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Smallholder adoption of soil and water conservation techniques in Ghana

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At the onset of climate change, the adoption of soil and water conservation (SWC) techniques in Africa sub of the Sahara has become even more crucial. The study aimed at estimating the determinants and effects of SWC adoption. The data was obtained from the Ghana Agriculture Production Survey (GAPS), a national level survey conducted by Ghana's Ministry of Food and Agriculture with technical and financial support from the International Food Policy Research Institute (IFPRI). A total sample size of 1,530 farm households selected from 20 districts across Ghana was used. The Poisson model was employed to estimate the determinants of adoption of SWC technology while the stochastic frontier model was used to analyze the effects of SWC technology adoption on technical efficiency. The study found that SWC adoption significantly affected technical efficiency in maize production. Significant policy variables that were found to positively influence the adoption of SWC techniques included credit, farm size, group membership and proximity to input sale points. Also, credit, education and extension services significantly influenced farmers' technical efficiency. There is the need for a holist approach to supporting farmers. In general, access to education, extension services and credit must be stepped up. Farmers must also be supported to form farm groups as a viable source of farm labour.

Key words: Adoption, poisson model, technical efficiency, soil and water conservation.

INTRODUCTION

Sustainable land management is the first pillar of the Comprehensive Africa agriculture program (CAADP), yet as reported by Marenya et al. (2012), adoption of improved land management practices remains low. For example, average application of fertilizer in sub-Saharan Africa (SSA) is only about 10 kg of nutrients/ha, which is the lowest level in the world (FAOSTAT, 2009). In Ghana, both governmental and non-governmental organizations have introduced a number of soil and water conservation (SWC) techniques, but the adoption rates are not better than what prevails elsewhere in the continent. Mindful of the fact that, most agricultural growth in the country has been attributed to land area expansion as opposed to yield increases (MOFA, 2007) improving factor productivity through dissemination of yields-enhancing technology has become a focus for Ghana's Ministry of Food and Agriculture. It is in this light that a study to estimate the determinants and effects of SWC techniques is most relevant. Even though research on the determinants of SWC techniques in other parts of the country abound (Nkegbe et al., 2011), this study which looks at the broader national picture, would provide empirical feedback to research and policy regarding rates of adoption of SWC and how such adoption affects farm yields and factor productivity.

Cereal production is a major component of small-scale farming in Africa. Among the cereals, maize is the most important as it forms the major staple for most communities (Djokoto, 2011). It is the largest staple crop and contributes significantly to consumer diets. It is

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also the number one crop in terms of area planted, accounting for between 50 to 60% of total cereal production in the continent. Though, the major producing areas are the forest and transitional zones of Ghana, it is grown in all parts of the country and maintains its role in agriculture sector and food security Millennium development accounts (MiDA, 2012). By investigating the adoption and productivity effects of SWC technology in Ghana, this paper contributes immensely in terms of providing feedback for research and policy.

Soil conservation practices involve managing soil erosion and its counterpart process of sedimentation, reducing its negative impacts and exploiting the new opportunities it creates (Noordwijk and Verbist, 2000). The common types of soil conservation technologies practiced in Ghana and considered in this study include mulching, crop rotation, row planting, water harvesting, fertilizer use, zero tillage, composting and agrochemical use

LITERATURE REVIEW

The extent of use of a new technology or innovation is known as adoption while diffusion is the dispersal of technology in a community. Several disciplines have looked at adoption and diffusion from their own perspectives. Sociologists explained adoption and diffusion in terms of the nature of communication channels and differences in social positions, while Economists explained adoption and diffusion in terms of profitability. Anthropologists and geographers also explained adoption and diffusion as the compatibility of innovation and information flow respectively (Boahene, 1995).

