Journal of Agriculture and Food Research 10 (2022) 100381

Contents lists available at ScienceDirect

Journal of Agriculture and Food Research

journal homepage: www.sciencedirect.com/journal/journal-of-agriculture-and-food-research

Do agricultural extension services promote adoption of soil and water conservation practices? Evidence from Northern Ghana

Gideon Danso-Abbeam

Department of Agribusiness, University for Development Studies, Tamale, Ghana

ARTICLE INFO

Keywords:
Africa RISING
Endogenous switching probit
Multivariate probit model
Soil and water conservation practices

ABSTRACT

Agricultural environment in many developing economies has become increasingly unpredictable in recent decades as a result of climate change, increasing the risk of crop failure. Access to meaningful information is required to mitigate the negative effects of the changing environment. This study examined the impact of agricultural extension services on the adoption of soil and water conservation (SWC) practices using data obtained from farming households in Northern Ghana. A multivariate probit model was used to assess the simultaneous or/and substitution adoption of SWC practices, while endogenous switching probit (ESP) was used to estimate the impact of extension services on adoption of SWC practices to account for observed and unobserved heterogeneities. The results showed that most of the SWC practices were adopted jointly, and factors such as non-farm economic activites and farm size influence the adoption of SWC practices. Moreover, farmers who accessed agricultural extension services had a higher probability of adopting most of the SWC practices (crop rotation, contour ploughing and manure application), and those who did not benefit from extension services would have had an equally higher likelihood of adopting the SWC practices had they accessed the services. The findings of the study imply that enhancing agricultural extension services will reduce adoption gaps in SWC practices, and consequently reduce farmers' exposure to climate-related agricultural production risks. With growing information and communication technologies, pluralistic extension service delivery that mixes governmental and private-sector-led approaches to extension operations to foster demand-driven extension delivery services are highly recommended.

1. Introduction

There is still concern about the implications of climate change on socioeconomic development, which may have an adverse consequence on several areas of household life due to the prevalence of unpredictable rainfall and high temperatures, as well as the low adoption of farming practices to lessen their impacts. Although less than 5% of the world's greenhouse gas (GHG) emissions come from Sub-Saharan Africa (SSA), the region is particularly susceptible to the effects of climate change due to its heavy dependency on rainfall [1]. In Ghana, more than half of the workforce is employed in agriculture, which is critical to food security, and the country's net foreign exchange reserves [2]. However, agriculture in Ghana is at risk because of its strong reliance on rain-fed production and drought susceptibility, especially since less than 2% of the agricultural area is under irrigation [3]. Unpredictable and varied rainfall, rising temperatures, and prolonged dry seasons are a few of the effects of climate change on Ghanaian agriculture. For example, there have been delays in the onset of rainy season in many parts of Ghana, particularly in the northern part of the country [4]. Therefore, an integrated approach such as climate-smart strategies to mitigate the negative effects of climate uncertainty and change is critical to the Ghanaian agricultural industry.

The [5] defines climate-smart as practices that contribute to the achievement of the three main goals of climate-smart agriculture, which are as follows: (a) sustainably improved agricultural productivity and incomes; (b) adapting and building resilience to climate change; and (c) decreasing greenhouse gas emissions. One of the key components of climate-smart agricultural practices which is been promoted by government and development partners in many developing economies including Ghana is the practice of Soil and Water Conservation (SWC). SWC includes the use of erosion management and other methods to reduce soil and nutrient loss and save soil moisture. These include limited tillage, application of organic manure, contour ploughing[1] and crop rotation, among other practices. These practices have been on

E-mail address: dansoabbeam@uds.edu.gh.

[1] In this study, conour ploughing and contour planting are used interchangeably.

https://doi.org/10.1016/j.jafr.2022.100381
Received 20 May 2022; Received in revised form 28 August 2022; Accepted 31 August 2022
Available online 6 September 2022

agenda of many government and other stakeholders as a way of mitigating the effects of climate change, improving sustainable agriculture and enhancing incomes and food security of smallholder farming households, particularly in SSA including Ghana. This is because, for example, soil erosion has been one of the environmental factors, which has led to severe alteration in land topography, loss of soil fertility, and difficulty in the implementation of land management practices [6]. Thus, adoption of SWC by farmers is expected to serve as a climate change adaptation strategy, and consequently lead to farmers' resilience to climate variability, improvement in farm incomes, and food security status. Development projects and farmers with firsthand experience in their communities have put these and many other SWC strategies to test. If the appropriate conditions are in place, SWC methods can help a wide spectrum of farmers [7]. The SWC measures will not be completely embraced until they are continued and thoroughly incorporated into the household's farming operations [8]. In spite of the promotion of SWC, the practices have not been widely adopted by farmers [6,9]. Key identified causes of low adoption rates of technological innovations including SWC is supply-side constraints such as imperfect information [10–12]. Thus, innovations such as SWC may not be of great benefits to the farmers if information about these SWC measures are not made consistently avaailable to them. As a result, improving the information market can be a key entry point for increasing the use of agricultural technologies such as SWC.

