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Sustainable Agricultural Practices in the Savannah Region of Ghana: Factors shaping Smallholder Adoption

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ABSTRACT

Global concerns have been expressed about climate change and its effects on human health and food security, particularly in developing nations like Ghana where agriculture depends primarily on the availability of rain. The low rate of adoption of Sustainable Agricultural Practices (SAPs), which aim to lessen the adverse consequences of climate change, raises concerns about the factors that shape adoption of SAPs in small-scale farming systems. This study uses cross-sectional data from 376 farming households in the East Gonja Municipality of Savannah Region, Ghana, to investigate factors that affect the adoption intensity of SAPs. The study used a variety of count data models, including Poisson, Negative Binomial, and Zero-Inflated Negative Binomial Regressions, to examine the robustness of the results. A diagnostic test to determine the suitability of the count data models revealed that the zero-inflated Poison model fit our data the best. The findings show that the adoption intensity of SAPs was significantly influenced by variables such as gender, engagement in non-farm income activity, land ownership, farm size, and membership of village saving and loans association (VSLA). The study suggests that, because VSLA enables farmers to obtain financing for SAPs, VSLA formation and facilitation should be strengthened to boost SAPs adoption. Farmers should also be encouraged to diversify their economic activity outside farming to generate additional revenue.

Keywords: *Adoption intensity, Sustainable Agricultural Practices, Village saving groups, Zero-inflated negative binomial*

Introduction

Agriculture is critical in promoting the growth and development of developing economies, particularly Ghana. Increased agricultural productivity translates into more food to feed the rising population, more revenue, and more raw materials for local industry and exports. Thus, increasing agricultural productivity is one of the most efficient methods to combat poverty, particularly in Third world nations (Mahama et al. 2020). An upsurge in agricultural output is necessary to achieve the Sustainable Development Goals (SDG), particularly goals one and two, which call for ending hunger and poverty, respectively. However, population growth, urbanization and climate change has resulted in a 22% decrease in agricultural land available per capita for crops and animal husbandry between 2000 and 2019 in the sub-Mediterranean area alone (FAO & FFI, 2022).

Resilience in agriculture is now at the center of agricultural policies around the world because of the climate-related shocks to agricultural productivity that farmers must deal with (Vera et al. 2017). Policymakers and other development stakeholders are increasingly motivated to support farmers' adoption of sustainable farming practices, especially smallholder farmers that will strengthen the agricultural and food systems. As a result of the dominance of conventional farming practices over the past few decades, food safety, human and animal health, and environmental concerns are now seriously threatened by problems like water contamination, soil pollution, biodiversity loss, degradation of land, water scarcity, and climate change (Alavaisha et al., 2019; Midingoyi et al., 2019; Ma and Wang, 2020; Yu et al., 2021; Yuan et al., 2021). In Savannah region, these concerns are a matter of national crisis. They produce a lot to contribute to the nation’s food basket yet face unprecedented challenges, especially floods (Dari et al., 2015). The effects of climate change impede agricultural production, farm revenue, food availability, and economic development, which has a negative impact on the poor, whose lives are dependent on agriculture (Setsoafia et al., 2022). Thus, to increase crop output, more eco-friendly materials and sustainable agricultural practices are required (FAO & FFI, 2022). A wide range of techniques that satisfy the requirements and expectations of farmers must be considered and implemented at various levels to achieve agricultural sustainability (Mahama et al., 2020), so that prolonged use will not lead to climate change that will constrain the future generation from sustaining agricultural productivity.

Agricultural sustainability is described as the management and maintenance of the natural resource base, as well as the orientation of technical and institutional change to assure the achievement and sustained satisfaction of human requirements for current and future generations (FAO, 1995; FAO, 2015). In addition to ecosystem health and human well-being, sustainable agriculture also addresses the economic, social, and environmental aspects of development. (HLPE, 2016). According to the World Bank (2020), sustainable agricultural practices (SAP) can be defined as agricultural practices that guarantee efficiency in the usage of natural resources at the same time mitigating the impacts of agriculture on the environment whilst supporting farmers adaptive capacity to climate change. In general, these practices include activities that have environmental, societal, and economic dimensions (Zeweld et al., 2017). Sustainable agriculture practices (SAPs) are therefore resource-saving, socially satisfactory, technically suitable, and economically efficient (FAO, 1995). Biological controls, new and improved livestock breeds, integrated pest management (IPM), legume crop rotations, diversified cropping, improved crop varieties, cropping systems, conservative soil, improved irrigation, drought tolerant crop varieties, green compost, legume intercropping, rotational grazing, conservation agriculture, agroforestry, laser land leveling, animal manure, and water conservation are some examples of sustainable agricultural practices (FAO, 2013; Van and Yapwattanaphun, 2015; Vanlauwe et al., 2015). The link between agriculture and the natural environment is key in sustaining high level of productivity for the present and future generations. Therefore, promotion and adoption of SAPs among smallholder farmers is vital if developing countries so desire to eliminate hunger and poverty while still dwelling in friendly ecosystem. Environmentally friendly farming practices have been shown to reduce greenhouse gas emissions by up to 20% in only one year (USAID, 2017). Previous studies such as (Agbenyo et al., 2022; Ma and Zheng, 2021; Li et al., 2020, Tong et al., 2019; Zhao et al., 2016) have asserted that friendly ecosystem farming practices adoption increases both household farm and off-farm income through increase in farm productivity. The adoption of better seed varieties, conservative soil techniques, fertilizer, and water conservation methods boosts farmers' revenue and food availability (Setsoafia et al., 2022). Midingoyi et al. (2019) also indicated that mango yields, and net profitability are positively impacted by the implementation of integrated pest management technologies.