According to Feder et al. (1985) rural sociologists were the first to undertake adoption and diffusion studies. These sociological studies, especially those by Ryan and Gross (1943) and Rogers (1962), provide the basis for economic studies. Rogers (1962), like others found that, diffusion was an S-shape function of time. This was interpreted to mean that, when a technology is first released, only few people adopt it. More people adopt it later thereby increasing the rate of adoption. The number of new adopters however decreases with time resulting in a decrease in the rate of adoption. Thus, the rate of adoption in a community increases initially and finally decreases.

Other studies that offer good economic approach to the study of diffusion and adoption of technology include Griliches (1957), Rogers (1962) and Feder et al. (1985). Griliches (1957) deals with the variation in parameters across districts using market size, corn acreage per farm and differences in profitability in the districts. Feder et al. (1985) found that, adoption decisions are influenced by farm size, risk and uncertainty, human capital, labour availability, credit constraints, land ownership and rental arrangements. Recent studies include that of Boyd et al. (2000) which dealt extensively on SWC practices in Sub-Sahara Africa (SSA) using Tanzania and Uganda as case studies.

In this study, the analysis was extended to include livelihood approaches to SWC, issues that have to do with farming systems, access to assets, transformation of structures and processes, institutions and policies. Bayard et al. (2006) studied the adoption and management of soil conservation practices in Haiti. In this study, they identified and analyzed factors influencing farmers' decisions to adopt rock walls. They also examined the factors which played a significant role in the management of land improvement technology. In their findings, it was discovered that age, education, group membership, and per capita income negatively influenced the ability to manage the rock walls, while age squared 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 study (Onweremadu et al., 2007) which dwelled on adoption levels 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 had potentials of disseminating such soil information to neighboring farmers. The study in question also found out that age, education, and income dictate the adoption status in the study area. .

In Ghana, Donkoh and Awuni (2011) did a similar work but their study was based only in the North, besides the study focused only on the determinants, but not the effects of adoption. Studies which proceeded to assess the impact of SWC techniques include Kato et al. (2009), Olarinde et al. (2012), and Kassa et al. (2013). However, the main limitation of Kassa et al. (2013) is that, it investigated farmers' perceptions about the impact of SWC techniques. Much as the perceptions of farmers with respect to the efficiency of SWC techniques are important, the approach is limited as farmers' perceptions may not be right or accurate. A methodology to measure the effects of SWC techniques in quantitative terms is more preferable. In this case, the studies by Kato et al. (2009) and Olarinde et al. (2012) were expedient. However, they estimated an average response model, and in the case of the latter, also used the propensity score matching. Estimation of technical efficiency is superior to these methods as it does not only give us the opportunity to measure the efficiency of individual farmers against the average but we are able to also know the determinants of such efficiency levels. This allows for a more pragmatic policy formulation.

The present paper contributes to the technology adoption literature with the examination of the factors influencing farmers' decision to adopt SWC techniques and the effects on their technical efficiency, from the perspective of a developing country.

METHODOLOGY

The study employed two main methods in analyzing the determinants of adoption and technical efficiency effects of SWC technology adoption. The first involved the estimation of a poisson model to determine the factors that influence the adoption of SWC techniques. As indicated earlier, many adoption studies involves the estimation of probit or logit model, usually in instances where only one technique (or single attribute dependent variable) is involved. In the case of this study, a number of SWC techniques are involved. We therefore employed the poisson model, which allows us to estimate more than one SWC as a function of farmer and farm covariates. The second approach uses the stochastic frontier model, to analsye the technical efficiency effects of SWC technology adoption.

The Poisson regression model

According to Greene (1997), the Poisson regression is represented by the basic Equation:

$$\Pr(Y=y) = \frac{e^{-\lambda}\lambda^{y}}{y!}, \qquad y = 0, 1, 2 \ldots\ldots\ldots$$

The parameter λ is assumed to be log-linearly related to regressors x_i. Therefore,

$$\ln(\lambda) = \beta^{'}x_i \qquad (1)$$

The log-likelihood function is given by the Equation:

$$lnL = \sum_{i=1,2,\ldots\ldots n}[-\lambda_i + y_i\beta^{'}x_i - lny_i!] \qquad (2)$$

The expected number of SWC practices per farm is given by the Equation:

$$E[y_i|x_i] = Var[y_i|x_i] = \exp(x_i\beta^{'} + \mu_1) \qquad (3)$$

where, β is a 1 × k vector of parameters; × is a k × 1 vector with the values of k independent variables in the i^{th} observation and n is the number of observations.

