UDS International Journal of Development [UDSIJD]
Volume 6 No. 3, 2019
http://www.udsijd.org
ISSN: 2026-5336

AGRICULTURAL INPUT CREDIT AND THE ADOPTION OF SUSTAINABLE AGRICULTURAL PRACTICES (SAPS) IN SELECTED SUB-SAHARAN AFRICA (SSA) COUNTRIES: AN ENDOGENOUS POISSON REGRESSION APPROACH

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Abstract

Smallholder farmers, mostly in sub-Saharan Africa (SSA), are the hardest hit by climate change impacts because of their over reliance on rainfall and other natural factors. This has led to the development and extension of a number of improved agricultural technologies and practices, otherwise known as sustainable agricultural practices (SAPs). The question that is often asked is whether or not agricultural credit can improve the adoption of SAPs. The objective of this study was to investigate the factors influencing access to agricultural credit and the effects on the adoption of SAPs in selected SSA countries. The Intensification of food crops agriculture in sub-Saharan Africa (AFRINT II) data set were used for the study. The sample involved about 3,000 households from nine African countries, namely; Ethiopia, Ghana, Kenya, Malawi, Nigeria, Tanzania, Uganda, Zambia and Mozambque. A Poisson regression with endogenous treatment effect was estimated to address a possible selectivity bias. In all, 47.5% of the respondents, as against 52.5%, had access to credit. The commonest technologies adopted were intercropping, integrated nutrient management, crop rotation and soil and water conservation. The estimation results suggest that access to credit and formal education as well as land ownership lead to the adoption of SAPs. However, while group membership facilitates access to credit, households headed by relatively old farmers have lower probability of accessing credit than those headed by the young. Both government institutions and the private sector must work at upscaling credit supply to farmers in a more sustainable way while taking affirmative action in favour of female headed households. Formal education and land entitlement should also be promoted to step up adoption of the improved technologies.

Keywords: ***Adoption, Agricultural credit, Endogenous treatment, Poisson regression, Sustainable Agricultural Practices***

Introduction

According to OECD/FAO (2016), agriculture contributes 15% of total GDP on average in Africa. The sector also employs more than 50% of the total labour force of which half are female (FAO, 2015). Of all the farms in Sub Sahara Africa (SSA), smallholder farms constitute approximately 80% and employ about 175 million people directly (AGRA, 2014). Most of these farmers are in the rural areas and have agriculture as their main occupation (OECD/FAO, 2016). Among the numerous challenges facing agriculture in SSA is the severe impacts of climate change and variability (Rosenzweig, et al; 2013; AGRA, 2014). This means that adaptation strategies are urgently needed to assist in minimising climate change impacts (Rickards and Howden, 2012). Directly or indirectly, most soils are also not good for sustainable agricultural production.

The adoption and diffusion of agricultural technologies has become a major concern of governments and development practitioners in many developing countries, especially SSA. While a number of technologies have been developed, the adoption rates have been low (Manda, Alene, Gardebroek, Kassie and Tembo, 2015). Several reasons may be given to explain the low adoption rates. These include rudimentary or inappropriate technologies, failure on the part of pure scientists to factor farmers' socioeconomic indicators into the design and extension of the technologies and lack of, or inadequate financial resources to acquire the designed technologies. Consequently, while scientists are contributing to improving some of these technologies, governments and civil society organisations are also assisting in giving loans to farmers for the effective adoption of these technologies. It behoves on social scientists to also keep researching into the socioeconomic factors influencing the adoption of agricultural technologies.

Agricultural credit used to be in the form of cash. However, as a result of alleged misappropriation by the farmers, governments and other credit institutions now prefer to give the credit in the form of non-cash input; examples in Ghana are the Sasakawa Global 2000 and the Block Farm Credit[1]). The question is, would agricultural credit input lead to the desired positive effect on the adoption of Sustainable Agricultural Practices (SAPs) in SSA?

The main objective of this study was to investigate the effect of agricultural credit input on the adoption of SAPs. Quite a number of studies have been done on the adoption of SAPs without necessarily focusing on the effect of agricultural input credit on adoption of SAPs (Adnan and Nordin, 2011; Simon, Garba and Bunu, 2014; Menozzi, Fioravanzi and Donati, 2016; Manda et al, 2015)). Most of these studies (Adnan and Nordin, 2011; Simon, Garba and Bunu, 2014; Manda et al., 2015) are also very limited in terms of location; that is to say that they either focus on one country or some parts of it. This study is broader and goes beyond Ghana to make comparison of the adoption situation in other SSA countries (Ethiopia, Ghana, Kenya, Malawi, Nigeria, Tanzania, Uganda, Zambia and Mozambque). Besides, the determinants of agricultural technology adoption are location, time and user-specific (i.e. the factors influencing adoption may differ depending on the location, time period and the farmers that would use the technologies). It is important therefore for social scientists to constantly update their research findings in order to better inform policy; hence this study.

The methodology, in terms of its application to similar studies, is also uncommon, to the best of my knowledge. The rest of the paper is as follows: Section 2 explains the methodology of the study while section 3 presents and analyses the results. The last section 4 draws conclusions from the findings and recommendations for policy formulation.

Agricultural technology adoption and credit

This study draws inspiration from the theories of agricultural development which Norton et al. (2010) summarised as follows: agricultural extensification; agricultural intensification; diffusion of innovation; and high pay-offs. In most countries the world over, agriculture started with vast idle arable lands and low human population. Therefore, increases in agricultural output were largely obtained through expansion in cultivated land. In this case, forests and jungles were opened up and labour resources exploited. This source of agricultural development was common in North and South America as well as Australia and Africa, during colonisation. However, in areas where land is inadequate the extensification model is not sustainable and even in places like Africa and Latin America where additional land exists, diseases, insects and soil infertility have meant that agricultural extensification is unsustainable.

In contrast to extensification, agricultural intensification means a more intensive use of agricultural resources. Specifically, this involves practices such as crop rotations, green manuring, terracing, drainage and irrigation. These practices were also common in England, Germany and other European countries. Agricultural intensification is otherwise called conservation agriculture where for instance, a given piece of farm land may be cultivated continuously for a long time but its fertility is improved through the application of soil and water conservation technologies. Another means of intensification is producing the same crop so many times within the year by planting shorter season varieties or by

