sites (PLSs). These are 1. The Kano-Katsina-Maradi (KKM PLS); 2. The Lake Kivu (LK PLS) and 3. The Zimbabwe-Malawi-Mozambique (ZZM PLS). Multistage stratified random sampling procedures were applied and carried out in the three PLSs within the previously selected districts (IAR4D and counterfactual) to select the villages where the treatment are being applied, that is villages where IAR4D are introduced, village/ communities where conventional approaches were in operation and villages where no interventions had been carried out over the last 2-5 years.

The data used for analysis in this paper are representatives of the baseline conditions of the nine task forces that constitute the challenge programme. These baseline conditions were captured using four set of questionnaire: (i) the household level, (ii) the plot level, (iii) the village/community level and (iv) the IP level. For consistency, information from the household level data was used in this study. The data used consist of variables such as socio-economic and demographic characteristics, farmer knowledge of soil and water management technologies (options) and the options used or adopted before 2008, the total value of crop sales. Generally, the structured questionnaire was designed to seek information on general household characteristics, awareness and level of use of improved technologies (of which are soil and water conservation technologies, which is the main focus of this study), market and marketing information, institutional variables such credit access, extension access, membership of farmers' and other organizations, access to input and output markets, etc. The data set (which was used for the analysis in this study) is made up of 2850 programme farmers, consisting of 950 farmers from each of the three PLSs of KKM, LK and ZMM.

RESULTS AND DISCUSSION

Profiles (Characteristics) of the Sampled Households: On Table 1, we present the profiles of the sampled farmers. The main characteristics of households considered in the study include the socioeconomic and demographic (age, gender, educational level, household sizes and their composition in terms of age range and gender, whether respondents has a secondary occupation or not, etc), farm and farming characteristics such as farming experience, farm size, value of total crop production, whether respondents had contact with research and extension or not. They also include the number of soil conservation and land management technology options that the farmers practiced. Descriptive statistics such as means, standard deviation and frequencies were computed to describe these profiles. The details of the computed results are presented on PLS and treatment bases.

The mean program age of respondents stand at 41.15 years with a standard deviation of 13.63. The least mean age of 39.83 (12.97) was recorded for respondents in the ARD sites of the ZMM, while the highest mean age of 49.12 (13.67) was recorded for respondents in the ARD sites of the KKM. This implies that most of the programme baseline farmers (respondents) were in their productive age brackets with farmers in the KKM being fairly older than their counterparts in the other two PLSs. The average programme schooling years per farmer was 2.33 with farmers in the ARD sites of the ZZM having the least years of schooling (1.44) and farmers in the IAR4D sites of the KKM having the highest number (3.28) of schooling years. The summary of mean profiles of the respondents are as follows: Average household size for the programme is about 7 persons per household, an average of less than one (0.44) of the respondents had secondary occupation, average number of years of farming experience range between 26.98 and 28.39 across the sites, average number of household members below 16 years is 1.73, mean number of adult household aged above 59 is 0.75. Average total farm sizes range between 2.29 and 2.58 hectares across the sites with a mean programme value of 2.42 hectares. The mean value of total crop production for the programme was $ 951.38 with