The equation can also be expressed as:

$$E[Y_i] = exp^{(\beta_1 x_{1i})}exp^{(\beta_2 x_{2i})} \ldots\ldots exp^{(\beta_k x_{ki})} \qquad (4)$$

$$= \exp(\beta_j X_{jn})\, C_i \qquad (i = 1, 2 \ldots\ldots\ldots\ldots\ldots\ldots..n)$$

where, j can take any value from 1 to k and identifies a specific explanatory variable and Ci is a constant representing the product of the remaining exponential terms in Equation (4). For dichotomous explanatory variables, if $x_{ji} = 0, E(Y_i) = C_i$, and when $x_{ji} = 1, E(Y_i) = \beta_j C_i$,

Therefore, $100 \times (exp^{\beta_j} - 1)$ calculates the percentage change on E(Y) when x_j goes from zero to one, for all observations (i). In general, for independent variables that take several integer values, the percentage change in the expected level of adoption when x_j goes from x_{j1} to x_{j2} can be calculated as:

$$100 \times \frac{exp^{\beta_j x_{j2}} - exp^{\beta_j x_{j1}}}{exp^{\beta_j x_{j1}}} \qquad (5)$$

Based on the conceptual framework, the empirical model is estimated using the farmers' characteristics plausibly assumed to influence their adoption decisions. The covariates include farm and farmer characteristics such as gender, age, age squared, education, farm size, household size, group membership, number of extension visits, credit obtained by the farmer and distance to market/input store. The empirical model for adoption is specified below:

$$Logy_i = (\beta_0 + \beta_1 Gender + \beta_2 Age + \beta_3 Age^2 + \beta_4 Edu + \beta_5 FSize + \beta_6 HHsize + \beta_7 Group\_mem + \beta_8 Ext\_Visits + \beta_9 Credit + \beta_{10} Input\_dist + \varepsilon_1)$$

Where; y = 0 if a farmer failed to adopt any of the eight farming practices during the farming season under review; y = 1 if a farmer adopted any one; y = 2 if a farmer adopted any two; y = 3 if a farmer adopted any three; y = 4 if a farmer adopted any four; y = 5 if a farmer adopted any five; y = 6 if a farmer adopted any six; y = 7 if a farmer adopted any seven; and y = 8 if a farmer adopted all the eight.

The stochastic frontier model

The stochastic frontier production function assumes the presence of technical inefficiency of production through which the determinants of technical efficiency are drawn. Hence, the function is defined as:

$$Y_i = f(X_i;\, \alpha_i) + \varepsilon \qquad (6)$$

for *i* = 1, 2, 3…… ………………n

Whereby Y_i is the output of farmer *i*, X_i are the input variables, α_i are production coefficients and ε is the error term that is composed of two elements, that is:

$$\varepsilon = v_i - u_i \qquad (7)$$

Where v_i is the stochastic error which is assumed to be identically, independently and normally distributed with zero mean and a constant variance (σ_v^2). The other second component (u_i) is a one-sided error term which is independent of v_i and is normally distributed with zero mean and a constant variance (σ_u^2), allowing the actual production to fall below the frontier but without attributing all short falls in output from the frontier as inefficiency.

Technical efficiency is associated with the ability to produce on the frontier isoquant (Farrell, 1957). In other words, it is the ratio of the observed output to the corresponding frontier output, conditioned on the level of inputs used by the farm. Inefficiency on the other hand is producing below the frontier isoquant. Jondrow et al., (1982) stated that technical efficiency estimation is given by the mean of the conditional distribution of inefficiency term u_i given ε; and thus is defined by:

Table 1. Summary definition of variables.