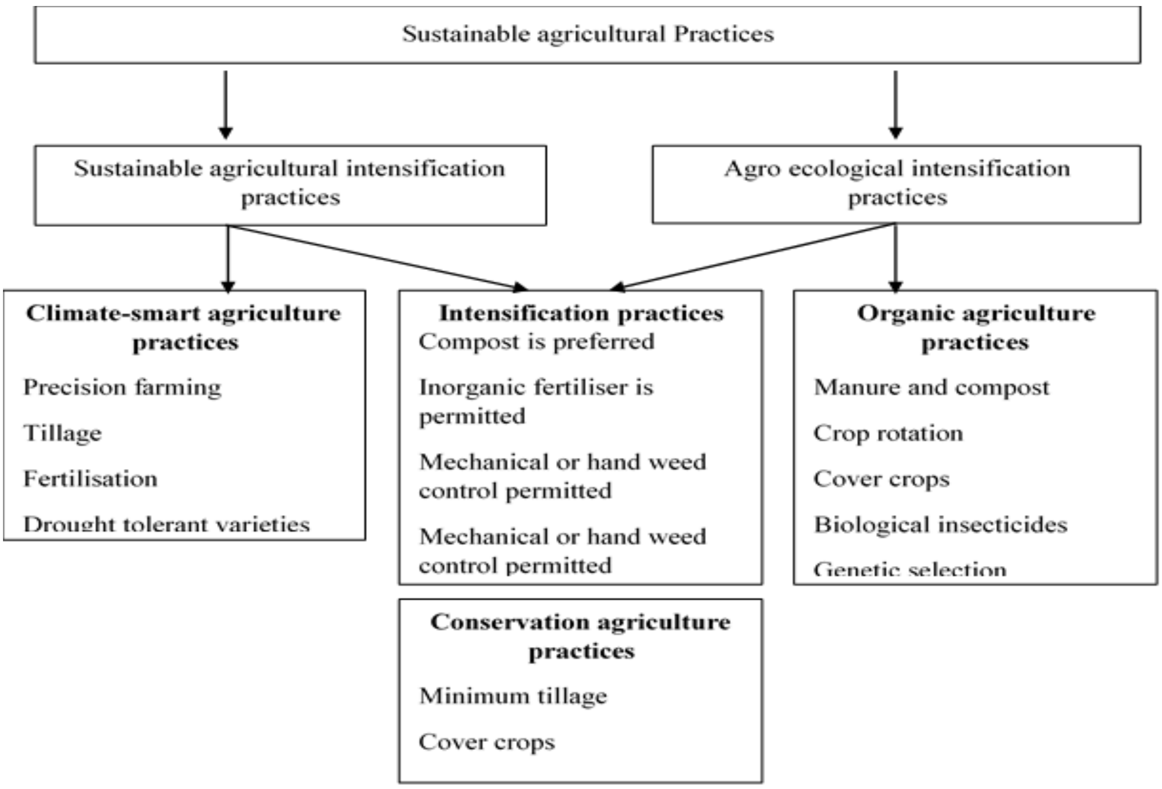
[1] The idea behind the SG 2000 and BFCP projects was to support farmers with credit in the form of mechanization Services certified improved seed, fertilizer herbicide and pesticides as well as extension services. The credit was to be paid either in kind or in cash after harvest. The objective was to encourage farmers to expand their farms and thereby enjoy economies of scale. While the SG 2000 started in the year 2000, the BFCP was launched in 2009.

diversifying the types of crops grown so that if some fail the farmer does not lose out completely. Agricultural development can also be attained through the diffusion of new knowledge across societies and countries. New technologies and knowledge can be transferred from their places of origin to new areas thereby increasing productivity. This means that the role of agricultural extension is crucial in making the transfer of such technologies and knowledge successful. The high pay-offs is a more recent agricultural development theory which builds on the earlier models but adds that the process of agricultural development can be accelerated through provision of new and improved inputs and technologies.

Population growth and the onset of climate change and variability have necessitated the adoption of new and improved technologies to avert or minimise their impacts on smallholder agriculture. This brings to the fore the concepts of sustainable agricultural practices.

Adnan and Nordin (2018) defined sustainable agriculture (SA) as an integrated system of crop production practices having a site-specific application over the long term. They identified the following as the components of SA: ensuring safe human food and fibre needs; making the most efficient use of non-renewable resources and on-farm resources and integrate, where applicable in a natural way; sustaining the economic viability of farm operations; and enhancing the quality of life for farmers and society as a whole.

Mockshell and Kamanda (2018) have done a review of the literature on SA pathways, involving detailed definitions of the concepts. They identified two broad categories of SAPs as sustainable agricultural intensification (SAI) and Agro ecological intensification (AEI) (see Figure 1). SAI also comprises climate smart agricultural practices and intensification practices. While climate smart agricultural practices include precision farming, tillage, fertilisation and drought tolerant varieties, intensification practices comprise composting, application of inorganic fertilisers, mechanical or hand weed control and transplanting of seedlings. In the same vein, AEI consists of intensification practices and organic agricultural practices. The latter involves adoption of manure and compost, crop rotation, cover crops, biological insecticides and genetic selection. Conservation agriculture (CA) which also comprises minimum tillage, cover crops and crop rotation can be classified under both SAI and AEI.



Source: Adapted from Mockshell and Kamanda (2018)

Figure 1 Sustainable Agricultural Practices

One of the crucial resources that are necessary, if smallholder farmers are to be able to adopt SAPs is agricultural credit. Adegeye and Dittoh (1985) defined credit as the process of obtaining control over the use of money, goods and services in the present in exchange for a promise to repay at a future date. Norton et al (2010) observed that access to credit becomes crucial as a developing country moves from traditional to modern agriculture. Credit helps farmers to purchase inputs such as machinery, seeds, fertilisers and chemicals. It also enables farmers to better manage risks since they can borrow during bad years and pay back the loans during favourable years. Norton et al (2010) stressed that without widespread access to credit, inputs associated with improved technologies can be purchased only by wealthier farmers. In this case capital formation and improvements on smaller farms can be hampered as it happened with the first Green revolution (Todaro and Smith, 2003). In recent times, however, misappropriation of (cash) credit has meant that credit institutions prefer to give non-cash input credit, such as seeds, tractor services, fertilisers and insecticides. Also, against the backdrop of smallholder farmers' inability to provide collateral securities, group lending has been adopted as a way of guarantee for repayment.

Rogers (2003) defined adoption as the extent to which recipients of a new technology or innovation use it. However, diffusion is when the use of the technology spreads in the community or society among many users. In this case, while adoption involves individual farmers, diffusion involves several farmers in the community or country. Adoption may be seen to be synonymous with adaptation. Wall and Smit (2005) observed that the history of agriculture reflects a series of adaptations to a wide range of factors from both within and without agricultural systems

While a significant body of research exists to assess the adoption of innovations (Rogers, 2003) and conservation practices in agriculture (Prokopy et al, 2008), growing research seeks to understand what drives the adoption of SAPs among farmers (Barnes and Toma, 2012; Arbuckle et al, 2013a, b; Wood et al, 2014). This is because an important condition for increasing the adaptive capacity of agriculture is a better understanding of the drivers and barriers for SAPs' adoption (Howden et al, 2007). The section that follows gives a brief review of some of the coping and adaptation strategies adopted in the study areas.

