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Adoption of Conservation Practices: Its Impact on Input Use and Performance in the Northern Region of Ghana

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Abstract

Conservation Agriculture (CA) is promoted worldwide on the basis of its contribution to economic, social, and environmental sustainability of agricultural production. In Ghana, despite the increasing interest in the promotion of CA and its practices, its rate of adoption is still low, mainly due to the conflicting evidences regarding its effectiveness. This paper contributes to the numerous debates by examining the impact of CA practices on hired labour, rates of inorganic fertilizers applied by adopters, maize yield, and profit of adopters. Using a cross-sectional data, a multinomial endogenous switching regression (MESR) model was employed to compute the Average Treatment Effect (ATE) and Average Treatment Effect on Treated (ATET) for yield, hired labour, inorganic fertilizer rate, and profit of adopters of CA practices. The study reveals that CA practices impact positively on hired labour employed on the farm, but have a negative impact on profits of adopters. No impact whatsoever of adoption of CA practices is observed on maize yield and also inorganic fertilizer application rates. Technical assistance, and training of farmers on strategies that minimize costs of production must be intensified to raise profits of adopters.

Keywords: average treatment effect, conservation agriculture, conventional agriculture, Ghana, Maize, multinomial endogenous switching regression model

1. Introduction

With the failure of the green revolution to meet the goals of sustainable production (Basu and Scholten, 2012), alternate technologies and practices were suggested and still emerging from rigorous research as the way forward to attaining sustainability in agriculture. One of these evolutions is "Conservation Agriculture" (CA) (Vanlauwe et al., 2014). The term "CA" emerged in the 1990s when efforts were made to group a number of crop management practices under a common name (e.g. zero/no-tillage, minimum tillage, etc.) (Hobbs, Sayre, and Gupta, 2008). The rationale for this grouping was that conservation agriculture should be viewed as an integrated management system based on three principles that are crucial to sustaining agricultural production (Hobbs, Sayre, and Gupta, 2008; Sommer et al., 2014; Vanlauwe et al., 2014). These principles consist of: (1) minimum physical soil disturbance by tillage practices (minimum and zero tillage practices); (2) permanent soil cover with plant materials (crop residues which also serve as mulch); (3) crop diversification in space and time (e.g. crop rotation, use of cover crops, and intercropping). Vanlauwe et al. (2014) propose a fourth principle: the proper management of soil fertility and the balancing of nutrient flows, including the integration of organic and inorganic fertilizers[Note1]. The application of conservation agriculture is however wide, functioning differently in different geographical locations including soil and crop types, as well as farming systems (Wall, 2007). Local adaptations can however present CA as differing from one geographical location to another, but of most importance is the conformity to the principles of CA (Erenstein, 2003).

In general, CA is defined as a management system that excludes the degradative components existing in conventional management systems by; removing practices that destroy the soil structure and which break down soil organic matter, the insufficient return of organic matter to the soil and lack of protection of the surface soil, and monoculture (Wall et al., 2013). The benefits of CA has been empirically validated by various researchers including Thierfelder and Wall (2010) in Zambia, Efthimiadou et al. (2010) in Sourthern Greece, Silici et al.

(2011) in Lesotho, South Africa, and Abdulai and Huffman (2014) in the Northern Region of Ghana. In view of these benefits, its widespread adoption is thought of as one that can; minimize cost of machinery, reduce carbon emissions, improve the quality of soils thus reducing erosion and other forms of negative externalities for society, increase crop-water availability, reduce the overall cost of production and improve upon productivity and food security (Stonehouse, 1997; Gowing and Palmer, 2008; Kassam et al., 2009). Conservation Agriculture is also seen as both an adaptive and mitigative measure to climate change (Thierfelder and Wall, 2010) and identified as one of the means through which sustainability in agriculture can be achieved (Webster, 1997; Gowing and Palmer, 2008; Sommer et al., 2014; Vanlauwe et al., 2014).