Table 1: Socioeconomic and farm characteristics(profiles) of sampled farmers

	PLS									
	KKM			LK			ZMM			Total
	IAR4D	ARD	Clean	IAR4D	ARD	Clean	IAR4D	ARD	Clean	(program) sample
Socio economic										
Age(years) mean	48.82(13.46)	49.122(13.67)	48.70(13.47)	41.29(14.19)	40.17(12.97)	41.40(12.93)	40.35(13.53)	39.83(12.97)	40.12(13.58)	41.15(13.63)
Gender(male)(no)	230	235	208	98	139	145	87	116	240	1885
Gender(female) no)	121	72	84	209	191	168	197	207	102	964
Schooling(years) mean	3.28(3.83)	3.10(3.98)	2.82(3.93)	2.13(3.46)	1.89(3.36)	2.21(3.56)	2.31(3.56)	1.44(2.99)	1.80(3.19)	2.33(3.59)
Household size(no)	10.46(4.10)	10.70(4.15)	7.53(4.51)	7.01(4.17)	5.32(3.81)	5.97(3.57)	6.95(5.25)	7.00(3.51)	6.80(8.06)	6.83(4.56)
Has secondary occupation(no) mean	0.40(0.49)	0.38(0.49)	0.43(0.50)	0.36(0.48)	0.56(0.50)	0.55(0.50)	0.38(0.49)	0.47(0.50)	0.40(0.49)	0.44(0.50)
Farming experience(years) mean	27.64(13.65)	27.18(14.82)	28.39(14.11)	28.24(13.50)	26.98(13.80)	28.41(13.98)	27.40(14.19)	27.71(14.26)	28.27(14.00)	27.80(14.02)
No of males(16 to 58 yrs) mean	2.13(2.63)	1.91(2.05)	2.41(2.98)	2.04(2.17)	2.02(2.06)	2.27(2.26)	2.30(3.05)	1.99(2.15)	2.33(2.59)	2.16(2.46)
No of females(16 to 58 yrs)	1.78(2.19)	1.73(2.15)	1.76(1.91)	1.74(1.86)	1.74(1.82)	1.63(1.78)	1.76(2.31)	1.68(2.02)	1.77(1.94)	1.73(2.00)
No of members below(16 yrs) mean	4.22(3.20)	3.87(2.91)	3.85(3.15)	4.16(3.10)	3.99(2.89)	3.86(2.95)	4.02(3.08)	4.13(3.10)	3.88(3.08)	3.99(3.05)
No of members(59 yrs and above) mean	0.70(0.91)	0.84(1.11)	0.70(0.87)	0.69(0.91)	0.85(1.09)	0.72(0.89)	0.71(0.93)	0.75(0.94)	0.77(1.01)	0.75(13.63)
Farm										
Farm size hectares(total) mean	2.52(0.79)	2.38(0.91)	2.39(0.83)	2.53(0.85)	2.37(0.92)	2.29(0.89)	2.58(0.80)	2.38(0.87)	2.38(0.81)	2.42(0.86)
Value of total crop production($)mean	1013.95 (679.16)	932.56 (580.64)	933.24 (631.10)	1030.36 (644.87)	943.19 (566.03)	948.91 (628.11)	909.15 (590.52)	935.41 (594.54)	908.98 (584.69)	951.38 (612.97)
Soil and water mgt techn. Options kno wn by farmer(number) mean	0.87(1.35)	1.76(1.71)	1.16(1.33)	0.91(1.51)	0.70(1.40)	0.86(1.53)	0.82(0.93)	0.76(1.23)	0.86(1.20)	0.95(1.40)
Crop protection mgt techn. options known by farmer(number) mean	3.00(0.00)	3.00(0.00)	3.00(0.00)	6.00(0.00)	5.83(0.62)	5.70(0.85)	4.00(0.98)	3.56(1.30)	3.63(1.39)	4.19(1.45)
Crop mgt techn. Options known by farmer(number)(mean)	3.40(2.50)	3.21(2.82)	3.02(2.35)	2.58(2.16)	3.56(2.71)	3.98(2.62)	3.02(1.95)	2.82(1.74)	3.26(2.10)	3.21(2.38)
Contact with research(mean)	0.02(0.13)	0.003(0.06)	0.00(0.00)	0.11(0.31)	0.10(0.30)	0.10(0.30)	0.05(0.22)	0.13(0.34)	0.09(0.29)	0.07(0.25)
Contact with extension(mean)	0.02(0.13)	0.009(0.09)	0.02(0.14)	0.03(0.17)	0.05(0.22)	0.09(0.29)	0.014(0.12)	0.09(0.29)	0.082(0.27)	0.05(0.21)

Table 2: Profiles(characteristics) of the adopters and non-adopters of SWMT based on selected variables

Variables	Non-adopters (n=2745)	Adopters (n=104)	Difference
Average age(years)	41.05(0.26)	43.85(1.40)	-2.80(1.36)**
Average household size(number)	6.80(0.09)	7.64(0.69)	-0.84(0.49)***
Mean value of total production($)	944(11.58)	1127.1(72.73)	-182.37(61.15)*
Proportion of respondents with secondary occupation(%)	43.53(0.009)	51.9(0.05)	-0.084(0.05)***
Average years of schooling	2.30(0.07)	3.04(0.35)	-0.74(0.36)**
Proportion of farmers with contact with research(%)	6.96(0.005)	3.85(0.02)	3.11(0.25)
Proportion of farmers with contact with extension	4.66(0.26)	3.85(1.40)	0.82(1.36)
Proportion of farmers in village where SWMT is practised(%)	36.87(0.01)	92.0(0.03)	-55.44(0.05)*
Average total land area(cultivated and non-cultivated) ha	2.42(0.02)	2.49(0.09)	-0.08(0.09)