The adoption rate is slower than anticipated despite all the information about SAPs' benefits on agricultural productivity and environmental sustainability, as well as the fact that SAPs provide a great opportunity to adjust to the effects of climate change while also reducing GHG emissions. However, smallholder farmers have not adopted SAPs at a high rate, which begs the issue of what variables might explain this adoption situation (Ehiakpor et al., 2021). This study aims to bridge the information gap by empirically exploring the variables that affect the level of SAP adoption among smallholder farmers in Savannah region and northern Ghana as a whole.

Brief literature review on determinants of adoption of SAPs

There is always plurality of causes especially in drawing causal inference such as adoption of SAPs, therefore there is no single factor that influences farmers' decision to adopt one or more SAPs. Factors such as farmer's demographic, institutional and community characteristics determine farmer's decision of SAPs adoption (Ehiakpor et al., 2021., Garcia and Krishna, 2021; Ma & Wang, 2022).

Previous research works (Pham et al., 2021; Yang et al., 2022; Olawuyi & Mushunje, 2019) have unveiled the determinants of farmers' adoption of sustainable agricultural practices. For instance, Ehiakpor et al. (2021) revealed that among Ghana's smallholder farmers, factors that positively and significantly influence SAPS adoption intensity include farm size, livestock owned, field demonstration participation, and financing access. Ma & Wang (2020) found that internet use, co-operative membership, remittances and environmental perception have significantly positive effect on SAPs adoption intensity while household head's gender have a negative significant effect on SAPs adoption intensity among farmers in China. Also, Pham et al. (2021) revealed that farm size, land tenure, farmers perception of land quality, gender of household head, household heads' educational level, farmer experience, household active labour, FBO/co-operative membership, off-farm income, livestock ownership among other variables are significant factors influencing farmer adoption levels of SAPs in Vietnam. In a study conducted in China, Yang et al. (2022) found that marital status, farmer experience, farm size, loan and risk preference were observed to have negative influence on adoption intensity of SAPs while age, labour force and personality of the farmer were observed to have a direct effect on SAPs intensity of adoption among banana farmers. Also, in study on determinants of sustainable agriculture in southwestern Nigeria, Olawuyi & Mushunje (2019) revealed that factors such as gender and social group membership negatively determine the adoption of conservative agriculture while farmer experience and frequency of extension visit positively affects conservative agriculture adoption.

In conclusion to this brief review of literature on determinants of SAPs, Garcia & Krishna (2021) in a review of 137 papers on adoption of sustainable intensive agriculture in the global south, found that access to information about farming appears to be a significant determinant of sustainable intensive agriculture in 64% of the sampled papers, follow by landholding with 55% significant appearance, farmers' age 53%, educational level 51%, the other significant determinants in the review study includes gender, credit access, input access, household size, market access.

Material and Methods

The study area, sampling and data collection techniques

Located in Ghana's Savanna Region's southeast, the East Gonja Municipality has a total land area of 8,340.10 square kilometers and a population of 117,755, of which 32,539 live in urban areas and 85,216 in rural ones (GSS, 2021). Guinea Savannah Woodland is the municipal's native vegetation, including a few small grooves that have survived the ages. The area around Volta Lake has abundant alluvial and loamy soils, which are generally classified as glysols. These soils are potentially rich in nutrients enough to support a wide range of crops, particularly the production of vegetables such as tomatoes, okra, lettuce, green pepper, pepper, etc. and crops such as rice, yams, maize, and other root crops.

For this study, cross-sectional data was collected from 376 agricultural households in the villages located in the East Gonja municipality of Ghana through primary data source. The data was collected using a multi-stage sampling strategy that included simple random sampling as well as stratified sampling. The municipality was simply chosen at random from a set of municipalities and districts in the Savannah region of Ghana. The municipality was divided into three zones, southern zone, middle zone and northern zone. Stratification helps to capture spatial heterogeneity, ensuring that data is not oversampled in one location while under-sampling in another. This ensures that most parts of the municipality are covered, improves data quality, and reduces sample bias. In the third phase, simple random sampling was applied to select 10 communities from each stratum or zone. Finally, 10 – 15 farming households were randomly selected from each community. The study had a total sample size of 376 farm households. A standardized questionnaire and in-person interviews were used to gather data.

Theoretical and conceptual frameworks

The study uses utility maximization theory as the primary theoretical framework for understanding adoption and intensity of adoption among smallholder farmers in the study area. This theory contends that smallholder farmers are rational and want to maximize their degree of satisfaction or utility from their own resources. Thus, farming households will intensify (adopt more SAPs) when the perceived benefits in terms of productivity and resulting farm revenue outweigh the risks and costs of adoption. Farmers who are risk-averse, for example, may be hesitant to increase their use of SAPs unless they are regarded as risk-reducing strategies that aim to minimize the challenges posed by climatic variability. Given that S^* is the difference in the level of satisfaction or utility for adopting and not adopting, U_A and U_N are utilities for adoption and non-adoption, respectively.