Despite the numerous benefits attributed to CA, its adoption has received little attention. Adoption of CA according to Giller, Witter, Corbeels, & Tittonell (2009) and Brouder and Gomez-Macpherson (2014) is concentrated in five countries constituting 87% of the world's adoption. The United States of America leads with 26.5million ha, followed by Brazil (25.5million ha) and Argentina (25.5million ha), Australia (17.0million ha) and Canada (13.5million ha). Full adoption of CA[Note 2] outside South America according to Bolliger et al. (2006) is rare. It is theorized by researchers and promoters as Pedzisa, Rugube, Winter-Nelson, Baylis, & Mazvimavi (2015) point out but practically, partial adoption is observed because CA adoption comes in phases and takes a long time for the incorporation of its three principles. Low rates of adoption are documented in Africa (Giller et al., 2009; Arslan, McCarthy, Lipper, Asfaw, and Cattaneo 2014) especially sub-Saharan Africa (SSA) where zero uptake of CA is observed in most countries (Gowing and Palmer, 2008).

Land preparation in the early 1980's for crop production in Ghana was mainly through the slash and burn method. Because there was low pressure on land, farmers could leave their farmlands after the soil has lost its fertility mainly from the practice of burning for some years to farm another fertile land while the abandoned land regains its fertility. This practice was considered as sustainable because of the practice of shifting cultivation (Boahen et al., 2007). However, as population growth, development and industrialization of the nation began to compete with agriculture over limited land, the practice of shifting cultivation gradually diminished (Boahen et al., 2007; Akowuah, 2010). Slash and burn method of land preparation was now regarded as unsustainable for agricultural production, due to its resultant effect on soil nutrient depletion, coupled with successive declines in yield (Boahen et al., 2007).

The issue of declining agricultural productivity provoked the government to search for new technologies and practices that will help in improving upon the fertility of soils and hence on crop productivity (Boahen et al., 2007). Conservation practices: minimum tillage, the use of cover crops, and rotation of cereals and grains with legumes were among the practices suggested. Promotion of these practices among farmers started in Ghana in 1995 (Boahen et al., 2007) and is still on-going (Sarpong and Anyidoho, 2012; Etwire et al. 2013). The Council for Scientific and Industrial Research-Savanna Agricultural Research Institute (CSIR-SARI), ADVANCE Ghana, the International Fertilizer Development Cooperation (IFDC) are some of the organizations encouraging the use of conservation practices among crop farmers (Etwire et al., 2013; Martey et al., 2014; Dalton, Yahaya, and Naab, 2014).

Despite the increasing interest in the promotion of CA and its practices, its rate of adoption is still low (Boahen et al., 2007; Akowuah, 2010; Dalton et al., 2014). Numerous debates are still on-going regarding its effectiveness stemming from the conflicting evidences worldwide (Giller et al., 2009; Corbeels et al., 2014; Pannell, Llewellyn, and Corbeels, 2014). In Ghana, the impact of bunding (a water and soil conservation) technology on rice yield and net returns is studied by Abdulai and Huffman (2014). However, no study is identified in literature that examined the impact of minimum tillage, maize-legume rotations, and integrated organic-inorganic fertilizer application practices in maize production in Ghana. Meanwhile Maize is the most important grain crop and the most produced in the 10 regions of Ghana, accounting for 55% of the nation's total grain production (Angelucci, 2013). In addition, it is considered as a very important crop for food security because 40% of harvest is consumed by the household (Akowuah, 2010). According to Birner & Resnick (2010) gaps in knowledge must be closed so that nations, especially in Africa would be able to implement policies that favour development. A study to assess the impact of conservation practices on the production of maize is thus very relevant for policy formulation and implementation towards agricultural development and food security in Ghana. Against this backdrop, this paper analyses the impact of conservation practices adopted for maize production in the Northern Region of Ghana on yield, inorganic fertilizer application rate, on hired labour, and on maize profits.

2. Materials and Methods

2.1 Data and Sampling

The study employed primary data collected at a cross-section from three districts in the Northern Region of

Ghana. A multi-stage sampling procedure was employed in the data collection process. The first stage involved a purposive selection of three districts; Kumbungu, West Mamprusi, and Yendi, because programmes and projects on conservation agriculture have taken place, while other programmes are still on going in these districts. In the second stage of the sampling procedure, five farming communities from each of the three districts were randomly selected. The third and final stage involved a random selection of maize farmers in the selected communities. In all 411 farmers were interviewed following the sample size estimation procedure by Bartlett, Kotrlik, and Higgins (2001) based on the 2010 population and housing census data.