farmers in the IAR4D sites of the KKM recording the highest mean value $1013.95. Results show that the number of farmers who actually use soil and water management technology options was very low as at the time of the baseline survey. The programme value recorded was about one farmer (mean). In the case of crop management and crop protection options, mean values of 4.19 and 3.21 farmers were recorded to be using them as soil conservation and other land management options on their farms. Based on the data, less than one percent of the respondents claimed that they had access to either research or extension.

Though most of the variables described above may have some level of influence on adoption of a set of agricultural technologies, particularly the use of soil conservation and other land management options, they cannot be said to be absolutely correlated with the decision to adopt SWMT technologies. We therefore describe in specific terms, the linkage between the adopters and non-adopters of SWMT technologies in relation to some variables which could be said to be correlated with the use of SWMT among the farmers. The results presented in Table 2 describe these relationships. The average age of household heads is statistically different between the adopters and non-adopters, with the adopters reporting higher average age (43.85 and 41.05 for adopters and non-adopters respectively). This suggests that the age of the farmer is correlated with SWMT adoption decision and that age is a determinant of the decision to adopt SWMT options. The average household size is also statistically different between adopters and non-adopters, with the adopters reporting larger household sizes (7.64 persons) than non-adopters (6.80 persons). This suggests that that family labour availability (resulting from larger household able bodied members) may be a determinant of the decision to adopt SWMT. Family labour availability is also an indication of ability of the farm household to generate more income (farm and non-farm income) as a result of adoption which may in turn lead to economic success and an increase in the land cultivation [43], [38]. The mean value of total crop production, the proportion of farmers with secondary occupation, the average years of schooling and the proportion of farmers in villages where SWMT is practised are also significantly different between the adopters and non-adopters. The proportions of farmers with contact with research and with extension do not significantly differ between the adopters and non-adopters, suggesting lack of correlation between adoption decision and contact with either research and or extension. These results are contrary to expectation as research and more importantly extension, have been known to influence farmers' decision to adopt agricultural technologies. The likely reason that can be adduced for these results (the insignificance of both research and extension) could be due to either correlation between these two important set of variables or respondents not adequately attending to this section of inquiry during the survey period. Though the adopters possessed slightly more lands (cultivated and non-cultivated) than the non-adopters, there was no statistical significance in the mean values of this variable between the adopters and non-adopters.

Econometric Analysis of the Impact SWMT Adoption: In this study, the impact of the adoption of soil and water management options on crop production was consistently estimated because the results of the observed mean differences (Table 2) in the outcomes of interest between the adopters and no-adopters (households) may not be solely due the adoption of soil and water management options on crop production. The value of total crop production was calculated by summing up the values (in US dollars) of all crop sales per farmer. This was done in order to achieve a common valuation method for the crops produced by the programme farmers. Crops that are grown differ on the basis of PLS, TF and treatment site. In general, crops grown include legumes, cereals, roots and

Table 3: Impact of SWMT adoption on crop production(value of total production-$): based on five estimation methods(Programme-wide)

Parameters	Inverse propensity score weighting(IPWS) method(1)	ATE(parametric-ols) estimation without interaction(2)	ATE(parametric-ols) estimation with covariate interaction(3)	LATE by WALD estimators(4)	LATE by LARF (estimation by propensity score) model(5)
ATE/LATE	-152.90(226.80)	35.23(21.40)	41.01(50.80)	0.34(0.01)*	0.21(0.05)*
ATE 1	37.15(30.53)	35.23(22.15)	35.43(22.17)	-39.14(1257.74)	0.33(0.04)*
ATE0	-159.56(226.80)	35.23(21.37)***	41.21(52.22)	751.26(30.15)*	0.20(0.05)*
Population selection bias	190.059(226.94)	-7.71e-07(0.75)	-5.58(46.58)	790.41(117.49)*	0.12(0.04)**

tubers, vegetables (fruit and leafy).The estimates of the impact of SWMT on crop production were computed using the "local average treatment effect" (LATE). These results were then compared with the corresponding ATE estimates that do not correct for the hidden biases and "non-compliance" problems [30].