A Review of Some Sustainable Agricultural Practices

Crop rotation is the cultivation of more than one crop on the same area in a sequence. The crop sequence can differ based on the existing condition, the choices available, the knowledge level of the farmer and possible trade-offs producers face (Chongtham et al., 2016). The objective is to ensure that not only one form or one set of nutrients are used on the soil. Crop rotation is essential for enhancing the quality of the soil and improving crop output. He et al. (2008) and Chongtham et al. (2016) reviewed that crop rotation is a sustainable agricultural technology that sustains and improves the physical properties of the soil. Crop rotation is very essential in organic farming than conventional farming since the use of inorganic fertiliser in the former is minimal or zero, considering the recent consumer choice for organic products, crop rotation must be promoted.

Intercropping or mixed cropping involves the cultivation of two or more crops in proximity. It is a crop companion strategy of growing one crop alongside another. It is a strategy that is used by most subsistence farmers. Appropriate selection of the companion crop is important to improve or maintain the soil nutrient (Akter et al., 2004). In most cases, this involves the intercropping of legume with cereal based crops. Ram et al. (1963) in Akter et al.(2004) opined that mixed cropping provides additional income from the companion crop, insures the main crop against failure and suppresses the weeds if the companion crop grows faster.

Fallowing is the deliberate act of allowing a piece of land to lie uncultivated for a season or more. Therefore, a fallow land is one that is not cultivated for a period. The objective of fallowing of land is to allow the land regain its physical and chemical properties naturally.

Pesticides/Insecticides are synthetic chemicals used in controlling pests. They are used to supress plant and animal pests and protect agricultural production and products from the farm (Sitaramaraju et al., 2014). The manufacture and use of pesticides in crop production has consistently increased over the years. Besides the negative effects of pesticides on soil and water contamination, human health and soil organisms(Sitaramaraju et al., 2014; Sande et al., 2011; Sabur and Molla, 2001), pesticides eliminate pests thereby leading to higher yields. Therefore, to offset these negative effects and obtain higher benefits, effective usage of appropriate pesticides is appropriate. Cooper and Dobson (2007) outlined a number of benefits from the use of pesticides including improvement in crop and livestock yields, improved food safety, human health and quality of life.

Integrated pest management (IPM) involves the bundle of technologies used in controlling pests and diseases on farms. Therefore, IPM involves the use of individual strategies such as chemical, manual or mechanical strategies. The objective of IPM is to control pests beyond levels that can cause economic injury to the crops. The strategy is important in biodiversity management and sustainable production. Empirical evidence (e.g. Thomas et al. 1990) suggests that the adoption of IPM leads to improved yields.

Soil and water conservation (SWC) practices are production strategies aimed at maintaining soil quality and avoiding land degradation, soil erosion and nutrient depletion. The unsuccessful outcome from SWC strategies is due to faulty adoption by farmers. SWC is important in preventing soil erosion, thereby improving upon the productivity of the land. The challenge to the adoption of SWC practices, however is land insecurity. That is to say that farmers are motivated to embark on long term improvement of the fertility of the soil when they have permanent ownership or entitlement of the land (Bewket, 2007).

Conservation agriculture (CA), is quite broader than SWC. The general principles underlying CA are minimal soil disturbance, soil cover and crop rotation. According to Erenstein et al (2012), these are very essential for sustainable agriculture and can produce averagely 50% of yields higher than in conventional production systems.

Minimum and zero tillage involves the cultivation of the soil with minimal disturbance from ploughing or tillage. The opposite is excessive and intensive tillage of the soil which results in loss of crop residue, organic matter and predisposition of the soil to sun burns (Arshad et al., 1990). No-tilled soil has approximately 26% of carbon and nitrogen more than tilled soils (Erenstein et al., 2012). As cropping intensity or tillage increases, the properties of the soil declines, hence, the decline in yields (Johansen et al., 2012).

Green manuring is the ploughing of plant tissues into the soil. It is a method used in organic production. Green manure is obtained by leaving crop debris on the field or deliberately cultivating green crops, especially, leguminous crops into the soil. Aside soil nutrient enrichment, green manuring also prevents soil erosion and efficiently regulates soil water. The method improves economic viability of agriculture while reducing environmental impacts from the sector (Cherr et al., 2006).

Integrated nutrient management (INM) involves the improvement in soil nutrient through a combination of different methods. It includes combination of inorganic fertilisers, compost, crop rotation and green manure (Odendo et al., 2009). The aim in integrated nutrient management is to ensure that natural and manmade nutrient sources are used together to promote crop yields in an efficient and environmentally sustainable manner (IFPRI, 2000).. Mohanty et al. (2015) estimated that integrated nutrient use leads to proper root development, higher yields and efficient water usage. Cited in Vanlauwe et al. (2015), Vanlauwe et al. (2001) argued that the combined use of organic and inorganic fertilisers is justifiable on grounds that the two fertiliser sources are not in constant supply, they differ in nutrient compositions and besides, positive gains have been observed from the combination.

Breaking had pan involves the physical loosening of the soil due to soil compaction. Soil compaction occurs when the soil particles are closely tight together, reducing pore space. It is the outcome from increased mechanisation, intensive agriculture, low use of organic fertiliser but high inorganic fertiliser usage and continuous ploughing (Amanullah et al., 2010). Soil compaction affects water infiltration, air percolation, seed emergence, root development and ultimately, decline in crop yield. Therefore, reducing soil compaction through deep tillage is vital for crop production. Mohanty et al. (2015) recommended the adoption of subsoiling annually in order to maintain the productivity of the soil.

Agroforestry is the practice of growing trees or shrubs alongside crops. The goal is to create diverse, ecologically sound and sustainable use of land. The Organic Research Centre (2010) outlined several benefits of agroforestry from productivity, environmental to socioeconomic benefits. The environmental benefits can be classified into carbon sequestration, biodiversity conservation, soil enrichment and air and water quality improvement

(Jose, 2009). Mbow et al. (2013) also stated that agroforestry has the potential to positively influence food security, adaptation and mitigation to climate change in order to preserve environmental resources of Africa's rural landscape.

Methodology

Theoretical model

The theoretical model of the study is the Endogenous Poisson model.

Following Terza (1998) and Miranda (2004), consider the ith household from a random sample $I = \{1.....n\}$. Conditional on a vector of explanatory variables x_i, an endogenous dummy c_i, and a random term ε_i, the dependent variable y_i, which is a count-is supposed to a follow a standard Poisson distribution

$$f(y_i/\varepsilon_i) = \frac{\exp\{-\exp(x_i'\beta + \gamma c_i + \varepsilon_i)\}\{\exp(x_i'\beta + \gamma c_i + \varepsilon_i)\}^{y_i}}{y_i!} \quad (1)$$

where β and γ are coefficient to be estimated. Note that the error term ε_i measures omitted and unobserved variables as well as any measurement error. Given a vector of explanatory variables z_i (which may contain some or all elements of x_i), c_i is characterised by an index process

$$c_i = \begin{cases} 1 & if\ z_i\alpha + v_i > 0 \\ 0 & otherwise \end{cases} \quad (2)$$

Where α is a vector of coefficient to be estimated. Suppose that w_i represent all exogenous variables and ε_i and v_i are jointly normal with mean zero and covariance matrix $\sum = \begin{pmatrix} \sigma^2 & \sigma p \\ \sigma p & 1 \end{pmatrix}$, given that ε_i, c_i and y_i are independent. Hence, the joint conditional probability density function of y_i and c_i, given w_i, can be written as

$$f(y_i, c_i/w_i) = \int_{-\infty}^{\infty} \{c_i f(y_i/c_i = 1, w_i, \varepsilon_i)\Pr(c_i = 1/w_i, \varepsilon_i) + (1-c_i) f((y_1/c_1 = 0, w_i, \varepsilon_i))\Pr(c_i = 0/w_i, \varepsilon_i)\} f(\varepsilon_i) c_i \varepsilon_i \quad (3)$$

where $f(\varepsilon_i)$ denotes the probability density function for the random term ε_i.