2.2 Farmers' Choice of Conservation Practices

Adoption of the three CA practices – minimum tillage, maize-legume rotation, and integrated organic-inorganic fertilizer practices will yield seven possible outcomes (Table 1), with the base category being non-adoption of all three practices.

Table 1. Conservation practices used by maize farmers

Practice choice	Minimum tillage M_1	Maize-legume rotation R_1	Organic-inorganic fertilizer integration F_1
$M_0R_0F_0$			
$M_1R_0F_0$	√		
$M_0R_1F_0$		√	
$M_0R_0F_1$			√
$M_1R_1F_0$	√	√	
$M_1R_0F_1$	√		√
$M_0R_1F_1$		√	√
$M_1R_1F_1$	√	√	√

Note: adoption of conservation practices is denoted by M_1 (minimum tillage), R_1 (maize-legume rotation, and F_1 (organic-inorganic fertilizer). Non-adoption of the three conservation practices is denoted by $M_0R_0F_0$.

2.3 Econometric Framework of the MESR Model

Because farmers make their own choices endogenously, their decisions are likely to be influenced by unobservable characteristics (e.g. managerial skills). Self-selection by farmers to adopt a conservation practice or set of practices requires a selection correction estimation method such as the Multinomial Endogenous Switching Regression (MESR) method. This method of analysis is applied in this study instead of the PSM and other approaches available for impact evaluation. Following Dubin and McFadden (1984), Bourguignon, Fournier, and Gurgand (2007), this model yields consistent and efficient estimates. Bourguignon et al. (2007) point out that the MESR model provides a reasonable correction for the outcome equations, even when the IIA assumption is not achieved compared to other multinomial models especially when estimating outcomes over selected populations. This model is also advantageous in evaluating individual practices as well as combination of practices. At the same time, it is able to reveal the interactions between alternative practice options (Wu and Babcock, 1998).

The relationship between the outcome variables; maize yield (Mt/ha), inorganic fertilizer rate (Lit/ha), labour (Man-days/ha), and profit (Gh¢) and the independent variables were specified, while the control group, non-adoption (conventional practices users) ($M_oR_oF_o$) was the base outcome and denoted as *j* = 1. Each outcome (maize yield, inorganic fertilizer rate, labour, and net profit) equation for each practice or combination of practices is specified as follows:

$$\begin{cases} M_0R_0F_0\colon & Q_{1i} = Z_{1i}\gamma_1 + u_{1i} \\ \quad\vdots & \qquad\qquad \vdots \\ M_1R_1F_1\colon & Q_{ji} = Z_{ji}\gamma_j + u_{ji} \end{cases}, \qquad j = 2, \dots, 8 \tag{1}$$

Where Q denotes the outcome variables - maize yield, inorganic fertilizer rate, labour, and profit respectively of the ith farmer, Z is a set of explanatory variables that influence (1) the outcome variables (maize output, farm size, seed rate, rate of organic manure application) and (2) the treatment group (gender, age, educ, MOcc, and Off-farm job). The error terms, denoted by u's, consist of unobservable individual effects e_i and a random error term ε_i. If the ε's and u's are not independent, the OLS estimates in equation (1) will be biased. A consistent estimation of γ_j requires the inclusion of the selection correction terms in equation (1) (Bourguignon et al., 2007). In the multinomial choice setting, there are 8 – 1 selection correction terms, one for each practice. The MESR in equation (1) is re-specified as:

$$\begin{cases} M_0R_0F_0: \quad Q_{1i} = Z_{1i}\gamma_1 + \sigma_1\hat{\lambda}_{1i} + u_{1i} \quad if\ I = 1 \\ \qquad\qquad \vdots \qquad\qquad \vdots \qquad\qquad\qquad\qquad\qquad\qquad j = 2, \dots, 8 \\ M_1R_1F_1 \ : \ Q_{ji} \ = Z_{ji}\gamma_j + \sigma_j\hat{\lambda}_{ji} + u_{ji} \quad if\ I = j \end{cases} \tag{2}$$

Where σ_j is the parameter of coefficients for $\hat{\lambda}_{ji}$, which shows the covariance between the ε's and u's. The framework developed above was used to examine the average treatment effect (ATE) by comparing the expected outcomes of adopters with that of non-adopters.