The LATE estimation is done for the outcome variable of interest (value of total crop production) using the two different estimation methods proposed by [41] and [40]. The adoption status dummy variable was interacted with some of the covariates *x* to account for the heterogeneous impact. To avoid having some of the predicted values of crop production being negative, an exponential LARF (using a non-linear weighted least square procedure) was also fitted (though estimates from the exponential function could not be computed due to the very low level of the required variables for this). Two different estimation methods were used for comparison purposes (these are based on [44], [44] or [35]. These are (i) the "semi parametric inverse probability weighting (IPW) estimation methods and (ii) a fully parametric method based on ordinary least squares regression for the relationship linking the outcomes to the SWMT adoption status variables and the vector of covariates *x*.

Impact of the Adoption Soil and Water Management Options on Crop Production: On Tables 3 are presented the results of the estimated impact of SWMT on the value of crop production for the programme (the three PLSs). Columns 4 and 5 present the results of the LATE estimation of SWMT options on value of crop production. These are estimated by the Wald estimator and by the "instrumental variable" proposed by [41] and [40] respectively. The results based on Abadie's [40] LATE estimator (column 5) indicate that SWMT adoption positively and significantly increases the value of crop production by 0.21(se=0.05) or 21% per farmer. (We sometimes describe the coefficient of impact parameters in percentage due to the small values of the estimated impacts). More importantly, we want to assert that our prior investigations and consequently, the findings here are with little background information concerning the level of impact that the adoption of SWMT has had on crop productivity. We can therefore deduce that since the data are baseline in nature, which were collected before the implementation of the IAR4D in the 3PLSs, the results here are in the real sense of it, the impact of the adoption of SWMT on value of total production resulting from the effect of the innovations which had been in use within the framework of the conventional approach of ARD.The results however reveal that the Abadie's [40] LATE estimate is significantly smaller in magnitude than the Wald estimate in column 4 (34%) or [0.34 (se=0.02)]. The LATE estimates are quite different from the ATE estimates. The ATE estimates of the impact of SWMT on our outcomes of interest do not however have a causal interpretation due to the problem of non-compliance (some of the ATE estimates have negative non-significant values due to the problem of very low SWMT adoption mentioned earlier on). The ATE estimates based on the parametric estimation with and without interaction are larger in magnitude [35.23 (se=21.40) and 41.01(se=50.80)] compared to the LATE estimates in column5. These estimates are however not significant. The estimate of the inverse propensity score weighting (IPSW) in column 1 is negative and also not significant [-152.90 (se=226.80)].

Impact of the Adoption Soil and Water Management Options on Crop Production: PLS and Treatment Estimates: The impacts of the adoption of SWMT on value of total production were predicted for each of the 3 PLSs (KKM, LK and ZMM) and for each of the programme-wide treatments (IAR4D, ARD and Clean sites). The results from 4 models (IPWS, ATE, parametric estimations without and with covariate interaction and the LATE by LARF) are presented on Tables 4. (The LATE by WALD function could not be estimated due to the very low level of variables needed for estimation). The results from the LATE by LARF are described the ATE estimates do not address the non-compliance problem.

Table 4: Impact of SWMT adoption on crop production(value of total production-$): based on four estimation methods(PLS estimates)

Parameters		Inverse propensity score weighting(IPWS) method	ATE(parametric-ols) estimation without interaction	ATE(parametric-ols) estimation with covariate interaction	LATE by LARF(estimation by propensity score) model
ATE/LATE	KKM	-337.14(3262.50)	35.23(21.96)	57.67(49.95)	0.17(0.05)**
	LK	91.21(509.69)	35.23(21.36)	41.01(50.80)	0.20(0.09)**
	ZMM	-26.12(593.39)	35.23(20.88)	35.94(59.81)	0.24(0.08)*
ATE 1	KKM	50.95(310.77)	35.23(22.70)	39.09(24.16)	0.32(0.05)*
	LK	116.45(205.17)	35.23(23.50)	35.43(22.17)	0.48(0.09)*
	ZMM	-90.61(207.74)	35.23(19.81)	43.68(25.96)***	0.22(0.05)*
ATE0	KKM	-355.15(3399.79)	35.23(21.92)	58.53(51.97)	0.15(0.05)***
	LK	-98.09(526.76)	35.23(21.30)***	41.21(52.22)	0.19(0.09)**
	ZMM	-24.47(605.31)	35.23(20.91)***	35.68(61.28)	0.24(0.09)*
Population selection bias	KKM	388.08(2959)	-2.83e-06(0.75)	-18.58(50.66)	0.14(0.05)**
	LK	207.66(553.19)	-73.19e-06(2.13)	-5.58(46.58)	0.27(0.10)*
	ZMM	64.49(493.82)	-4.83e-06(1.08)	8.00(54.15)	-0.18(0.06)