The utility maximization theory argues that a smallholder farmer will adopt if and only if $S^* = U_A - U_N > 0$, where U_A and U_N are latent variables that can be expressed as a function of farming household characteristics.

Considering the theoretical framework, the study's conceptual model hypothesized that farming households' decision to adopt, and intensity of adoption are influenced by their demographic characteristics (gender, age, educational attainment, farming experience, etc.), farm-related factors (farm size, distance from farm), and institutional factors (access to extension service, membership in farmer groups, among others).

Analytical strategy

To analyze factors that influence SAP adoption intensity, the dependent variable is specified as the number of SAPs adopted by the farmer. The number of SAPs considered in this study varies from 0 – 12, representing non-negative integer numbers. In this case, count data models such as Poisson or Negative Binomial regressions are appropriate (Cameron and Trivedi, 2013). The Poison regression is the most commonly used count data model when analyzing count data (Green, 2008). However, the appropriateness of the Poisson regression rests on the assumption of equi-dispersion. Thus, equal distribution of the variance and mean. When the variance is more than the mean, it's referred to as overdispersion and it's referred to as under-dispersion where the variance is less than the mean.

Aside from the Poisson model, negative binomial regression model can also be employed to evaluate count data (Hardin & Hilbe, 2014). In contrast to Poisson, negative binomial adds an additional term or parameter to change the mean and variance separately. The overdispersion of data is thus addressed by negative binomial regression model (Bauer, 2007). Negative binomial occasionally has too many zeros despite its ability to account for overdispersion. Running a negative binomial may produce inaccurate parameter estimates and biased standard errors if the actual zeros exceed the expected zeros. In various situations where there is excess zero counts, Zero-inflated count models, including zero-inflated Poisson (ZIP) and zero-inflated negative binomial (ZINB) are usually applied. When there are too many zeros, the ZIP is used; when there are too many zeros and too much data dispersion, the ZINB is applied. Our preliminary findings show that ZINB effectively matched our data and was used in this study; thus, the approach is explained below.

Let the response y_i denote a non-negative integer count (number of SAPs adopted) for the i^{th} observation, $i = 1, \cdots, N$, then the probability distribution of the ZINB random variable y_i can be expressed as;

$y_i = 0$ with probability p_i (1)

$y_i \approx negative\,binomial\,(\lambda_i, k)$ with probability $(1 - p_i)$

(2)

This implies:

$$\Pr(y_i = 0) = p_i + (1 - p_i)(1 + k\lambda_i)^{-\frac{1}{k}}$$

$$= (1 - p_i)\frac{\Gamma(y_i + \frac{1}{k})}{\Gamma(y_i + 1)\Gamma(\frac{1}{k})}\frac{(k\lambda)^{y_i}}{(1 + k\lambda)^{y_i + \frac{1}{k}}} \quad (3)$$

$y_i = 1, 2.......n$

$$E(y_i) = (1 - p_i)\lambda_i$$
$$V(y_i) = (1 - p_i)\lambda_i(1 + \lambda_i(p_i + k)) \quad (4)$$

$$V(y_i) = (1 - p_i)\lambda_i\big(1 + \lambda_i(p_i + k)\big) + e \quad (5)$$

Where $E(y_i)$ is the expected mean of the response, $V(y_i)$ is the variance, λ

measures the amount of dispersion, and the mean and variance of the ZINB is further represented by $(1-p_i)\lambda_i$.

Results and discussions

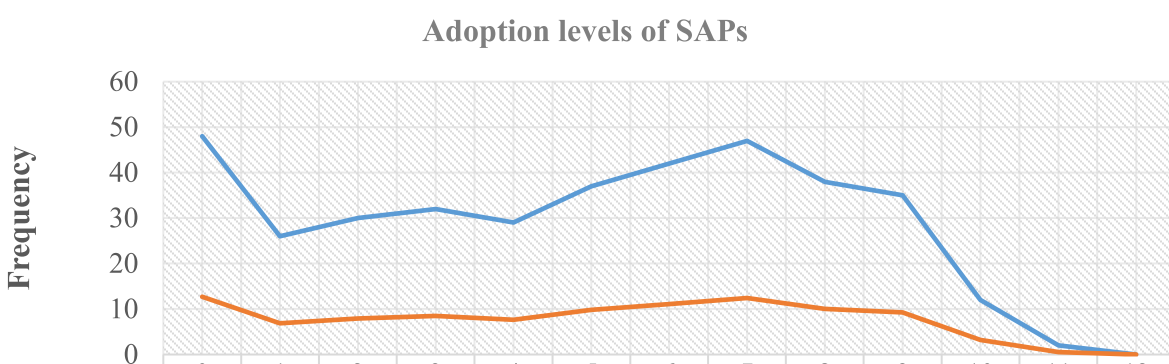
3.1 Descriptive statistics

In investigating the factors that determine SAPs adoption intensity measured as the quantity of SAPs adopted in the studied communities, 12 SAPs were considered. Each SAP is considered a binary where a farmer is asked to respond whether he/she practices the SAPs. The responses are coded 1 if Pest management (IPM), cover cropping, agroforestry, irrigation, drought tolerant crops, and a farmer adopts and 0 otherwise across all the SAPS. maize legume rotation, animal manure, Improved seed variety, legume intercropping, zero/minimum crop residue retention, tillage, integrated stone bund are the SAPs considered in this study.