2.4 Average Treatment Effect (ATE) Estimation

In assessing the impact of the conservation practices on the outcome variables (maize yield, inorganic fertilizer rate, labour, and maize profit), counterfactuals which are the maize yield, inorganic fertilizer rate, labour, and maize profit that would have been obtained if the returns (coefficients) on the characteristics of adopters had been the same as the returns (coefficients) on the characteristics of the non-adopters, and vice versa were specified. This approach deals with both selection bias due to unobserved heterogeneity and controls for selection bias due to observed heterogeneity. Following Di Falco, Veronesi, and Yesuf (2011) the conditional expectation for the outcome variables were expressed and calculated from equation (2) as follows:

Adopters of conservation practices with adoption (actual):

$$E\left[Q_{ji}\middle|I = J, Z_{ji}, \hat{\lambda}_{ji}\right] = Z_{ji}\gamma_j + \hat{\lambda}_{ji}\theta_{j\varepsilon} \tag{3}$$

Non-adopters (users of conventional practices) without adoption (actual):

$$E\left[Q_{1i}\middle|I = 1, Z_{1i}, \hat{\lambda}_{1i}\right] = Z_{1i}\gamma_1 + \hat{\lambda}_{1i}\theta_{1\varepsilon} \tag{4}$$

Adopters had they decided not to adopt (counterfactual):

$$E\left[Q_{1i}\middle|I = j, Z_{ji}, \hat{\lambda}_{ji}\right] = Z_{ji}\gamma_1 + \hat{\lambda}_{ji}\theta_{1\varepsilon} \tag{5}$$

Non-adopters had they decided to adopt (counterfactual):

$$E\left[Q_{ji}\middle|I = 1, Z_{1i}, \hat{\lambda}_{1i}\right] = Z_{1i}\gamma_j + \hat{\lambda}_{1i}\theta_{j\varepsilon} \tag{6}$$

Equations (3) and (4) denotes the actual observed expected maize yield, inorganic fertilizer application rate, labour, and net profit in the sample for adopters and non-adopters respectively, and the counterfactual expected outcome for adopters and non-adopters were respectively represented by equations (5) and (6). These equations were used to calculate the average adoption effects (i.e. average impact on the outcome variables) on adopters which is given as the difference between equations (3) and (5) (Kassie et al., 2015) as follows:

$$\begin{aligned} ATE &= E\left[Q_{ji}\middle|I = j, Z_{ji}, \hat{\lambda}_{ji}\right] - E\left[Q_{1i}\middle|I = j, Z_{ji}, \hat{\lambda}_{ji}\right] \\ &= Z_{ji}(\gamma_j - \gamma_1) + \hat{\lambda}_{ji}(\theta_j - \theta_1) \end{aligned} \tag{7}$$

The first term on the right-hand side of equation (7) represent the expected change in the outcome variables, if the characteristics and resources of adopters had the same returns (coefficients) as the returns on the characteristics and resources of non-adopters (Kassie, Teklewold, Marenya, Jaleta, & Erenstein, 2015a). The first term on the right-hand side of equation (5) represents the expected change in adopters' mean outcome, if adopters' characteristics had the same return as non-adopters, i.e. if adopters had the same characteristics as non-adopters (Teklewold, Kassie, Shiferaw, & Köhlin, 2013). The second term (i.e. λ_j) is the selection term that captures all potential effects of differences in unobserved variables. Similarly, the average effects of adoption of conservation practices on non-adopters had they adopted was computed as the difference between equations (4) and (6) as follows:

$$E[Q_{1i}|I=1,Z_{1i},\hat{\lambda}_{1i}] = E[Q_{ji}|I=1,Z_{1i},\hat{\lambda}_{1i}] = Z_{1i}(\gamma_j-\gamma_1)+\hat{\lambda}_{ji}(\theta_j-\theta_1) \tag{8}$$