Empirical Model

Given equation 1 above, the dependent variable (y_i) of this study is the number of SAPs that a farm household adopts. It is a count variable, and therefore, follows the poisson distribution. This is hypothesised to be determined by agricultural credit input (c_i) as well as some demographic and institutional variables (x_i). C_i is also influenced by some demographic and institutional variables, which, for the purposes of clarity is represented by z_i. Clearly, there may be some unobserved variables that determine both y_i and c_i such that if we estimate the equations for the two variables separately, we may not be able to measure the true effect of c_i and other variables on y_i. For example, innovativeness, on the part of a farm manager, may mean that that household would adopt a SAP. At the same time this quality may lead him/her to access credit. In this case, it becomes difficult to separate the effect of the farm manager's innovativeness on his/her adoption behaviour from the effect of credit access on adoption. In other words, if per chance, after the estimation of the two equations separately, if we find that adoption has impacted significantly on adoption, how do we know whether it is the credit or the farmer's innovativeness that is responsible? Terza's (1998) and Miranda's (2004) models offer a solution like that of Heckman's (1979) Treatment effect model that corrects for selectivity bias problems in some simultaneous equation models. It should however, be noted, that it is not automatic that there is endogeneity between credit access and adoption. Miranda (2004) has given a good illustration of the test that shows whether the selection variable (credit in this study) is endogenous or exogenous. Either way, Miranda (2004) suggested estimation packages that are similar but not exactly, the same (see Miranda, 2004; pp 45&46). The empirical model to be estimated to measure the effect of agricultural credit input on the adoption of CAS is given as follows:

$$\begin{aligned} Credit &= \alpha_0 + \alpha_1 SexFM + \alpha_2 AgeFM + \alpha_2 EducFM + \alpha_3 Credit + \alpha_4 Gext + \alpha_5 NGOext \\ &\quad + \alpha_6 FBO + \beta_7 LandT + \alpha_8 NonFarm + V_i \end{aligned} \qquad (4)$$

$$\begin{aligned} CAS &= \beta_0 + \beta_1 SexFM + \beta_2 AgeFM + \beta_2 EducFM + \beta_3 Credit + \beta_4 Gext + \beta_5 NGOext \\ &\quad + \beta_6 FBO + \beta_7 AHsize + \beta_8 NonFarm + \beta_9 Exchlabour + \varepsilon_i \end{aligned} \qquad (5)$$

The variables are defied in Table 1 with their a priori expectations,
equations 4 and 5 are estimated by Full Maximum likelihood estimation in Stata version 15.

Data Source and Sampling Procedure

The data for the study is Afrint II in SSA. It was collected between 2007 and 2010[2]. This follows Afrnt I which was collected between 2001 and 2004. Afrint II is also known as the Afrint 2008 data set. It covers nine (9) African countries, namely; Ghana, Kenya, Malawi, Nigeria, Tanzanian, Ethiopia, Mozambique, Uganda and Zambia. These countries were selected because they had chalked some successes in agricultural intensification at the individual farmer or state levels, like the Green revolution in Asia. These countries were also relatively less constrained in accessing productive resources. Thus, the countries were purposively selected. The purposive sampling techniques was not only employed in the first stage of the sampling procedure, both the second and third also followed the same technique of sampling. Thus after the countries were selected, the regions in the various countries as well as the villages in the regions were also purposively selected based on their agricultural potentials. The last stage, which was the selection of the households involved simple random sampling based on the listing of all households in the village.

In addition to household questionnaire, some key informant interviews (involving community leaders and extension agents) and focus group discussions (also involving women) were also held at the community level. The total sample size was about 3,000 and the total number of SAPs were 18 adopted at various levels by the farm households. These are as follows: Crop rotation; Intercropping with nitrogen fixing crops (beans etc); Fallowing; Improved fallowing; Animal manure; Zero or minimum tillage; Breaking the hard pan; Soil and water conservation (level bunds, grass strips, terracing etc); Improved planting practices; Integrated (soil) Nutrient Management (INM); Integrated Pest Management (IPM); Agroforestry; Pesticides/herbicides; Rain water harvesting; and Irrigation.

Table 1: Definition of variables and *a priori* expectations

Variable	Definition	Expected sign	
		Credit	Adoption
Sex of Farm Manager	Dummy: 1 for male and 0 for female	+	+
Age of Farm Manager	The total number of years	+	-
Education of Farm Manager	The total number of years of formal education	+	+
Gov't Extension	Dummy: 1 for yes and 0 for never	+	+
NGO Extension	Dummy: 1 for yes and 0 for never	+	+
FBO Membership	Dummy: 1 for yes and 0 for no	+	+

[2] The author has heard of Afrint III. Unfortunately, all attempts to access it have proven futile. However, it is hoped that though the figures may change the patterns of access to credit and adoption of the SAPs may not have changed significantly.

Active Household Members	Total number of household members working on farm manager's farm	N/A	+
Adult Non-Farm Employees	Total number of household members engaged in non-farm employment	N/A	+/-
Exchange Labour	Dummy: 1 if farm manager engaged exchange labour in the farming season and 0 otherwise	N/A	+
Land Tittle	Dummy: 1 if a farm manager's plot has a title and 0 otherwise	+	N/A
Agricultural Input Credit	Dummy: 1 if a farm manager accessed input credit in the farming season under review and 0 otherwise	N/A	+
Coping and Adaptation Strategies	No. of coping and adaptation strategies adopted by the farm manager in the farm season under review	N/A	N/A

Results and Discussion

The descriptive statistics of the variables are contained in Table 2. We find that 77% of the respondents are male. The respondents' average age is also 47.8 and the average number of years spent on formal education is five. This means that in general, the educational level of respondents is at the primary level. While 69% of the respondents received extension advice from government staff, 40%% received same from NGO staff and 30% belonged to FBOs. Similarly, while 29% of the respondents had titles to their farm plots only 17% had access to agricultural inputs. The average number of active household members was 3.7. However, on average, the number of adults engaged in non-farm activities was very low (less than 1), while 30% of the respondents engaged exchange labour on their farms.