Most farmers in Africa, especially in Ghana, live in rural communities and rely significantly on public extension services for information on modern agricultural practices such as SWC. A well-functioning agricultural extension system is needed in order to ensure that small-scale farming is more productive and profitable. Thus, growth in agricultural productivity drives on a sound and effective agricultural extension delivery systems [13,14]. As a result, the Ghanaian government has increased support for agricultural extension services in order to ensure that farmers receive knowledge on cutting-edge production technologies in order to increase adoption and, in turn, productivity and farm revenue, particularly in the era of the changing climate [15]. Moreover, private suppliers of extension services have sprung up as a result of Ghana's government agenda of expanding the private sector. Blue Town, ESOKO, Farmerline, and Viamo are examples of firms, social purpose enterprises, and organizations that provide extension services along the agricultural value chain. These enterprises use information and communication technology (ICT) such as mobile phones, internet access, radio, and videos to supply farmers with farm services such as production technologies and market information. NGO involvement in providing and financing extension services has also increased in the last few years. For example, the Ghana Extension Systems Strengthening Project (GESSiP) is an initiative financed by the Alliance for a Green Revolution in Africa (AGRA) that aims to improve smallholder farmers' productivity and incomes in Brong Ahafo (now Bono and Bono East) and Northern (now Northern and Savannah) regions of Ghana. Quality extension services, enhanced technology, and sound agronomic practices are the goals of GESSiP. Farmers and other value chain actors benefit from the increased involvement of the private sector and NGOs in extension service delivery. The farmer field school is another method being employed by government, business, and NGOs. Farmer field school, a participatory method to education, technology development, and dissemination, is built on adult learning principles such as experience learning. The concept of farmer-to-farmer extension is also used by some other organizations, including the private sector and NGOs. Extension programmes educate farmer-trainers, who in turn train other farmers. New farming technology can only be embraced by rural farmers who have access to a well-functioning extension system and are aware of them. The availability of high-quality extension services facilitates adoption of farming practices such as SWC that aims to mitigate the effects of climate change, boost farm productivity, and improve on the general livelihoods of farmers [11,15,16]. Extension programmes can expose rural farmers to new technologies and teach them about alternative ways in order to lessen the information asymmetry associated with new technology [17].

Despite these benefits associated with extension service delivery, extension service in many developing economies are plaque with many challenges, including inappropriate design of programmes and messages. There are many smallholders who do not employ agricultural extension services because they are not tailored to their unique needs [18,19]. Thus, the low uptake of agrarian technology is not the result of farmers' reluctance to use it but rather the result of a lack of competent extension service delivery methods, inadequate extension agents and limited logistics [20]. For example, in Ghana, if all extension employees in government sector are assigned, the extension staff-to-farmer ratio is around 1 extension agent to about 1300 farmers [21] . Thus, extension service may hinder adoption of farm practices or technologies such as SWC if it excludes the poorest farmers or lacks the incentives and efficient systems to relay reliable information to farmers on time. Although extension has been cited as a primary pathway for policymakers and other agricultural stakeholders to promote agricultural innovations and knowledge such as in SWC, their impact on adoption is quite mixed [11,15,22].

Many studies (e.g. Refs. [23–27]) have analyzed the adoption of SWC in SSA. However, most of these studies focused on the determinants of adoption of SWC, with extension contacts as one of the independent variables. However, specifying an adoption model with extension variable a just predictor does not make the coefficient to be interpreted as impact, as it may suffer from sample selection bias and endogeneity. When farmers make the decision to access extension services on their own accord, which is actually the situation, sample selection bias emerges. It is said that access to extension services is endogenous when there are unobserved factors that affect the adoption of SWC and also correlate with having access to extension services. In this case, making extension service just an independent variable without addressing the issues of sample selection bias and endogeneity will lead to potential bias estimates. Considering the important of extension services to agricultural information dissemination, a true and unbiased estimates is critical for farm-level policy design and implementation.