According to Teklewold et al. (2013) and Kassie et al. (2015) average effects are insufficient for impact analysis due to its inability to account for both observed and unobserved factors influencing outcome variables, especially in cases of multiple adoption. The ATE which gives the difference of the expected outcomes between the treatment and control groups, is irrelevant to policy makers because it includes the effect on non-adopters (Heckman, 1997; Teklewold et al., 2013; Kassie et al., 2015). Heckman (1997) propose the Average Treatment Effect on Treated (ATET), which dwells solely on the effects on the treatment group. The Average Treatment Effect on Treated (ATET) is further estimated as the impact of adoption of conservation practices (true average adoption effect). The ATET compares the outcome variables of adopters with their counterfactuals (outcome variables had these same households not adopted these practices). The average treatment effects (ATEs) for maize yield, inorganic fertilizer rate, labour, and net profit were estimated using the augmented inverse-probability weights (AIPW), while the inverse-probability-weighted regression adjustment (IPWRA) method was used to estimate the average treatment effects on treated (ATETs) for maize yield, inorganic fertilizer rate, labour, and net profit. Both AIPW and IPWRA are “doubly robust” estimators, with the AIPW method including an augmentation term that corrects the estimator when the treatment model is mis-specified, unlike the regression adjustment (RA), and the inverse-probability weights (IPW) estimators (StataCorp., 2013).

3. Results

3.1 Socio-Demographic and Farming Characteristics

Of the sample, 49 are females representing 11.9 percent, and the remaining 362 males representing 88.1 percent (Table 2). Most of the respondents in the three districts are married (89.8%), and have no formal education (68.9%) with farming as the main occupation for most of the respondents (82.7%). A minor of these farmers are civil servants, artisans, petty traders, and labourers.

Table 2. Socio-demographic and farming information

	All farmers		Kumbungu		Yendi		West Mamprusi	
	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)
Total no. of respondents	411	100	135	32.8	135	32.8	141	34.4
Gender:								
0 = female	49	11.9	1	0.7	4	3.0	44	31.2
1 = male	362	88.1	134	99.3	131	97.0	97	68.8
Marital status:								
1 = single	38	9.2	5	3.7	12	8.9	21	14.9
2 = married	369	89.8	129	95.6	123	91.1	117	83.0
3 = divorced	4	1.0	1	0.7	0.0	0.0	3	2.1
4 = widowed	0	0.0	0	0.0	0	0.0	0	0.0
Level of formal education:								
None	283	68.9	96	71.1	91	67.4	96	68.1
Primary/middle	56	13.6	21	15.6	18	13.3	17	12.1
JHS	37	9.0	6	4.4	13	9.6	18	12.8
Secondary	28	6.8	10	7.4	11	8.1	7	5.0
Tertiary	7	1.7	2	1.5	2	1.5	3	2.1
Farming as main occupation:								
0 = No	71	17.3	17	12.6	28	20.7	26	18.4
1 = Yes	340	82.7	118	87.4	107	79.3	115	81.6

Off-farm employment:									
	Artisan	30	25.4	19	43.2	5	13.2	6	16.7
	Civil Servant	17	14.4	4	9.1	5	13.2	8	22.2
	Petty trading	42	35.6	18	40.9	12	31.5	12	33.3
	Labourer	29	24.6	3	6.8	16	42.1	10	27.8
Practices:									
	$M_0R_0F_0$	22	5.4	5	3.7	9	6.7	8	5.7
	$M_1R_0F_0$	31	7.5	23	17.0	2	1.5	6	4.3
	$M_0R_1F_0$	70	17.0	9	6.7	29	21.5	32	22.7
	$M_0R_0F_1$	37	9.0	12	8.9	1	0.7	24	17.0
	$M_1R_1F_0$	42	10.2	2	1.5	18	13.3	22	15.6
	$M_1R_0F_1$	40	9.7	24	17.8	1	0.7	15	10.6
	$M_0R_1F_1$	54	13.1	16	11.9	18	13.3	20	14.2
	$M_1R_1F_1$	115	28.0	44	32.6	57	42.2	14	9.9

Source: Survey Data, July-August 2016

Note: adoption of conservation practices is denoted by M_1 (minimum tillage), R_1 (maize-legume rotation, and F_1 (organic-inorganic fertilizer).