The descriptive statistics of the various components of SAPs adopted by farmers are presented in Table 1. From the table, over 77% of the farmers practice crop residue retention which appears to be the most highly adopted SAPs, followed by maize legume rotation, legume intercropping, cover cropping and animal manure with 56%, 54%, 52% and 51% adoption rates, respectively. About 4.7% of the sampled farmers adopted stone bund, which is the least adopted practice in the study area. Improved seed variety has an adoption rate of 41% while zero/minimum tillage is practiced by 31% of the sampled farm households. Also, 26% practice IPM technology while 40% grow trees on their farms. In addition, about 18% of the farmers use irrigation technology while 30% adopt drought-tolerant crops.

Table 1 Description of SAPs components in the study

Description of SAPs variables	Mean	Std. Dev.
1 if the farmer uses improved seed variety, and 0 otherwise	0.413	0.493
1 if the farmer practice maize legume rotation, and 0 otherwise	0.561	0.497
1 if the farmer applies animal manure on farmland, and 0 otherwise	0.511	0.501
1 if legume intercropping is practice and 0 otherwise	0.540	0.499
1 if farmer retains crop residue on farmland after harvest, and 0 otherwise	0.778	0.416
1 if zero or minimum tillage is practice and 0 otherwise	0.315	0.465
1 if farmer adopts integrated Pest Management and 0 otherwise	0.265	0.442
1 if cover cropping is adopted and 0 otherwise	0.519	0.500
1 if the farmer adopted agroforestry and 0 otherwise	0.399	0.490
1 if irrigation technology is adopted and 0 otherwise	0.185	0.389
1 if farmer adopts drought tolerant crops and 0 otherwise	0.296	0.457
1 if stone bund is adopted and 0 otherwise	0.048	0.213



	0	1	2	3	4	5	6	7	8	9	10	11	12
Freq.	48	26	30	32	29	37	42	47	38	35	12	2	0
Percent	12.7	6.88	7.94	8.47	7.67	9.79	11.11	12.43	10.05	9.26	3.17	0.53	0

Figure 1: The distribution of adoption levels Sustainable Agricultural Practices

Table 2: Descriptive statistics of the variables

Variable	Definition	Mean	Std. Dev.
Adoption of SAPs	Number of SAPs adopted	4.828	3.062
Age	Age of household head in years	39.204	9.751
Sex	1 if household head is a male	0.937	0.244

Farmer experience	Number of years in crop farming	16.582	8.687
Landholding per active labor	Number of farmland(acreage) per household active labor	1.394	1.178
Off-farm Income	Income earned from other sources other than farming	1404.825	1508.388
Education (years)	Number of years in formal education	1.706	3.710
Extension contacts	Number of extension visits	2.447	2.909
FBO membership	1 If farmer is a member of FBO and 0 otherwise	0.603	0.490
Agric trainings	Number of agricultural trainings participated	1.098	1.024
Own land	1 if farmer owns farmland and 0 otherwise	0.611	0.488
Farm size	Size of household farmland measured in acres	4.427	1.524
Farm distance	Distance of farmland from homestead measured in kilometers	2.394	1.040
VSLA membership	1 if farmer participates in VSLA and 0 otherwise	0.500	0.501
Other training	Number of other training modules participated aside agricultural training	2.939	1.47

Figure 1 depicts the distribution of farm households' adoption levels in terms of the number of SAPs.

The figure shows that 48 farmers who make up 12.7% of the sampled population have adopted none of the 12 SAPs, while 47 farmers who make up 12.4% have adopted seven SAPs and 11.1% have adopted six of the SAPs components. Also, about 10% or 38 farmers used eight SAPs. Additionally, 9.8% and 9.3% of the survey's farmers adopted five and nine elements of the SAPs, respectively, whereas 8.5% and 7.9% adopted three and two elements, respectively. In addition, 29 farmers representing 7.7% and 37 farmers representing 7.8% each adopted five SAPs. Moreover, 3.2% and 6.9%, respectively, adopted 10 SAPs. None of the sampled farming households adopted all 12 of the study's SAPs, with 0.53% adopting 11 of the 12 components.

Descriptive statistics of socioeconomic variables

The descriptive analyses of the key variables considered in this study are reported in Table 3.2. For each of the 12 SAPs, farm households adopt 4.8 of them on average. As the anticipated mean value of 6.5 is greater than the actual mean, this indicates a low adoption rate.