Table 2 Descriptive Statistics of variables

Variable	Obs	Mean	Std.Dev.	Min	Max
Sex of farm manager	3793	.773	.419	0	1
Age of farm manager	3767	47.847	14.659	20	102
Education of farm manager	3763	5.011	4.216	0	30
Governmental extension advice	3792	.69	.744	0	1
NGO extension advice	3787	.396	.658	0	1
FBO membership	3782	.305	.46	0	1
Formal land title registration	3523	.286	.452	0	1
Agricultural input credit	3773	.168	.374	0	1
No of active household members	3773	3.699	2.659	0	28
Adult Non-Farm Employees	3181	.417	.974	0	13
Exchange labour	3757	.295	.456	0	1

Credit Access and Adoption levels

From Appendix 1, the country with the highest percentage of farmers who received credit was Ghana (15.08), followed by Ethiopia (12.59), Nigeria (11.45), Zambia (11.21) and Tanzania (10.60). The rest are Uganda (10.47), Malawi (10.36), Mozambique (10.28) and Kenya (7.95). Tiring in this with Appendix 2, we observe that Ghana also records the highest adoption level (14.93), followed by Ethiopia (12.65), Nigeria (11.39), Zambia (11.18), Mozambique (10.58), Tanzania (10.50) Uganda (10.45), Malawi (10.45) and Kenya (7.87). From the results, it appears there is a positive correlation between the percentages of credit received and the adopting levels of households.

Turning to Appendix 3, we observe the intensity of adoption vis-à-vis the percentage of adopters. We observe that the highest percentage of adopters (8.82) adopted 11 of the technologies followed by 8.22% who adopted 10 of the technologies. The third highest percentage of adopters (8.16%) adopted 12 technologies while the fourth and fifth highest percentages adopted 13 and 9 technologies respectively. The rest are as indicated in the table.

Credit Access and Other Socioeconomic Variables

The results in Table 3 indicate that farms managed by male farmers had greater access to credit than those managed by female farmers. This does not come as a surprise given that women in Africa are generally marginalised or discriminated against when it comes to agricultural resources (Donkoh, Abdulai and Ansah, 2016). Another category of farmers who had greater access were those with rights to their lands. However, credit access was relatively low for farmers with FBO membership and those who were engaged in non-farm activities. Detailed discussion of the determinants of access to agricultural input credit is in the latter part of the section that follows.

Table 3: Percentage distribution of Agricultural inputs across other socioeconomic variables

Category of respondent	Credit Access	
	Frequency	%
Female farm manager	862	22.73
Male farm manager	2,931	77.27
Total	**3,793**	**100.00**
No FBO membership	2630	69.05
FBO Memberships	1179	30.95
Total	**3809**	**100.00**
No land right	1254	32.92
With land right	2555	67.08
Total	**3809**	**100.00**
No non-farm adult participation	1914	64.40
With non-farm adult participation	1058	35.60
Total	**2972**	**100.00**

The factors influencing the adoption of sustainable agricultural practices

The main objective of the study was to investigate the effect of agricultural input credit on the adoption of sustainable agricultural practices. From the methodology section we noted that the estimation of Endogenous Poisson model would be most appropriate because it corrects for selectivity bias problems that may arise as a result of some observed and unobserved factors that may influence both credit access and the adoption of CAS. Following Terza (1998) and Miranda (2004), we estimated two set of equations; one assumed endogeneity of the credit variable while the other did not. In other words, the results in Table 4 panel A assumes that credit is an endogenous variable while in panel B, the assumption is that credit is exogenous. One of the main differences between the two sets of results is the *rho* variable in Panel A as opposed to Panel B. The *rho* tests for the correlation between the error terms of the credit and adoption equations. Its significance implies that the two errors were correlated, meaning that selectively bias problem was present in the model so that if it was not corrected the coefficients of the explanatory variables would be biased.

This leads us to the comparison of the two sets of results. It is clear that the coefficient of agricultural credit variable is higher in the endogenous switching model results (Panel A) than the exogenous switching model results (Panel B). Thus in Panel A, once the selectivity bias problem has been corrected, the true impact of the selection variable (agricultural credit) is realised. Also, it is observed that, in general, the coefficients in Panel A are slightly lower than those in Panel B. Thus the results in Panel A are preferred to those in B because in Panel A selectivity bias has been corrected for. Being a poisson (count) model, the coefficients are relevant as opposed to the other limited dependent variable models (e.g. probit/logit) in which the marginal effects are crucial (Greene, 2003).

From the first part of Panel A, all the factors, except adult non-farm employment are significant maintaining their expected signs. Furthermore, among the significant factors it is government extension advice and exchange labour that are significant at 5%; the rest are all significant at 1%. The coefficient of the agricultural credit variable is positive indicating that farmers who accessed agricultural input credit during the year under review had a higher probability of adopting the practices than those who did not access credit. This is a very important finding which meets our *a priori* expectations. Also, contrary to the findings of many studies (e.g. Assan et al, 2018; Sheahan and Barret, 2017; Manda et al, 2015)). sex of the farm manager has a negative sign, indicating that farms whose managers were female had a high probability of adopting the sustainable practices than their male counterparts. However, the positive coefficient of the age of the farm manager indicates that farms managed by the old had a higher probability of adoption than those managed by the relatively young persons. Similarly, farms managed by those with formal education tended to adopt more of the practices than those managed by those without formal education. Both extension from government and NGOs also went a long way to increase the probability of adopting SAPs. This also does not come as a surprise because extension officers do not only recommend sustainable practices to farmers, they offer them useful advice relative to the sources and uses of the practices. In Manda et al. (2015) also, formal education and access to extension staff positively influenced adoption of SAPs in rural Zambia.

FBO membership plays a similar role in the sense that sustainable agricultural practices are sometimes also introduced to farmers through the association in the same way that the individual farmers learn the adoption of such practices from one another. Generally, the adoption of agricultural practices requires extra labour because some of the practices such as SWC techniques are labour intensive. In this case, household labour may not be enough; farmers would have to depend on exchange labour (locally called “nnoboa”) as a complementary resource to the household labour. We observe that the findings of the current study are at sync with that of similar studies (e.g. Assan et al, 2018; Sheahan and Barret, 2017; Azumah et al, 2016).

Turning to the results relating to the determinants of credit access in the second part of Table 4, we observe that all the variables are significant. While age and government extension are significant at 5%, the sex variable is significant at 10%. The rest of the variables are all significant 1%. While in the first part, the results indicate that farms managed by the relatively old had a higher probability of adoption, the results show that these category of farms had a lower probability of accessing credit compared with those managed by the young. On the other hand, while the farmers that accessed government extension services had a higher probability of accessing credit, those that accessed extension services from NGOs had a lower access to credit. Perhaps, the services from government extension staff were tied to input credit as opposed to the ones from NGOs. A case in point is the Block Credit programme where agricultural inputs are sold on credit to farmers through the agricultural extension officers (Donkoh, Abdulai and Ansah, 2016).