The study makes two significant contributions to the body of empirical literature and informed policy-decisions. First, a multivariate probit (MVP) model was applied to examine the complementarity or/ and substitutability of the four key SWC commonly practiced in the study areas as well as factors that influence farmers' choice of SWC practices. Second, through the use of endogenous switching probit (ESP), the determinants of farmers' access to extension services and the quantitative impact of extension services on farmers' adoption of SWC practices were identified and estimated, respectively. The ESP estimator account for both observed and unobserved differences in household characteristics. For the purpose of policy guidelines, this study provides a road map for key players on the critical strategy to be taken to enhance adoption of SWC through extension service delivery. SWC measures are expected to be used more frequently by farmers as a result of this enhanced understanding.

2. Methods and materials

2.1. Empirical strategy

The study used descriptive statistics and two econometric techniques to achieve the stated objectives. The descriptive analysis involved the use of frequencies, percentages, graphs, and independent sample *t*-test technique to examine the significant difference in mean characteristics of the two groups (farmers who had access to extension services versus farmer who did not have access to extension services). The econometric technique involves the use of MVP model to examine the interdependency among the key SWC, as well as the determinants of adoption of each of the SWC. ESP that accounts for self-selection bias that may emanates from observed and unobserved heterogeneities and predict the average treatment effects was employed. The following sections describe the MVP and ESP models, respectively.

2.1.1. Multivariate probit model

In the MVP system, adopting a particular component of SWC does not restrict a farming household from adopting another component of SWC. Thus, farmers are more likely to simultaneously use a mix of the SWCs (use of manure, crop rotation, minimum tillage, contour ploughing). Farming households are assumed to be rationale and will therefore select a bundle that best meets their predicted adoption needs, taking into account interdependency and simultaneous adoption decisions. As a result, the study used the MVP model in this study to describe the relationship between the set of explanatory variables and each of the dependent variables (components of SWC addressed in this study), while permitting the free correlation of the unobserved characteristics. Mulwa et al. [28], Ojo et al. [29] and Asfaw et al. [30] found that using univariate modelling (e.g., probit/logit) for this type of study omits critical information on the interdependency of SWC component of adoption, and the denial to comprehend this interdependency may result in biased and inaccurate coefficient estimates [31,32]. The general equation can be expressed as:

$$Y_{jk} = \alpha_{jk} x_{jk} + \varepsilon_{jk} \tag{1}$$

where Y_{jk} is the dependent variable representing adoption of SWC components, x_{jk} is the vector of variables hypothesized to affect the adoption decisions of SWC, α_{jk} is the estimated parameter and ε_{jk} is the error term. In the MVP structure, each of the observed dependent variable (crop rotation, use of manure, minimum tillage and contour ploughing) was considered as a dummy and assigned a value of 1 if a farming household adopt a particular practice and 0 otherwise. Thus, the latent variable can be specified as:

$$Y^*_{jk} = \alpha_{jk} x + \varepsilon_{jk}, \ (k = R, T, C, M) \tag{2}$$

where Y^*_{jk} is the latent variable of the k^{th} SWC adoption, given that it is a binary dependent variable influenced by a set of observed characteristics. The letters R, T, C, M denote the components of SWC: crop rotation, minimum tillage, contour ploughing and manure application, respectively.

The relationship between the observed dependent variable and its latent variable can be expressed as:

$$Y_{jk} = \begin{cases} 1 \ if \ Y^*_{jk} > 0 \\ 0 \ if \ Y^*_{jk} \leq 0 \end{cases} \tag{3}$$

where $(k = 1, \ .... 4)$ denote the general equation for adoption of SWC. In the MVP system, where there is a possibility of simultaneous adoption of SWC, the error term is based on a multivariate normal distribution (MVN) given a conditional mean of zero and variance normalized to unity where $(\mu R, \mu T, \mu C, \mu M) \approx MVN(0, \Omega)$ and the symmetric covariance matrix Ω is given by:

$$\Omega = \begin{bmatrix} 1 & \rho RT & \rho RC & \rho RM \\ \rho TR & 1 & \rho TC & \rho TM \\ \rho CR & \rho CT & 1 & \rho CM \\ \rho MR & \rho MT & \rho MC & 1 \end{bmatrix} \tag{4}$$

The stochastic relationships between distinct SWC components are masked by off-diagonal factors in the lattice of covariance [33]. Non-zero off-diagonal elements in this formulation enable for correlation across numerous latent equations or error terms, which indicate unobserved variables affecting the selection of alternative adoption decisions of SWC. MVP model postulates that the rho (ρ) is more than just a correlation between two variables; rather, it provides a wealth of information. If two SWC elements have a positive relationship, it means that they are complementary and that one SWC (such as crop rotation) may be dependent on the other when implemented. If SWC is correlated negatively, then the farming household is seen as substituting SWC with each other in any setting.