Variable	Definition/measurement	Mean	Standard deviation
Revenue	Amount in Ghana Cedis	344.76	738.24
Gender	Dummy (male = 1; female = 0)	0.75	0.43
Age	Number of years	50.56	15.86
Education	Years spent in formal schooling	3.78	5.08
Farm Size	In acres	5.05	7.05
Household Size	Number of people	6.20	4.13
Number of extension visits	Number of visits made to extension services and by extension agents (per year)	0.00	0.00
Group Membership	Dummy (1 if the farmer is a member of a group and 0 otherwise)	0.41	0.49
SWC	Total number of SWC techniques adopted by a maize farmer	1.09	1.30
Fertilizer	Amount in Ghana Cedis	11.75	25.44
Labour	Amount in Ghana Cedis	2.60	6.66
Distance/proximity to input store	In kilometers	0.91	3.93
Credit	Amount in Ghana Cedis	16.76	319.39

Source: Result from data analysis (2012).

$$E(u|\varepsilon_i) = \frac{\sigma_u - \sigma_v}{\sigma} - \left[\frac{f(\varepsilon_j\lambda|\sigma)}{1 - F(\varepsilon_i\lambda|\sigma)} - \frac{\varepsilon_i\lambda}{\sigma}\right] \quad (8)$$

here $\lambda = \sigma_u/\sigma_v$, $\sigma^2 = \sigma_u^2 + \sigma_v^2$ while f and F stand for the standard normal density and cumulative distribution function, respectively evaluated at $\varepsilon_j\lambda/\sigma$. We define the farm–specific technical efficiency in terms of observed output (Y_i) to the corresponding frontier output (Y_i*) using the existing technology derived from the equation above as:

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{E(Y_i|u_i,X_i)}{E(Y_i|u_i = 0,X_i)} = e^{-[E(u_i|\varepsilon_i)]} \quad (9)$$

The values of TE range between 0 and 1 where the latter shows that the farm is fully efficient.

Data

The data used for this paper is from a cross-sectional baseline survey known as the Agriculture Production Survey (GAPS). The GAPS was conducted by Ghana's Ministry of Food and Agriculture with technical and financial support from the Ghana Strategy Support Program (GSSP) of the International Food Policy Research Institute (IFPRI). The data represents the first phase of the survey piloted in twenty districts across the country during the 2011/2012 cropping season. This paper uses a sample 1,530 which was collected from 800 enumeration areas located in 20 districts across the then regions of Ghana.

RESULTS

This section presents the results of the estimation of Poisson and frontier models. Table 1 presents the definition and measurement of key variables contained in the analysis as well as the descriptive statistics of the variables used in the study.

The mean of the total value of output was found to be GH¢ 344.00 per acre. This was achieved by utilizing on average, 5 acres of land, GH¢ 3.00 of labour, GH¢ 12.00 of fertilizer and the adoption or otherwise of SWC . The average age of the farmers was 51 years. The level of education among maize farmers was low, considering the mean schooling years of 4. The mean household size was 6. About 41% of the farmers participated in group activities while 59% did not take part in any group activities. The average distance from the farm to the market/input store was 1 km and the average credit obtained per farmer was GH¢ 17.00.

Factors influencing the adoption of SWC techniques in Ghana

One objective of this paper was to identify and analyse the factors that influenced the adoption of SWC techniques in the 2011/2012 farming season in Ghana. The dependent variable is a vector of SWC techniques including mulching, composting, crop rotation, water harvesting, fertilizer use, agrochemical use, zero tillage and row planting. This composite vector of SWC techniques is used in a Poisson estimation procedure to determine the farmer and farm characteristics that influence the adoption or otherwise of these techniques. The estimation results of the Poisson model are presented in Table 2. Note that, the dependent variable of the model (No. SWC) is observed and not latent, therefore the coefficients of the variables are useful, in that they measure the direct effects of the

Table 2. Maximum likelihood estimation of the determinants of SWC technology adoption.