Similarly, FBO membership increased the probability of accessing credit by farming households, just as it increased their probability of adopting the farm practices. One important finding from the study is the fact that land title ownership increased farmers’ access to finance. This is understandable, given that titled land may be used as collateral in securing loans. This is in contrast with households whose members were engaged in non-farm employments.

Such farmers were not as cash-constrained as those who were not engaged in non-farm employments, and therefore did not require agricultural credit.

Table 4: Full Maximum Likelihood Estimation of the effect of Credit on the adoption of Coping and Adaptation strategies in SSA

	Panel A		Panel B	
Variable	**Coefficient**	**Standard Error**	**Coefficient**	**Standard Error**
Practices (SAPs)				
Sex	-0.1250***	0.0248	-0.1188***	0.0237
Age	0.0027***	0.0007	0.0023***	0.0007
Educational level	0.0282***	0.0023	0.0290***	0.0024
Agricultural input credit	0.6174***	0.0492	0.1337***	0.0254
Government extension advice	0.0377**	0.0167	0.0563***	0.0156
NGO extension advice	0.0712***	0.0188	0.0479***	0.0175
FBO membership	0.0744***	0.0261	0.2062***	0.0230
Active household members	0.0096***	0.0036	0.0119***	0.0036
Adult non-farm employment	-0.0177	0.0108	-0.0285***	0.0103
Exchange labour	0.0539**	0.0216	0.0645***	0.0217
Constant	1.3737***	0.0444	1.4181***	0.0425
Switch (Credit)				
Sex	0.0744	0.0732	0.1016	0.0759
Age	-0.0050**	0.0020	-0.0065***	0.0020
Government extension advice	0.1094**	0.0468	0.1455***	0.0469
NGO extension advice	-0.1402***	0.0497	-0.1716***	0.0502
FBO membership	1.0272***	0.0626	1.0394***	0.0631
Land title ownership	0.7014***	0.0554	0.6746***	0.0599
Adult non-farm employment	-0.1193***	0.0354	-0.1236***	0.0367
Constant	-1.4013***	0.1187	-1.3678***	0.1212
Sigma	0.3713***	0.0130	0.3303***	0.0108
Rho	-0.7744***	0.0503		
	Number of observations = 2982 Wald chi2(10) = 655.57 Prob > chi2 = 0.0000 Log likelihood = -8808.9055		Number of observations = 2982 Wald chi2(10) = 606.00 Prob > chi2 = 0.0000 Log likelihood = -8831.8413	

*** and **, significance at 1% and 5%, respectively

The coefficients of the credit model are also marginal effects.

Conclusions and Recommendations

From the findings, the following conclusions can be drawn. First, agricultural credit input is important in enhancing the adoption of SAPs in SSA. Second, while both government and NGO extension services impact positively on the adoption of SAPs, the former also facilitates credit access, suggesting that government extension services offered in the adoption of SAPs was tied to credit access. Other variables relevant in enhancing adoption were education, FBO membership, active household labour force as well as exchange labour. Other variables relevant to credit access were FBO membership and land title ownership. The issue of gender is crucial; while farms managed by women have higher probability of adoption, they rather have less probability of accessing credit than those managed by men. The implication of this is that women are often discriminated against in terms of accessing farm resources including credit. However, if they get the financial resources, they are able to adopt the technologies needed to expand their output. In terms of methodology, the correction for selectivity bias using Terza's (1998) and Miranda's (2004) models is relatively uncommon, to the best of the author's knowledge.

Farmers' input credit schemes must be stepped up by both government and private organisation if they are to increase their adoption of SAP. Programmes like the Sasakawa Global 2000 and the Block Farm Credit must be re-introduced and well managed for a greater and more sustainable impact. This must come with good extension services and strong FBO membership drive and exchange labour force. Lastly, while both categories of farmers must be supported, women farmers must be given priority in any agenda to scale up the adoption of SAP. Relative to the methodology, a panel study is recommended.

References

Adegeye A. J and Dittoh J. S. (1985). ***Essentials of Agricultural Economics***. Ibadan: Impact Publishers Nigeria Ltd.

Akter, N., Alim, M. A., Islam, M. M., Naher, Z., Rahman, M., and Hossain, A. S. M. I. (2004). Evaluation of mixed and intercropping of lentil and wheat. ***Journal of Agronomy***, *3*(1): 48–51.

Alliance for a green revolution in Africa (AGRA) (2014) Africa Agriculture Status report:

Climate change and smallholder agriculture in sub-Saharan Africa. Nairobi, Kenya.Issue no. 2

Amanullah, M. M., Srikanth, M., and Muthukrishnan, P. (2010). Soil compaction and deep tilllage-a review. ***Agricultural Review***, *31*(2): 105–112.

Arshad, M. A., Schsitzer, M., Angers, D. A., and Ripmeester, J. A. (1990). Effects of till vs no-till on the quality of soil organic matter. ***Soil Biology and Biochemistry***, *22*(5): 595–599.

Assan, E., Suvedi M, Olabisi, L.S and Allen, A. (2018) Coping with and Adapting to ClimateChange: A Gender Perspective from Smallholder Farming in Ghana ***Environments***, 5: 86.

Azumah, S.B, Donkoh, S.A., Ansah, I.G.K (2016) Contract farming and the adoption of climate change coping and adaptation strategies in the northern region of Ghana, ***Environment, Development and Sustainability a Multidisciplinary Approach to the Theory and Practice of Sustainable Development,*** 18 (4): 854-z pp

Bewket, W. (2007). Soil and water conservation intervention with conventional technologies in northwestern highlands of Ethiopia : Acceptance and adoption by farmers. ***Land Use Policy***, *24:* 404–416.

Cherr, C. M., Scholberg, J. M. S., and Mcsorley, R. (2006). Green Manure Approaches to Crop Production: A Synthesis. ***Agronomy Journal***, *98:* 302–319.

Chongtham, I. R., Bergkvist, G., Watson, C. A., Sandström, E., Bengtsson, J., and Öborn, I. (2016). Factors influencing crop rotation strategies on organic farms with different time periods since conversion to organic production. ***Biological Agriculture and Horticulture.*** https://doi.org/10.1080/01448765.2016.1174884

Cooper, J., and Dobson, H. (2007). The benefits of pesticides to mankind and the environment. ***Crop Protection***, 26*:* 1337–1348.

Donkoh, S.A., Abdulai, E. Setsoafia, E.D., and Ansah, I.G.K (2016). Participation and output effect of a Block Farm Credit Programme in selected districts of Northern Ghana, ***Agricultural Finance Review***, 76 (3): 348 - 361.

Erenstein, O., Sayre, K., Wall, P., Hellin, J., and Dixon, J. (2012). Conservation

Agriculture in Maize- and Wheat-Based Systems in the (Sub) tropics : Lessons from Adaptation Initiatives in South Asia , Mexico , and Southern Africa. ***Journal of Sustainable Agriculture,*** 36(2): 180–206.

Greene, W. H. (2003). ***Econometric analysis***. Upper Saddle River, New Jersey: Pearson Education, Inc.