Of the sample, farmers using the three conservation practices ($M_1R_1F_1$) form the majority (28%). The minimum tillage practices in use by farmers in the three districts are planting on old ridges, use of bullocks for tilling, and the use of hand hoes for tillage (Table 3). Hand hoe use dominates the other practices with 52.4% of farmers against 23.8% each for the other practices. Cowpea, soybean, groundnut, and pigeon pea are the legumes used in rotation with maize, but soybean and groundnut use dominate with 44.64% and 44.3% of farmers respectively, because these legumes have relatively high demand on the market. Organic sources of fertilizer for the integrated fertilizer management practice are animal manure and compost, which are almost equally used by farmers.

Table 3 presents the specific conservation practices used by farmers in the three districts.

Table 3. Conservation practices in use

Conservation practices	**No. of farmers**	**Proportion (%) of farmers using each conservation practice**
Minimum tillage		
1. Planting on old ridges	20	23.8
2. Use of bullock	20	23.8
3. Hand hoe	44	52.4
Maize-legume rotation		
1.Cowpea	16	7.14
2. Soy bean	100	44.64
3. Groundnut	97	43.30
4. Pigeon pea	11	4.91
Organic-inorganic fertilizer		
1. Manure	57	48.72
2. Compost	60	51.28

Source: Survey Data, July-August 2016

Most farmers (61.8%) cultivate the local variety of maize, because of its ability to withstand both drought and diseases (Table 4). The hybrid varieties, though highly productive are less cultivated. Amongst the hybrid maize varieties cultivated, Obaatanpa is the most grown (22.9%) (Table 4). The variety least grown by farmers is yellow maize (0.5%).

Table 4. Maize varieties cultivated by farmers

Maize variety	Proportion (%) of farmers
Local	61.8
Okomasa	10.9
Obaatanpa	22.9
Popcorn	0.5
Dobidi	2.2
Laposta	0.2
Mamaba	1.0
Yellow maize	0.5

Source: Survey Data, July-August 2016

The total number of adopters in the sample is 389 while that of non-adopters is 22. Table 5 presents averages of some variables by status of adoption. The average age of adopters of conservation practices is 40.61 years, while that of non-adopters is 39.77 years. Formal education, proxied by the number of years spent in school is very low amongst both adopters and non-adopters with majority of them having no level of education. The average year in school for adopters is 0.59 with a deviation of 1.03 from the mean while that of non-adopters is 0.55 with a deviation of 0.80. The average years of farming experience for non-adopters, 23.27years, is more than the mean years of experience of adopters (19.96). On average adopters seem to receive more frequent visits from agricultural extension agents with visits made 1.44 times per month compared to 1.05 times per month for non-adopters.

Table 5. Mean of variables by status of adoption

Variable	Adopters	Non-adopters
Farm size in ha	1.4082	1.1909
	(1.29716)	(0.64874)
Age in years	40.61	39.77
	(13.177)	(16.251)
Years of experience in farming	19.96	23.27
	(13.327)	(14.871)
Education in years	0.59	0.550
	(1.030)	(0.800)
Frequency of extension visits/2 months	1.44	1.05
	(1.591)	(1.676)

*Source: Survey Data, July-August 2016. *Note: Standard deviations in parenthesis*

3.2 Impact of Conservation Practices on Maize Yield, Inorganic Fertilizer Rate, Labour, and Profits

Result of the unconditional average effects of maize yield, inorganic fertilizer rate, labour, and maize profits presented in Table 6.

Table 6. The average effect of adoption (ATE) of conservation practices

Adoption effect		**Outcome variables**			
Conserv. Practice(s)		Maize yield (Mt/ha)	Inorganic fertilizer rate (Kg/ha)	Labour (Man-days/ha)	Maize profit (Gh¢/ha)
Average treatement effects (ATE)	$M_1R_0F_0$	0.558**	0.265	31.75***	-773.7***
		(0.258)	(0.864)	(6.512)	(166.0)
	$M_0R_1F_0$	0.468*	-0.185	12.10**	-686.2***
		(0.274)	(0.779)	(4.709)	(184.4)
	$M_0R_0F_1$	0.686**	1.086	16.10*	-449.5
		(0.473)	(1.080)	(8.302)	(419.4)
	$M_1R_1F_0$	0.364	0.385	10.95**	-1,015***
		(0.277)	(0.734)	(5.278)	(166.6)
	$M_1R_0F_1$	0.720***	0.486	12.16*	-675.1***
		(0.275)	(0.889)	(6.337)	(196.5)
	$M_0R_1F_1$	0.658**	0.713	9.534**	-669.0***
		(0.300)	(0.697)	(4.520)	(167.9)
	$M_1R_1F_1$	0.365	1.015	11.14**	-909.4***
		(0.249)	(0.961)	(4.362)	(173.7)

Source: Survey Data, July-August 2016. Robust standard errors in parentheses; *** indicates statistical significance at 1%, ** at 5%, and at * 10% levels.