The average household head is 39.2 years old. The study also reveals a 94% male household head majority. The average landholding per household active labor is 1.4 acres, also on average, farmers spent 16.6 years in crop farming while earning a mean income of GH¢1,404.8 from other sources aside farming. The table also shows that the mean number of years in formal education is 1.706, while agricultural extension visits stood 2.4. While nearly 60% of the farmers belong to farmer-based organizations, the mean number of agricultural trainings received by farmers is approximately 1. Moreover, about 60% of the farmers farm on their own land. The average farm size of the farmers is 4.4 acres located at an average distance of 2.4km from their homestead. About 50% of farming households are members of VSLA. Farmers also participate in other training other than agricultural training at an average of about 3 training modules

Determinants of SAPs adoption intensity

The estimates of the drivers of adoption intensity of SAPs for Poisson, Negative Binomial, and Zero Inflated Negative Binomial are presented in Table 3 for comparative analysis. The first point of call for modelling count data such as adoption of SAPs is the Poisson regression. However, the appropriateness of this model relies on equi-dispersion assumption, thus the variance and mean of the dependent variable are equal. Table 3 shows that the variance of adoption of SAPs (dependent variable) far outweighs its mean, an indication of overdispersion. Also, both the deviance and the Pearsons goodness-of-fit in Table 3 have *p-value* of less than 0.05 which signifies the appropriateness of Negative Binomial over Poisson regression. The significance of the *LR test of alpha =0* in the negative binomial significantly rejects the null hypothesis of the errors not exhibiting overdispersion (equi-dispersion) hence proven the validity of the Negative Binomial over the Poisson. In some cases, both Poisson and Negative binomial suffer from the problem of excess zeros generated from the count dependent variable (adoption intensity of SAPs); hence, the need for Zero Inflated Negative Binomial (ZINB). To examine the appropriateness of the ZINB due to excess zeros, the Vuong test was applied. The Vuong test result is positive (11.36) and significant at 1% level. This is an indication that the ZINB is better preferred to the negative binomial and the Poisson model. To further test for better model selection, the information criterion was employed. The results for both Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) for both Poisson, Negative Binomial and ZINB are shown in last two rows of Table 3. The results revealed that ZINB has lower values of AIC and BIC than Poisson and Negative Binomial hence the ZINB model is preferred for analysis and discussions.

Out of the 15 variables considered in this study, five have been revealed to have significant influence on adoption intensity of SAPs. These include gender, land ownership and farm size that influences the intensity of SAPs adoption negatively whereas off-farm income and VSLA membership have positive significant influence on intensity of SAPs adoption. From the empirical results, gender is negative and significant at 5% level. This implies female headed households adopts a greater number of SAPs compared to their male counterparts. The reason could be that most agricultural and climate change projects such as Resiliency in Northern Ghana (RING), Labour Intensive Public Works (LIPW) etc. have been targeting more women than men in the Municipality. The finding is in line with (Ma & Wang, 2020, Olawuyi & Mushunje, 2019, Donkor, 2019) who found that being a female increases the likelihood of adoption intensity of SAPs. However, the findings disagree with (Umeh and Igwe, 2019; Awuni et al., 2018; Mohammed et al., 2015) which found that male-headed households have positive relationship with SAPs adoption. Adoption of farm technology goes with cost; in that it requires an amount of capital for effective and sustained practice. For this reason, the significant positive effect of off-farm income on SAPs adoption intensity. An increase in household income from other sources other than farm income will lead to farmer adoption of more SAPs. This finding is in line with (Ma & Wang, 2020) who found that households that receives remittances adopts more SAPs than those who do not. Mutyasira et al. (2018) also found off-farm income to be a significant and positive factor influencing the adoption of SAPs in Ethiopian Highlands.

However, Manda et al. (2015) found that off-farm income has a negative effect on SAPs adoption levels of farmers and further stated that time and energy required for agricultural activities have been deterred by activities of off-farm, reduction in technologies investment and labour availability.

The coefficient of land ownership is significantly negative at 5% level, and this suggests that farmers farming on their own land reduces their likelihood of adopting more SAPs compared to those who farm on rented land. Renting land for farming naturally raises the cost of production, therefore farmers will be motivated to use SAPs to optimize their returns on their land. However, this conclusion is at odds with Bazezew (2015) and Manda et al. (2015) which found farmers farming on their own land increases the likelihood of adopting more SAPs than the other wise in Ethiopia and Zambia, respectively. The size of farmland cultivated by farm households is also seen to be a negatively significant determinant of SAPs adoption intensity. As farmers increase the size of his/her farmland, the likelihood of adopting more SAPs reduces. The notion behind this could be that adoption of SAPs or new farming technology requires some amount of capital injection hence making it costly for relatively large-scale farmers to adopt. The finding is like Mutyasira et al. (2018) and Yang et al. (2022) who also found farm size had a significant negative effect of on adoption intensity of SAPs. Also, an inverse association is revealed in a study by Awuni et al (2018) between farm size and intensity of adoption of improved agricultural technologies among rice farmers in Northern Ghana. However, Ehiakpor et al. (2021) found that large-scale farmers are more likely to adopt SAPs than small-scale farmers.