Table 5: Impact of SWMT adoption on crop production(value of total production-$): based on four estimation methods(Treatment estimates)

Parameters		Inverse propensity score weighting(IPWS) method	ATE(parametric-ols) estimation without interaction	ATE(parametric-ols) estimation with covariate interaction	LATEbyLARF(estimation bypropensityscore)model
ATE/LATE	Programme-IAR4D	4.77(627.38)	35.23(21.57)	46.88(50.61)	0.24(0.09)**
	Programme-ARD	-169.96(525.73)	35.23(21.53)	38.02(55.08)	0.17(0.06)**
	Programme-CLEAN	-291.73(3260.10)	35.23(21.10)	38.33(46.95)	0.21(0.07)**
ATE 1	Programme-IAR4D	84.32(82.63)	35.23(22.21)	38.89(24.21)	0.27(0.05)*
	Programme-ARD	78.67(92.29)	35.23(22.67)	40.42(23.11)	0.40(0.08)*
	Programme-CLEAN	-66.71(418.32)	35.23(22.53)	5.68(25.41)	0.32(0.07)*
ATE0	Programme-IAR4D	1.59(652.95)	35.23(21.54)	47.20(51.97)	0.23(0.11)**
	Programme-ARD	-178.25(541.52)	35.23(21.49)***	37.94(56.56)	0.15(0.06)**
	Programme-CLEAN	-298.91(3351.59)	35.23(21.08)***	38.73(48.37)	0.20(0.07)**
Population	Programme-IAR4D	79.55(643.42)	3.98e-06(0.64)	-7.99(39.32)	0.03(0.08)
selection bias	Programme-ARD	248.63(479.72)	1.54e-06(1.15)	2.40(51.34)	0.22(0.07)**
	Programme-CLEAN	225.03(2870.45)	5.12e-06(0.43)	-12.65(51.71)	0.11(0.06)***

Table 6: Estimated coefficients of the local average response function(LARF) for the value of total production

	Coefficients	
Variable	Coefficient of the non-interacted term	Coefficient of the interacted term
SWMT adoption	-204.66(30.17)*	102.70(127.47)
Farmer in SWMT village	266.85(21.64)*	303.46(24.19)*
Extension contact	-57.94(26.42)**	-46.60(27.13)***
Farmer used SWMT in the past	-70.97(33.85)**	-134.75(43.75)*
Household size	-0.033(1.24)	-0.34(1.32)
Age	-2.25(0.50)*	-2.65(0.53)*
Gender	31.03(13.84)**	46.90(14.87)*
Practised SWMT on upland	74.74(13.49)*	88.94(14.12)*
Number of observation	1237	
Adjusted R^2	0.14	
F-statistics for the joint significance of all coefficients	F(8, 1228)(201.52)*	
F-statistics for the joint significance of coefficients of non-interacted terms	F(8, 1228)(176.05)*	
-const	759.58(22.65)*	762.31(23.50)*

The computed LATE estimates as follows: KKM = 17%; LK=20% and ZMM=24%. On the basis of the treatments across the PLSs, the estimates are IAR4D= 24%; ARD=17% and Clean sites=21%. These estimates are all significant at a maximum of 5%. They are also comparable with the programme-wide estimates. Comparing these estimates to the programme-wide values, we observed that the differences in the impacts are minimal with the LK value being close to the programme-wide value. The results are also an indication of the very low level of the farmers who adopted the SWMT practices at the baseline survey.