Variable	Coefficient	Standard error	Z
Gender	0.4402	0.0685	6.43***
Age	0.0049	0.0087	0.56
Age squared	-0.0001	0.0001	-0.72
Education	-0.0472	0.0056	-8.42***
Farm size	0.0103	0.0027	3.85***
Household size	0.0338	0.0053	6.42***
Group membership	0.3916	0.1387	2.82***
Extension visits	-1.2113	0.6432	-1.88*
Credit	0.0001	0.0000	2.58**
Distance	-0.0573	0.0117	-4.88***
Constant	-0.4495	0.2291	-1.96**

*, ** and *** are levels of significance at 10, 5, and 1%, respectively, number of observations 1506, LR X^2 (10), 291.67, Prob >X^2, 0.0000***, Pseudo R^2 0.0634, Log likelihood-2153.3927. Source: Result from data analysis (2012).

explanatory variables on the dependent variable. The factors influencing farmers' adoption of SWC included gender, age, age squared, farm size, household size, years of education, cooperative participation, number of extension visits, total credit and distance to selling point/market.

Many of the right hand side covariates were significant and exhibited patterns consistent with our *a priori* expectations. The goodness of fit parameters of the model indicated that, the model adequately predicted the determinants of the adoption of SWC technology. The chi-squared value was significant at 1%, implying that all the variables jointly determine the dependent variable. Household characteristics such as gender, household size and years of education were found to be significant at 1% level of significance.

Gender and household size were positively related to the number of technologies adopted while years of education of the farmers was found to have negative influence on the number of techniques adopted. This means that male farmers tended to adopt more of the techniques than their female counterparts. Also, farmers with larger household size tended to adopt the techniques more than those with smaller household size. This is consistent with our *a priori* expectation because the adoption of SWC techniques is laborious and needs more hands. The negative sign of the education variable means that those with no education or lower educational background tended to adopt the techniques more than those with higher level of education. This goes contrary to many studies (Abbey and Admassie, 2004; Doss and Morris, 2001; Foltz, 2001) that argue that, farmers who have better education and are able to read and understand information about the technology tend to have greater probability of adoption than their illiterate counterparts. Farm size was also found to be significant at 1% level of significance and maintained the expected positive sign. This is to say that, farmers with larger farm size adopted more technologies than their counterparts. This is however, consistent with our *a priori* expectation and confirmed that of other studies, especially Donkoh and Awuni (2011).

Group membership was also found to be significant at 1% level of significance and had a positive influence on adoption implying that farmers who belong to a farmer group had greater probability of adoption than those who did not. However, while the extension variable was significant at 10% level of significance, it showed a negative influence on adoption, hence inconsistent with the findings of Donkoh and Awuni (2011). Similarly, the fact that, credit was significant and maintained its expected positive sign implies that credit is an important source of capital which facilitated SWC technique adoption in the cropping season. This is consistent with Foltz's (2001) hypothesis that, farmers who have better access to credit stand a better chance of adopting technology faster than those who are capital-constrained. Ekboir et al. (2002) and Simtowe and Zeller (2006) had similar findings.

The closer an input store was to the farmer's field, the greater the adoption of SWC techniques. Proximity to an input store is not only an incentive for farmers to buy the inputs, but it reduces the cost of transporting the input to the farmer's house.

Effect of SWC technique adoption on output of maize farmers in Ghana

The parameters and related statistical results obtained from the stochastic frontier production function analysis are presented in Table 3. The study revealed a significant effect of SWC technique adoption on maize output. This is consistent with the findings of Olarinde et al. (2012) and Kato et al. (2009). In addition to the SWC variable, all

Table 3. Maximum likelihood estimation of the stochastic frontier model for maize farmers in Ghana.