He, X., Cao, H., and Li, F. (2008). Factors influencing the adoption of pasture crop rotation in the semiarid area of China â€™ s Loess Plateau. ***Journal of Sustainable Agriculture,*** *31*(1), 161–180.

Heckman, J. J. . (1979). Sample selection bias as a specification error. ***Econometrica***, *47*(1): 153–161.

IFPRI. (2000). ***Integrated Nutrient Management, Soil Fertility and Sustainable Agriculture : Current Issues and Future Challenges*** 32: 29 p.

Johansen, C., Haque, M. E., Bell, R. W., Thierfelder, C., and Esdaile, R. J. (2012). Field Crops Research Conservation agriculture for small holder rainfed farming : Opportunities and constraints of new mechanized seeding systems. ***Field Crops Research***, 132*:* 18–32.

Jose, S. (2009). Agroforestry for ecosystem services and environmental benefits : an overview. ***Agroforestry System*****,** 76, 1–10.

Manda, J., Alene, A.D, Gardebroek, C., Kassie, M and Tembo, G. (2014). ***Journal of Agricultural Economics.*** Doi:10.1111/1477-9552.12.12127. 1-24

Mbow, C., Noordwijk, M. Van, Luedeling, E., Neufeldt, H., Minang, P. A., and Kowero, G. (2013). Agroforestry solutions to address food security and climate change challenges in Africa. ***Current Opinion in Environmental Sustainability*****,** 6: 61–67.

Menozzi, D., Fioravanzi, M and Donati, M. (2015) Farmers' motivation to adopt sustainable agricultural practices. ***Bio-based and Applied Economics*** (4) (2): 125-147.

Mockshell, J and Kamanda, J. (2018). Beyond the agroecological and sustainable agricultural intensification debate: Is blended sustainability the way forward? ***International Journal of Agricultural Sustainability***, 16 (2): 127-149.

Mohanty, M., Bandyopadhyay, K. K., Painuli, D. K., Ghosh, P. K., Misra, A. K., and Hati, K. M. (2015). Water transmission characteristics of a Vertisol and water use efficiency of rainfed soybean (Glycine max (L .) Merr .) under subsoiling and manuring Water transmission characteristics of a Vertisol and water use efficiency of rainfed soybean (Glycine. ***Soil and Tillage Research***, *93:* 420–428. https://doi.org/10.1016/j.still.2006.06.002

Miranda, A (2004). FIML estimation of an endogenous switching model for count data. ***The Stata Journal*** 4(1): 40–49

Norton, G.W and Alwang, J, Masters W.A (2006) ***Economics of Agricultural Development World Ssystems and Resource Use,*** (2nd Ed.), London and New York: Routledge, Taylor and Francis Group

Odendo, M., Obare, G., and Salasya, B. (2009). Analysis of factors influencing the adoption of integrated soil nutrient management technology in western kenya. ***African Journal of Agricultural Research*****,** *4*(11): 1303–1311.

OECD/FAO (2015) OECD-FAO Agricultural Outlook 2016-2025, OECD Publishing, Paris. http:dx.doi.org/10.1787/agr-outlook-2016-en

Prokopy, L.S., Floress, K., Klotthor-Weinkauf, D., Baumgart-Getz, A., 2008. Determinants of agricultural best management practice adoption: evidence from the literature. Journal of Soil and Water Conservation 63 (5), 300e311.

Rogers, E.M. (2003). ***Diffusion of Innovations***, (5th Ed.). New York: Free Press.

Rosenzweig, C., Elliott, J., Deryng, D., Ruane, A.C., Müller, C., Arneth, A., Boote, K.J., Folberth, C., Glotter, M., Khabarov, N., Neumann, K., Piontek, F., Pugh, T.A.M., Schmid, E., Stehfest, E., Yang, H., Jones, J.W., (2013). Assessing agricultural risks of climate change in the 21st century in a global gridded crop model inter comparison. Proc.

Natl. Acad. Sci. U.S. A. 111, 3268–3273.
Rickards, L. and **Howden**, S.M. (**2012**) Transformational Adaptation Agriculture and Climate Change. *Crop and Pasture Science*, 63: 240-250.
Sabur, S. A., and Molla, A. R. (2001). Pesticide use, its impact on crop production and evaluation of IPM technologies in Bangladesh. ***Bangladesh Journal of Agricultural Economics***, *24* (1and2): 21–38.
Sande, D., Mullen, J., Wetzstein, M., and Houston, J. (2011). Environmental Impacts from Pesticide Use : A Case Study of Soil Fumigation in Florida Tomato Production. ***International Journal of Environmental Research on Public Health***, *8*: 4649–4661.
Simon, B.B, Garba, A. and Bunu, G.M (2013) Determinats of sustaibale agaricultural land management practices among Arable crop farmers in northern part of Taraba state, Nigeria. ***ARPN Journal of Science and Technology*.** 3 (7): 726-730.
Sitaramaraju, S., Prasad, N. V. V. S. D., Reddy, V. C., and Narayana, E. (2014). Impacts of pesticides used for crop production on the environment. ***Journal of Chemical and Pharmaceutical Sciences***, 3: 75–79.
Terza, J. (1998). Estimating count data models with endogenous switching: Sample selection and endogenous treatment effects. ***Journal of Econometrics,*** 84: 129–154.
Todarao, M., and Smith (2011) ***Economic Development***, (11th Ed.). England: Pearson Education Ltd
Thomas, J. K., Ladewig, H., and Mcintosh, W. A. (1990). The Adoption of Integrated Pest Management Practices Among Texas Cotton Growers. *Rural Sociology*, *55*(5), 395–410.
Vanlauwe, B., Descheemaeker, K., Giller, K. E., Huising, J., Merckx, R., Nziguheba, G., and Wendt, J. (2015). Integrated soil fertility management in sub-Saharan Africa : unravelling local adaptation. *Soil*, *1*, 491–508. https://doi.org/10.5194/soil-1-491-2015
Wall, E. and Smit, B (2005) Climate Change Adaptation in Light of Sustainable Agriculture ***Journal of Sustainable Agriculture***, 27(1): 113-123.