Determinants of Total Value of Crop Production: In order to obtain the LATE estimates in the computation of the impact values based on Abadie's [40] estimation procedure, the determinants of the total value of crop production per farmer as given by their local average response functions (LARF) were estimated. The estimated parameters are presented on Table 6. The results indicate that the adoption of SWMT significantly decreases (at 1% level) the value of total crop production. This suggests that in relative terms, the value of crop production per farmer decreases because of the observed low adoption level of SWMT. This result is not unexpected as the low impact values earlier on recorded clearly points to this. Significant and negative relationship between SWMT adoption and value of total crop production suggests that farming with SWMT practices has not been profit-oriented. This is contrary to related studies, e.g. [45]; [15]; [11], who found improvement in farmers' economic, returns due to their investments in soil conservation practices. On the other hand, variables on whether the farmer lives in village where SWMT is practiced, gender and whether the farmer practices SWMT on upland or not are statistically significant (at a minimum of 5% level). This, as discussed earlier on in the descriptive summary of the farmers' profile suggest that the mean differences in the observed outcome (value of total crop production) between the adopters and non-adopters of SWMT are not solely due to the observed household characteristics that would have been assumed to influence the adoption of SWMT among the farmers. Moreover, a number of coefficients for the interacted terms are statistically significant [although the adjusted R-squared (Adjusted R^2) is small, not less than 75% of the coefficients are statistically significant], thus confirming the heterogeneity of the impact of SWMT adoption on the value of total crop production. Furthermore, the F statistics for the joint significance of the interacted terms as well as the non-interacted terms indicate that they are jointly statistically significantly different from zero. The coefficient of gender of the household head is positive and significant, suggesting that all things being equal, male-headed households have higher income from the sale of crop. This is also an indication that female-headed households exhibit lower productivity than the male-headed households. Different hypotheses have been proposed to explain this result. For instance, [18] suggests that this finding does not necessarily mean that females are less efficient or productive but may be related to the different kinds of productive activities performed by male and females. He further argues that gender inequalities, limit the access of women to information, land, capital and other inputs and this can adversely affect productivity. This difference could also be explained by unmeasured non-economic activities performed by females in the household, since in less developed areas (especially in SSA), female household heads are not only in charge of their family business but they also take care of many other needs (child care, cooking, cleaning, etc.). The coefficient of age is negative and significant (at 1% level), indicating that older farmers earn less from the sale of their crop than the younger ones. This also indicates that (as seen from the estimated mean programme-wide age in Table 1), that majority of the farmers in the study areas were in their productive and active age bracket, meaning that the impact of the adoption of SWMT is going to be pronounced on the younger farmers. This result also indicates that older farmers adopt less SWMT practices. The result here agrees with the findings of [46] and this suggests that older farmers still hold tenaciously to their old practice.

Conclusion and Implication of Findings for the SSA CP Iar4d's Innovation Platforms: The SSA CP is promoting the IAR4D through packages of technological innovations. These technological innovations are meant to improve upon the way agricultural researches have been carried out to achieve maximum results and in order to improve the lives of the majority of the resource-poor African farmers. In this study, we carried out the assessment of the impact of the adoption of soil and water management practices (SWMT) of farmers in three regions of sub Saharan Africa by evaluating the impact of the previous adoption of SWMT options on the (production outcome) total value of crop production. The counterfactual outcome framework was used to consistently estimate the causal effect of SWMT adoption on the total crop production value of the surveyed farmers as measured by the local average treatment effect (LATE). The results show that the adoption of SWMT lead to significant but mostly small improvement in the value of total crop production. The programme-wide impact as at the time of the baseline survey was about 21 percent. The highest impact on the value of total crop production was observed in households from the Zimbabwe-Malawi-Mozambique Pilot Learning Site (ZMM PLS) (24 percent) and then in households in the IAR4D (programme-wide) sites (24 percent). However, the findings indicate that there is scope for improving farmers' income through increased use of the SWMT for crop production. This also suggests that there is the need on the part of the stakeholders in the IAR4D's Innovation platforms to explore more avenues for incentives to the farmers to use a lot more of the SWMT options on their farms.

The present level of adoption of SWMT is very low relative to the number of participating farmers in the intervention programme. IAR4D stakeholders, particularly research and extension have a serious duty to provide more technical support, most especially, in the area of enlightenment on the many benefits (economic and environmental) derivable from the practice of these important soil and water conservation technologies.

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