Variable	Coefficients	Standard error	Z
Output function			
Constant	7.0039	0.0927	75.11***
Farm size	0.1041	0.0515	2.02**
Labour	0.1129	0.0519	2.18**
Fertilizer	-0.1039	0.0346	-3.0***
Number of SWC adopted	0.19440	0.03755	5.18***
Inefficiency model			
Constant	2.7113	0.3530	7.68
Gender	0.3697	0.0888	4.16***
Age	-0.0084	0.0136	-0.62
Age squared	0.0001	0.0001	1.05
Education	-0.0271	0.0069	-3.91***
Farm size	-0.0050	0.0063	-0.80
Household size	0.0437	0.0099	4.39***
Group membership	0.3723	0.2438	1.53
Number of extension visits	-0.0619	0.0101	-6.08***
Credit	-0.0004	0.0002	-2.31**
Distance	-0.3898	0.0864	-4.51***
Sigma square	17.7146	1.6702	
Gamma (γ)	0.9763	0.0038	
Sigma square (σ_u^2)	17.2942	1.6672	
Sigma square (σ_v^2)	0.4204	0.0568	
Mean technical efficiency	0.5011		
Loglikelihood function	-3928.0657		

*, ** and *** are levels of significance at 10, 5, and 1% respectively. Source: Result from data analysis (2012).

the conventional inputs were significant and maintained their expected sign, except fertilizer input, which although was significant had a negative sign, implying that, the greater its application the less the output. Kumornu et al. (2013) also found a negative sign for fertilizer in the Eastern region of Ghana. Also, in general, maize farmers in Ghana is averagely efficient as the estimated mean technical efficiency was found to be 0.50 ranging between 0.35 and 0.83. Thus, there is room to increase output without increasing input amounts at the present level of technology by 50%.

In the inefficiency effects model, the variables that significantly influenced farmers' technical efficiency were gender, education, household size, extension visits, credit and distance to the market. The negative sign of the gender variable implies that, female farmers were more technically efficient than their male counterparts. This is in contrast with that of Donkoh (2011) who found that, male headed households were more efficient. Also, in this present study, technical efficiency was greater for farmers with many years of formal education, farmers who received extension visits as well as famers who had access to credit. These findings are consistent with that of many studies (Seidu, 2008; Binam et al., 2008; Kumornu et al., 2013). The negative sign of the distance variable, however, also implies that, farmers who stayed farther away from the market were more technically efficient.

DISCUSSION

Even though the negative significance of the education variable did not meet our *a priori* expectations, the finding is quite plausible as a result of two reasons. First the adoption of SWC techniques does not require much formal education compared with some modern technologies. SWC techniques are indigenous techniques which have been with the farmers since time immemorial; hence they do not need formal education to understand its adoption. Perhaps this also explains why the extension variable did not meet our *a priori* expectation.

Second, the adoption of SWC techniques is quite laborious and time consuming, which means that it is unattractive to the educated since they are normally busy with other non-farm activities. The labourous nature of the adoption of SWC techniques and its consequent need for a large labour force is evidenced by the significance and positive sign of the household size and group membership variables. In Africa, the household and farmer groups are a significant source of farm labour. In the case of household labour, even children have their role to play in the farming business, especially when it comes to activities such as mulching and water harvesting. Against the backdrop of limited money to hire labour, farmers put themselves into group to work for one another for reciprocal gains.

The importance of agricultural credit in peasant farming cannot be over-emphasized. This is also evidenced by the positive significant coefficient of the credit variable. With credit, farmers can access the tradable SWC techniques such as inorganic fertilizers and insecticides. Credit is not the only factor that facilitates the adoption of tradable SWC techniques; proximity to input stores where these techniques are sold is important. Already, some of these inputs are expensive to farmers and they would not like to incur extra costs by way of transportation, to cart the inputs to their houses or farms.