Table 3 Determinants of Adoption Intensity of SAPs

	Poisson		***Negative Binomial***		***ZINB***	
Variables	***Coef.***	***dy/dx***	***Coef.***	***dy/dx***	***Coef.***	***dy/dx***
Age	-0.0014 (0.003)	-0.0067	-0.0019 (0.004)	-0.0094	0.00003 (0.003)	-0.0001
Sex	-0.0207 (0.093)	-0.110	0.0033 (0.140)	0.016	-0.1863** (0.095)	-0.2658
Farmer experience	-0.0008 (0.004)	-0.0037	-0.0005 (0.005)	-0.0023	0.0021 (0.004)	0.0099
Land per active labor	-0.0381 (0.024)	-0.1844	-0.0419 (0.034)	-0.2030	-0.0167 (0.024)	-0.0805
Off-farm income	0.00005*** (0.000)	0.0002	0.00005** (0.000)	0.0002	0.00005** (0.000)	0.0002
Educational level	0.0025 (0.006)	0.0123	0.0013 (0.009)	0.0064	-0.0023 (0.006)	-0.0109
Extension service	-0.0053 (0.011)	-0.0258	-0.0059 (0.017)	-0.0288	0.0104 (0.012)	0.0502
FBO membership	-0.0624 (0.065)	-0.3017	-0.0887 (0.093)	-0.4304	0.0118 (0.067)	0.0569
Agricultural training	0.0002 (0.034)	0.0008	0.0124 (0.050)	0.0603	-0.0189 (0.034)	-0.0913
Land ownership	-0.1829*** (0.049)	-0.885	-0.2167*** (0.071)	-1.0512	-0.1239** (0.050)	-0.5977
Farm size	-0.0578*** (0.022)	-0.2795	-0.0632** (0.031)	-0.3063	-0.0504** (0.022)	-0.2429
Farm distance	0.018	0.0871	0.0235	0.1141	0.004	0.0195

	(0.025)		(0.035)		(0.025)	
VSLA member	0.6654*** (0.121)	3.2192	0.6846*** (0.174)	3.3201	0.4337*** (0.124)	2.4891
Other training	-0.0475** (0.025)	-0.230	-0.0466 (0.034)	-0.2260	-0.0082 (0.0253)	-0.0396
Constant	1.788*** (0.185)		1.8049*** (0.265)		1.8535*** (0.1909)	
alpha			0.2111 (0.038)			
Deviance goodness-of-fit = 812.6836 Prob >chi2(362) = 0.0000 Pearson goodness-of-fit = 598.6255 Prob > chi2(362) = 0.0000 LR chi2(14) = 137.45 Prob > chi2=0.0000			LRchi2(14) =63.35Prob> chi2=0.0000		LR chi2(14) = 81.06 Prob > chi2 =0.0000	
Log likelihood = -971.40135			Log likelihood =-936.16		Log likelihood = -884.3731	
AIC = 1972.803			AIC= 1904.336		AIC = 1806.746	
BIC = 2031.786			BIC= 1967.252		BIC = 1881.459	

*LR test of alpha=0: chibar2(01) = 70.47 Prob >= chibar2 = 0.000 Vuong test of ZINB vs. Standard Negative Binomial: z = 11.36 Pr>z = 0.0000, *, **, and *** signify 10%, 5%, and 1% significance, standard errors in parenthesis*

It is worth noting that group membership in rural communities has been central in terms of agricultural technology diffusion and information sharing. Membership of VSLA from the results is positive and highly significant determinant of adoption intensity of SAPs and this implies that participation in VSLA by farmer households increases the likelihood of adoption intensity of SAPs than their counterparts who have not participated. VSLA's main goal is to give rural farmers easy access to finance while also creating a savings avenue and serving as a platform for the dissemination of agricultural technologies and knowledge. Through the hiring of labor, the purchase of better seed, organic manure, and other agricultural inputs, credit accessibility tends to increase farmers' adoption of SAPs. This finding again coincides with Mutyasira et al (2018) who found that farmer group involvement has a significant and direct influence on SAPs adoption. The adoption of rotating legume crops among smallholder farmers in Ghana was also found to be positively and significantly impacted by VSLA participation, according to Ehiakpor et al. (2021).

Conclusion and Recommendation

Using count models, this study examined the factors that influence the intensity of SAP adoption across rural farmers within East Gonja Municipality. The study focused on 12 different types of SAPs including integrated pest management, improved variety of seeds, legume intercropping, crop rotation, cover cropping, stone bunding, among others. The results indicate that the level of awareness of SAPs is quite high, but adoption is moderate as most farmers only adopt part of the available practices. The research findings further showed that off-farm income and VSLA participation are significant positive drivers of SAP adoption intensity, whereas gender, land ownership, and farm size are significant but negative drivers of SAPs.

Financial inclusion is very pivotal in improving the agricultural sector; therefore, policies should be geared towards scaling up VSLA across the country and linking them to financial institutions to access credit and other financial services to improve the agricultural sector and easy adoption of farm technologies such as SAPs. Also, SAPs should be promoted across all genders, landowners and large-scale farmers to ensure high productivity while conserving the natural environment. Non-farm income activity is becoming significant to smallholder households, particularly in regions such as the Savannah Region of Ghana where agriculture is strongly seasonal and climate-related risks are on the rise. Promoting non-farm economic activities require rural skills development and vocational training within the rural communities. This may include organizing training on marketable vocational skills like tailoring, carpentry, hairdressing, bakery, soap-making and ICT services among others in collaboration with technical and vocational training institutes (TVET) to provide short courses relevant to rural youth and women.