The Average Treatment Effects (ATE) indicate that maize yields of adopters are higher than yields of non adopters in exception of adopters of both minimum tillage and maize-legume rotation practices ($M_1R_1F_0$) and the joint adoption of all three practices ($M_1R_1F_1$). Higher yields of adopters compared to yields of non-adopters imply that conservation practices contribute significantly to yields. This finding agrees with results of Thierfelder and Wall (2010), Rusinamhodzi et al. (2012), Ngwira et al. (2012), and Kassie et al. (2015) but contrasts findings of Rasul & Thapa (2003).

The average difference in the rates of inorganic fertilizers is positive for all adopted practices except for adopters of maize-legume rotation practice ($M_0R_1F_0$) who apply less fertilizers compared to non-adopters ($M_0R_0F_0$) (-0.185Kg/ha). The positive differences indicate that adopters are using more fertilizers per hectare compared to the rates applied by non-adopters (Table 6). However, these differences are not significant. The recommended rates of chemical fertilizers, according to scientists at the Soil-section of the CSIR-SARI, for the integrated organic-inorganic practice ($M_0R_0F_1$) is approximately 70kg/ha and 1.5tons of organic fertilizer (animal manure or compost) per hectare, and approximately 70kg per hectare for the practice of maize-legume rotation (Appendix VI). The recommended rate for conventional farming, maize mono cropping ($M_0R_0F_0$) is approximately 267kg/ha. Despite these recommended rates, results of the study show that adopters are applying fertilizers more than the rates applied by non-adopters, which have negative implications for both the environment and health of consumers. According to Carter, Noronha, Peters, and Kimpinski (2009), Miriti et al. (2012), and Palm, Blanco-Canqui, DeClerck, Gatere, and Grace (2014) conservation agricultural practices improve soils organic carbon (C), soil particulate C and nitrogen (N) which can contribute to reduce soils' fertilizer requirements. The applications of higher rates of chemical fertilizers also mean higher costs, which can translate to reduce profits for adopters.

Adopters of all the conservation practices use significantly more labour compared to non-adopters. The highest average difference in labour between adopters of minimum tillage practice ($M_1R_0F_0$) and non-adopters ($M_0R_0F_0$) is 31.75 Man-days/ha (Table 6). A minimum tillage practice, especially one that involves the use of hand hoes requires more labour for tillage operations, explaining the significant labour by adopters of this practice. Increase in on-farm employment is important for the social pillar of sustainability (Riesgo and Gómez-Limón 2006; Gómez-Limón and Sanchez-Fernandez 2010), however, this has negative implications for profits of adopters.

Average profits are lower for adopters of all the conservation practices compared to the average profit for non-adopters. This is indicated by the significant and negative average differences. Adopters of both minimum tillage and maize-legume rotation practices ($M_1R_1F_0$) have the lowest profits compared to that of non-adopters with an average effect of -1,015Gh¢/ha. This result reiterates that observed by Corbeels et al. (2014) where adoption of CA did not increase farm profits compared to the profits of non-adopters. The lower incomes could be due to the fact that more inputs especially labour is required by adopters in implementing conservation practices, thus increasing the variable costs of operation.

Estimates of Average Treatment Effect (ATE) only show the difference of expected outcomes between adopters and non-adopters. The Average Treatment Effect on Treated (ATET) estimates the impact or true average adoption effect of households by comparing the outcome variables of adopters with the outcome variables had these same households not adopted these practices. Results of the average treatment effects on treated are presented in Table 7.