A closer examination of the results of the adoption and efficiency models reveals some contradictions in the way that the explanatory variables influenced the dependent variables. For instance, while the probability of adoption was greater for households that were closer to the input stores, these households were less efficient than their counterparts who were farther away. However this is not unsurprising, technical efficiency is more than just the adoption of SWC. To be efficient in one's farming work, one needs to have an undivided attention. Other things being equal, farming in the rural or peri-urban is more effective than farming in the urban centers (proximity to inputs stores implies living in a relatively urban area). Farmers in the urban centers normally tend to have a divided attention, which goes a long way to adversely affect their farming work. Besides, MoFA (2007) recognized that, the problem of input demand in Ghana goes beyond proximity of input stores to farmers, there is the need, beyond the establishment of input stores in the districts, for the passage and enforcement of laws and regulations as well as foster an enabling environment to enhance trade in and use of input.

Also, even though education and extension services influenced adoption negatively, they maintained a positive correlation with technical efficiency. While the adoption of SWC techniques may not have required education and extension services because the farmers were familiar with the techniques, there might be other areas that they (education and extension services) were needed to enhance farmers' technical efficiency.

Furthermore, even though male farmers had greater adoption, they were less efficient than their female counterparts. The argument in the literature is that women are normally marginalized in terms of access to complementary inputs that facilitate technology adoption. This could explain their relatively low probability of adoption. This notwithstanding, they were more technically efficient. The point has always been raised in favour of women that affirmative action must be taken to bring them up to the level of their male counterparts in terms of access to socioeconomic benefits. Lastly, while the probability of adoption was greater for larger households, smaller households were more technically efficient. The danger in the use of large families on small plots is the likelihood of negative marginal returns, which translates into technical inefficiency.

The implication of these seemingly contradictory findings on policy formulation is to take a holistic approach, so that both adoption and technical efficiency are increased. However, it should be noted that, in principle, technology adoption is not an end in itself but a means to raising the efficiency of farmers. This means that, in dealing with variables that exert contracting influence on technology adoption and efficiency, priority should be given to technical efficiency. This implies, from our findings, that besides credit, access to education and extension visits should be promoted. Similarly, group membership should be encouraged since it facilitated adoption, without leaving any negative impacts on efficiency.

Ownership of large farms should also be encouraged since it did not only increase adoption but increased output (in the first part of the stochastic frontier model). This should however, not be done at the expense of small-scale farmers, considering the fact that, they constitute over 90% of the farming population (Seini, 2002). The usual way is to encourage the formation of the out grower schemes where large farmers are strengthened to form nuclei to also strengthen smaller farms.

Conclusion

The objectives of this study were to investigate the factors that influenced the adoption of SWC techniques and to determine the effects of adoption on maize output in Ghana. While the first objective was achieved by estimating a Poisson model the stochastic frontier model was estimated to meet the second objective. Significant policy variables that were found to positively influence the adoption of SWC techniques were credit, farm size, group membership and proximity to an input store. Also, adoption, credit, education and extension services significantly influenced farmers' technical efficiency. We propose a holistic approach in formulating policies to increase adoption and efficiency, while giving priority to technical efficiency.

The strength in this study lies in the opportunity to estimate the adoption behavior of farmers when multiple techniques are involved and see how policy variables influence adoption and technical efficiency at the same time. We have proposed that, where a variable exerts contrasting effects on adoption and output/technical efficiency, the latter should be given priority since the former is only a means to achieve the latter. The limitation of the study lies in the fact that, we could not apply Heckman's two stage model to correct for selectivity (which is applicable in the case of the probit/logit model) and incorporate a welfare model so as to see the (net) effect of technology adoption on the living standards of farmers. Our data does not include welfare variables to make this possible. We hope that future studies would overcome these limitations.

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Abbreviations: CAADP, Comprehensive Africa agriculture program; **CSOs,** civil society organizations; **FBOs,** farmer base organizations; **GAPS,** Ghana agriculture production survey; **GSSP,** Ghana strategy support program; **IFPRI,** international food policy research institute; **MDGs,** millennium development goals; **MiDA,** millennium development accounts; **METASIP,** medium term agricultural sector investment program; **SWC,** soil and water conservation; **SSA,** sub-Sahara Africa.

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