Reference

Agbenyo, W., Jiang, Y., Jia, X., Wang, J., Ntim-Amo, G., Dunya, R., Siaw, A., Asare, I., & Twumasi, M. A. (2022). Does the Adoption of Climate-Smart Agricultural Practices Impact Farmers' Income? Evidence from Ghana. *International Journal of Environmental Research and Public Health*, *19*(7), 3804. https://doi.org/10.3390/ijerph19073804

Alavaisha, E., Manzoni, S., & Lindborg, R. (2019), "Different agricultural practices affect soil carbon, nitrogen and phosphorous in Kilombero - Tanzania", *Journal of Environmental Management*, *234*, 159–166. https://doi.org/10.1016/j.jenvman.2018.12.039

Awuni, J. A., Azumah, S. B., & Donkoh, S. A. (2018). Drivers Of Adoption Intensity of Improved Agricultural Technologies Among Rice Farmers: Evidence from Northern Ghana. *Review of Agricultural and Applied Economics*, *21*(2), 48–57. https://doi.org/10.15414/raae.2018.21.02.48-57

Bazezew, H. A. (2015). Adoption of conservation agricultural practices: the case of Dangila District, Amhara Region, Ethiopia. Global Journal of Agricultural Economics Extension and Rural Development, 3, 295-307.

Dari, T., Aboagye, D., & Koomson, J. (2013). Coping with floods in the savannah region of Ghana. *Arts and Social Sciences Journal 21*(2), 48–57.

Ecoagriculture Partners. (2015). Ecoagriculture Policy Focus: Scaling up Sustainable Agriculture Land Management in Bungoma County, Kenya. Washington, DC 20036, USA. https://www.ecoagriculture.org

Ehiakpor, D. S., Danso-Abbeam, G., & Mubashiru, Y. (2021). Adoption of interrelated sustainable agricultural practices among smallholder farmers in Ghana. *Land Use Policy*, *101*, 105142. https://doi.org/10.1016/j.landusepol.2020.105142

FAO & FFI (Food and Agricultural Organization and Future Food Institute), (2022), "24-hour Global Marathon for Sustainability – Food for Earth (2021)", *Rome*. https://doi.org/10.4060/cb9571en.

FAO. (2013), "Climate-smart agriculture", Sourcebook. FAO, Rome

Food and Agricultural Organization of the United Nation [FAO]. (1995).

Sustainable agriculture and rural development. In: Loftas T (ed) Dimensions of Need-an atlas of food and agriculture. FAO, Rome.

Godfray, H. C. J., Beddington, J., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. P., Pretty, J., Robinson, S., Thomas, S. M., & Toulmin, C. (2010). Food Security: The Challenge of Feeding 9 Billion People. *Science*, *327*(5967), 812–818. https://doi.org/10.1126/science.1185383

GSS [Ghana Statistical Service]. (2021). Ghana 2021 Population and Housing Census Publications, General Report. *PHC*, *Volume 3e*. https://statsghana.gov.gh

HLPE. (2016). *Sustainable agricultural development for food security and nutrition: What roles for livestock? A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security*. Rome. https://www.fao.org/cfs/cfs-hlpe

Jones-Garcia, E., & Krishna, V. V. (2021). Farmer adoption of sustainable intensification technologies in the maize systems of the Global South. A review. Agronomy for Sustainable Development, 41(1), 8.

Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., & Mekuria, M. (2013). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. *Technological Forecasting and Social Change*, *80*(3), 525–540. https://doi.org/10.1016/j.techfore.2012.08.007

Li, J., Ma, W., Renwick, A., & Zheng, H. (2020). The impact of access to irrigation on rural incomes and diversification: evidence from China. *China Agricultural Economic Review*, *12*(4), 705–725. https://doi.org/10.1108/caer-09-2019-0172

Ma, W., & Wang, X. (2020), "Internet Use, Sustainable Agricultural Practices and Rural Incomes: Evidence from China", *Australian Journal of Agricultural and Resource Economics*, *64*(4), 1087–1112. https://doi.org/10.1111/1467-8489.12390

Ma, W., & Zheng, H. (2021). Promoting fruit and vegetable consumption in rural China: Does off-farm work play a role? *Q Open*, *1*(2). https://doi.org/10.1093/qopen/qoab010

Mahama, A., Awuni, J. A., Mabe, F. N., & Azumah, S. B. (2020). Modelling adoption intensity of improved soybean production technologies in Ghana - a Generalized Poisson approach. *Heliyon*. https://doi.org/10.1016/j.heliyon.2020.e03543

Manda, J., Alene, A. D., Gardebroek, C., Kassie, M., & Tembo, G. (2016). Adoption and Impacts of Sustainable Agricultural Practices on Maize Yields and Incomes: Evidence from Rural Zambia. *Journal of Agricultural Economics*, *67*(1), 130–153. https://doi.org/10.1111/1477-9552.12127

Midingoyi, S. G., Kassie, M., Muriithi, B., Diiro, G. M., & Ekesi, S. (2019). Do Farmers and the Environment Benefit from Adopting Integrated Pest Management Practices? Evidence from Kenya. *Journal of Agricultural Economics*, *70*(2), 452–470. https://doi.org/10.1111/1477-9552.12306

Mohammed, A., Jaleta, M., & Berg, E. (2015). Adoption of multiple sustainable agricultural practices and its impact on household income: evidence from southern Ethiopia. *International Journal of Agriculture and Biosciences*, *4*(5), 196–205. https://www.cabdirect.org/cabdirect/abstract/20163023993