Appendix 1 Percentage distribution of countries with Access to Agricultural inputs

Country (c001)	Do you at present obtain any form of agricultural input credit?					
	No	%	Yes	%	Total	%
Ethiopia	250	6.63	225	5.96	475	12.59
Ghana	524	13.89	45	1.19	569	15.08
Kenya	210	5.57	90	2.39	300	7.95
Malawi	355	9.41	36	0.95	391	10.36
Nigeria	359	9.51	73	1.93	432	11.45
Tanzania	373	9.89	27	0.72	400	10.60
Uganda	343	9.09	52	1.38	395	10.47
Zambia	341	9.04	82	2.17	423	11.21
Mozambique	385	10.20	3	0.08	388	10.28
Total	3140	83.22	633	16.78	3773	100.00

Appendix 2: Percentage Distribution of Adoption levels of countries

Adop-tion	Country																			
	Ethiopia		Ghana		Kenya		Malawi		Nigeria		Tanzania		Uganda		Zambia		Mozambique		Total	
	Freq.	%	Freq.	%	Freq	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
0	7	0.18	1	0.03	0	0.00	0	0.00	25	0.66	13	0.34	7	0.18	4	0.10	8	0.21	65	1.71
1	0	0.00	0	0.00	1	0.03	0	0.00	13	0.34	17	0.45	0	0.00	3	0.08	18	0.47	52	1.36
2	0	0.00	0	0.00	2	0.05	0	0.00	20	0.52	9	0.24	2	0.05	0	0.00	28	0.73	61	1.60
3	0	0.00	1	0.03	3	0.08	1	0.03	41	1.08	16	0.42	8	0.21	10	0.26	42	1.10	122	3.20
4	0	0.00	6	0.16	6	0.16	0	0.00	43	1.13	14	0.37	9	0.24	25	0.66	64	1.68	167	4.38
5	1	0.03	8	0.21	7	0.18	1	0.03	41	1.08	14	0.37	12	0.31	22	0.58	66	1.73	172	4.51
6	8	0.21	42	1.10	8	0.21	0	0.00	31	0.81	18	0.47	19	0.50	22	0.58	55	1.15	203	5.33
7	24	0.63	49	1.29	14	0.37	1	0.03	38	1.00	33	0.87	26	0.68	12	0.31	44	1.15	241	6.33
8	29	0.76	76	1.99	12	0.31	5	0.13	46	1.21	35	0.92	28	0.73	17	0.45	24	0.63	272	7.14
9	48	1.26	82	2.15	11	0.29	12	0.31	43	1.13	34	0.89	39	1.02	20	0.52	11	0.29	300	7.87
10	83	2.18	79	2.07	7	0.18	9	0.24	25	0.66	38	1.00	32	0.84	23	0.60	17	0.45	313	8.22

11	107	2.81	63	1.65	13	0.34	17	0.45	26	0.68	45	1.18	33	0.87	27	0.71	5	0.13	336	8.82
12	84	2.20	48	1.26	14	0.37	24	0.63	9	0.24	40	1.05	40	1.05	46	1.21	6	0.16	311	8.16
13	70	1.84	26	0.68	19	0.50	36	0.94	12	0.31	37	0.97	62	1.63	37	0.97	4	0.10	303	7.95
14	20	0.52	29	0.76	16	0.42	67	1.76	14	0.37	23	0.60	37	0.97	39	1.02	5	0.13	250	6.56
15	1	0.03	24	0.63	8	0.21	82	2.15	6	0.16	2	0.05	22	0.58	27	0.71	4	0.10	176	4.62
16	0	0.00	29	0.76	34	0.89	84	2.20	1	0.03	7	0.18	10	0.26	32	0.84	0	0.00	197	5.17
17	0	0.00	4	0.10	29	0.76	59	1.55	0	0.00	4	0.10	8	0.21	30	0.79	2	0.05	136	3.57
18	0	0.00	2	0.05	96	2.52	0	0.00	0	0.00	1	0.03	4	0.10	30	0.79	0	0.00	133	3.49
Total	**482**	**12.65**	**569**	**14.93**	**300**	**7.87**	**398**	**10.45**	**434**	**11.39**	**400**	**10.50**	**398**	**10.45**	**426**	**11.18**	**403**	**10.58**	**3810**	**100.00**

Appendix 3 Percentage Distribution of Adoption type by countries

Practice	Ethiopia		Ghana		Kenya		Malawi		Nigeria		Tanzania		Uganda		Zambia		Mozambique		Total	
	Yes	%	Yes	%	Yes	%	Yes	%	Yes	%	Yes	%	Yes	%	Yes	%	Yes	%	Yes	%
Crop rotation	474	12.82	294	7.95	225	6.09	365	9.88	130	3.52	263	7.12	384	10.39	403	10.90	238	6.44	2776	75.11
Intercropping	318	8.40	560	14.80	299	7.90	394	10.41	308	8.14	315	8.32	378	9.99	316	8.35	349	9.22	3237	85.52
Intercropping with nitrogen fixing crops (beans etc.)	104	2.75	372	9.83	286	7.56	371	9.80	292	7.72	220	5.81	373	9.86	286	7.56	319	8.43	2623	69.32
Fallowing	423	11.21	358	9.49	255	6.76	338	8.96	198	5.25	227	6.02	323	8.56	375	9.94	220	5.83	2717	72.03
Improved fallowing	15	0.40	36	0.95	118	3.12	305	8.07	222	5.87	74	1.96	28	0.74	179	4.73	20	0.53	997	26.37
Animal manure	464	12.31	504	13.37	295	7.82	391	10.37	184	4.88	280	7.43	310	8.22	336	8.91	156	4.14	2920	77.45
Zero or minimum tillage	23	0.61	451	11.95	167	4.42	272	7.21	158	4.19	282	7.47	65	1.72	290	7.68	90	2.38	1798	47.64
Breaking the hard pan	248	6.59	120	3.19	242	6.43	316	8.40	145	3.85	93	2.47	282	7.49	308	8.18	36	0.96	1790	47.57
Green manure/ compost/ residue	404	10.72	415	11.02	253	6.72	360	9.56	108	2.87	227	6.03	334	8.87	267	7.09	69	1.83	2437	64.69

incorporation																				
Chemical fertilizer	472	12.54	521	13.84	290	7.70	391	10.39	229	6.08	288	7.65	189	5.02	416	11.05	120	3.19	2916	77.47
Soil and water conservation (level bunds, grass strips, terracing etc.)	414	10.98	300	7.96	245	6.50	358	9.50	198	5.25	221	5.86	237	6.29	139	3.69	75	1.99	2187	58.03
Improved planting practices	79	2.10	471	12.52	181	4.81	390	10.37	89	2.37	254	6.75	283	7.52	346	9.20	145	3.85	2238	59.49
Integrated (soil) nutrient management (INM)	20	0.53	67	1.79	163	4.34	314	8.37	80	2.13	29	0.77	93	2.48	208	5.54	11	0.29	985	26.25
Integrated pest management (IPM)	163	4.33	41	1.09	174	4.62	32	0.85	29	0.77	46	1.22	139	3.69	143	3.80	14	0.37	781	20.75
Agroforestry	140	3.72	119	3.16	237	6.30	303	8.06	60	1.60	136	3.62	195	5.18	124	3.30	18	0.48	1332	35.42
Pesticides/ herbicides	470	12.51	464	12.35	257	6.84	320	8.52	174	4.63	286	7.61	205	5.46	272	7.24	72	1.92	2520	67.06
Rain water harvesting	407	10.80	209	5.54	220	5.84	111	2.94	183	4.85	49	1.30	215	5.70	136	3.61	54	1.43	1584	42.02
Irrigation	467	12.41	437	11.61	244	6.48	380	10.10	75	1.99	230	6.11	147	3.91	304	8.08	222	5.90	2506	66.58