Table 7. The average treatment effect on treated (ATET) of adoption of conservation practices

Adoption effect Conserv. Practice(s)		Outcome variables			
		Maize yield (Mt/ha)	Inorganic fertilizer rate (Kg/ha)	Labour (Man-days/ha)	Maize profit (Gh¢/ha)
Average treatment effects on treated (ATET)	$M_1R_0F_0$	0.259	-503.8	32.55***	-1,604***
		(1.016)	(1,468)	(8.195)	(392.2)
	$M_0R_1F_0$	1.880	-504.7	12.07*	-1,759***
		(1.728)	(1,468)	(7.042)	(435.1)
	$M_0R_0F_1$	1.244	-375.2	34.14***	-962.3
		(1.118)	(1,454)	(21.67)	(642.7)
	$M_1R_1F_0$	0.202	-452.1	13.82**	-1,919***
		(1.027)	(1,438)	(6.948)	(438.2)
	$M_1R_0F_1$	0.646	-502.7	15.70**	-1,625***
		(1.029)	(1,468)	(7.671)	(444.2)
	$M_0R_1F_1$	0.773	-467.7	11.26	-1,579***
		(1.136)	(1,445)	(6.849)	(489.8)
	$M_1R_1F_1$	0.241	-500.3	16.97**	-1,660***
		(1.011)	(1,468)	(6.638)	(471.1)

Source: Survey Data, July-August 2016. Robust standard errors in parentheses; *** indicates statistical significance at 1%, ** at 5%, and at * 10% levels.

The ATET results indicate an insignificant impact of adoption of conservation practices on both maize yields and inorganic fertilizer rates, contrary to findings such as that of Laik et al. (2014) and Rockstrom et al. (2009). This implies that no difference exists in both maize yields and fertilizer application rates of adopters compared to the yields and rates applied if these same farmers had not adopted these conservation practices.

The recommended rate of chemical fertilizer, NPK (15-15-15) according to scientists at the Council for Scientific and Industrial Research – Savanna Agricultural Research Institute (CSIR-SARI) are approximately; 270kg/ha for mono-cropping of maize, 135kg/ha for maize-legume rotations, 70kg/ha for integrated organic-inorganic fertilizer application, and 35kg/ha for adoption of both maize-legume rotation and integrated fertilizers.

Adoption impacts positively on labour, by increasing the average number of labour used per hectare of plot as indicated by the significant and positive ATET results in Table 7. Results imply that adopters would have required averagely less labour if they had not adopted conservation practices. Though the increase in labour demand per hectare increases with adoption of conservation practices, it has negative implications for the smallholder farmer by increasing the variable cost incurred in the production of maize leading to a decline in profits. Similar results were obtained for adopters of conservation practices in the study of Teklewold et al. (2013).

Adoption impacts negatively on profits, indicated by the significant and negative ATET results for all the adopted practices. The results show that profits would have been far lower had adopters of all the conservation practices not adopted these practices. Teklewold et al. (2013) on the contrary observe that adoption of conservation practices impacts significantly and positively on profits. The lower profits obtained could be linked to higher variable costs of operation especially from the rise in labour demand. This result has critical implications for attaining economic sustainability in production.

4. Conclusion and Policy Recommendation

Applying the MESR model in this study and using a cross-sectional data, this study analysed the impact of adoption of minimum tillage, maize-legume rotation, and integrated organic-inorganic fertilizer practices on both inputs use and performance (yield and profits). Results of the study reveal that conservation practices have a positive impact on farm employment, but impacts negatively on profits of adopters, which is detrimental economically to these smallholder commercial maize producers. Adoption of these practices had no impact on maize yields and on inorganic fertilizer rates.

Both international and local organisations facilitating the adoption of conservation agricultural practices must intensify training on strategies that minimize costs of production and which leads to raise profits of adopters. Technical assistance on required application rates of fertilizers for each practice or combination of practices should be offered to reduce significantly the rates of fertilizers applied by adopters.

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Notes

Note 1. Though the goals of both organic farming and CA are to reduce pollution and promote natural soil processes, the two concepts are not the same (Gowing and Palmer, 2008). Conservation Agriculture (CA) allows the use of agrochemicals (e.g. fertilizers, weedicides), while organic farming prohibits their use.

Note 2. “Full adoption of CA” is realized when individual practices are combined in a unified, locally adapted manner, with the simultaneous application of the three principles (Erenstein, 2003). On the other hand, the use of practices that embody either one or two of the three CA principles is referred to as “partial CA.

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