Mohammed, A., Jaleta, M., & Berg, E. (2015). Adoption of multiple sustainable agricultural practices and its impact on household income: evidence from southern Ethiopia. *International Journal of Agriculture and Biosciences*, *4*(5), 196–205. https://www.cabdirect.org/cabdirect/abstract/20163023993

Mutyasira, V., Hoag, D. L., & Pendell, D. L. (2018). The adoption of sustainable agricultural practices by smallholder farmers in Ethiopian highlands: An integrative approach. *Cogent Food & Agriculture*, *4*(1), 1552439. https://doi.org/10.1080/23311932.2018.1552439

Nkegbe, P. K., & Shankar, B. (2014). Adoption intensity of soil and water conservation practices by smallholders: evidence from Northern Ghana. *DOAJ: Directory of Open Access Journals - DOAJ*. https://doi.org/10.13128/bae-13246

Olawuyi, S. O., & Mushunje, A. (2019). Social Capital and Adoption of Alternative Conservation Agricultural Practices in South-Western Nigeria. *Sustainability*, *11*(3), 716. https://doi.org/10.3390/su11030716

Pham, H., Chuah, S., & Feeny, S. (2021). Factors affecting the adoption of sustainable agricultural practices: Findings from panel data for Vietnam. *Ecological Economics*, *184*, 107000. https://doi.org/10.1016/j.ecolecon.2021.107000

Pretty, J., Toulmin, C., & Williams, S. (2011). Sustainable intensification in African agriculture. *International Journal of Agricultural Sustainability*, *9*(1), 5–24. https://doi.org/10.3763/ijas.2010.0583

Setsoafia, E. D., Ma, W., & Renwick, A. (2022), "Effects of sustainable agricultural practices on farm income and food security in northern Ghana", *Agricultural and Food Economics*, *10*(1). https://doi.org/10.1186/s40100-022-00216-9

Sharma, A., Bailey, A., & Fraser, I. (2011). Technology Adoption and Pest Control Strategies Among UK Cereal Farmers: Evidence from Parametric and Nonparametric Count Data Models. *Journal of Agricultural Economics*, *62*(1), 73–92. https://doi.org/10.1111/j.1477-9552.2010.00272.x

Teklewold, H., Kassie, M., & Shiferaw, B. (2013). Adoption of Multiple Sustainable Agricultural Practices in Rural Ethiopia. *Journal of Agricultural Economics*, *64*(3), 597–623. https://doi.org/10.1111/1477-9552.12011

Tey, Y. S. (2013). *The adoption of sustainable agricultural practices: an integrative approach for Malaysian vegetable farmers* [PhD Dissertation]. University of Adelaide.

Tong, Q., Swallow, B., Zhang, L., & Zhang, J. (2019). The roles of risk aversion and climate-smart agriculture in climate risk management: Evidence from rice production in the Jianghan Plain, China. *Climate Risk Management*, *26*, 100199. https://doi.org/10.1016/j.crm.2019.100199

USAID. (2017). *Greenhouse gas emissions in Ghana. In USAID Factsheet*. USAID: Washington, DC, USA.

Van Thanh, N., & Yapwattanaphun, C. (2015), "Banana Farmers' Adoption of Sustainable Agriculture Practices in the Vietnam Uplands: The Case of Quang Tri Province", *Agriculture and Agricultural Science Procedia*, *5*, 67–74. https://doi.org/10.1016/j.aaspro.2015.08.010.

Vanlauwe, B., Descheemaeker, K., Giller, K. E., Huising, J., Merckx, R., Nziguheba, G., Wendt, J. O., & Zingore, S. (2015). Integrated soil fertility management in sub-Saharan Africa: unravelling local adaptation. *Soil*, *1*(1), 491–508. https://doi.org/10.5194/soil-1-491-2015

Vera, T. S., Wiliams, C. E., & Justin, C. O. (2017). Understanding the factors affecting adoption of subpackages of CSA in Southern Malawi.

Yang, Q., Zhu, Y., Liu, L., & Wang, F. (2022), "Land tenure stability and adoption intensity of sustainable agricultural practices in banana production in China", *Journal of Cleaner Production*, *338*, 130553. https://doi.org/10.1016/j.jclepro.2022.130553

Yu, L., Chen, C., Niu, Z., Gao, Y., Yang, H., & Xue, Z. (2021), "Risk aversion, cooperative membership and the adoption of green control techniques: Evidence from China", *Journal of Cleaner Production*, *279*, 123288. https://doi.org/10.1016/j.jclepro.2020.123288

Yuan, J., Li, X., Sun, Z., & Ruan, J. (2021), "Will the Adoption of Early Fertigation Techniques Hinder Famers' Technology Renewal? Evidence from Fresh Growers in Shaanxi, China", *Agriculture*, *11*(10), 913. https://doi.org/10.3390/agriculture11100913.

Zhao, Y., Chai, Z., Delgado, M. S., & Preckel, P. V. (2016). An empirical analysis of the effect of crop insurance on farmers' income: results from Inner Mongolia in China. *China Agricultural Economic Review*, *8*(2). https://doi.org/10.1108/caer-05-2014-0045