2.1.2. Impact of agricultural extension access on SWC adoption: endogenous switching probit

The key objective of this study is to quantitatively estimate the impact of access to extension services[2] on adoption of each of the components of SWC. Thus, the study hypothesized that farmers' access to extension services have the potential to promote adoption of the SWC components. Each of the SWC components and access to extension services can be linked through equation (5) as follows:

$$SWC_s = \alpha E_s + \varphi X_i + \varepsilon_i \tag{5}$$

where SWC_s, E_s and X_i denote SWC components, extension access, and vector of explanatory variables hypothesized to influence SWCs. α and φ are parameters respectively measuring the magnitude of the effect of extension and other explanatory variables on adoption of SWC, while ε_i is the error term. From Eq. (5), the extension variable looks exogenously given, while it is potential endogenously determined. Thus, variables that explained access to extension are also likely to explain adoption of SWC components. Moreover, farmers' access to extension services may also be influenced by other factors such as motivation, managerial skills, and farmers' entrepreneurial drive, among others. These factors are referred to as unobserved factors because they cannot be directly measured by the researcher. These observed and unobserved factors make farmers' access to extension services voluntary, leading to sample selection bias.

Many studies (e.g., Refs. [34–36]) have used propensity score matching (PSM) to address the issue of endogeneity and self-selection bias. The major setback of this approach, however, is its reliance on only observable factors to account for self-selection bias. Therefore, to be able to account for selection bias that emanates from both observed and unobserved factors, the study employed instrumental variable (IV) approach, specifically, the ESP that accounts for both observed and hidden biases. Another significant feature of ESP is that it has the ability to accommodate outcome variable with binary outcome (1, 0) unlike other instrumental variable estimators such as endogenous switching regression (ESR) that takes only continuous variable as a response or outcome variable. Moreover, ESP estimates the average treatment effect on the treated (ATT) and the average treatment effect on the untreated (ATU), which cannot be estimated by a conventional IV estimator like Heckman. The ATT denotes the mean outcome (adoption of SWC practices) of farming households who had access to extension services if there are equal returns in characteristics of access and non-access to extension services. Likewise, the ATU, which is the expected change in the outcome of farming household that did not access extension services if they had similar characteristics as those who had access to extension services.

Following [37], the ESP was used to describe the behaviour of the farming households with the four sets of SWC binary outcomes: crop rotation, minimum tillage, contour ploughing, and manure application. Access to extension, which is the treatment variable, determines which regime the farming households face. Thus, extension access E_s and the outcomes SWC can take one of the two potential values;

$$\begin{aligned} E_s &= 1 \ if \ \gamma Z_i + \mu_i > 0 \\ E_s &= 0 \ if \ \gamma Z_i + \mu_i \leq 0 \end{aligned} \tag{6}$$

$$SWC^*_{1i} = \beta_1 Z_{1i} + \varepsilon_{1i} \quad SWC_{1i} = I(SWC^*_{1i} > 0) \text{ Regime 1} \tag{7}$$

$$SWC^*_{0i} = \beta_0 Z_{0i} + \varepsilon_{0i} \quad SWC_{0i} = I(SWC^*_{i} > 0) \text{ Regime 2} \tag{8}$$

[2] In this study, access to extension services, recipients of extension services; and beneficiaries of extension services, are ll used interchangeably.

where SWC^{*}_{1i} and SWC^{*}_{0i} are the latent variables that determine the observed SWC adoption outcomes SWC_1 andSWC_0. Z_1 and Z_0 are set of variables that explain the variation in regime 1 and regime 2, respectively. γ, β_0, and β_1 are parameters to be estimated, and μ, ε_{0i} and ε_{1i} are the error terms assumed to be normally distributed with mean-zero.

In the ESP model, counterfactual scenarios of the SWC adoption status can be derived for farmers who had access to extension services and those who do not. Thus, ESP calculates both ATT and ATU.

Through the application of exclusion constraint, the study improves the model identification, following [37]. Model identification is restricted due to the inclusion of at least one variable in the treatment model [Eq. (6)], which is not included in the outcome models [Eq. (7)] and [Eq. (8)]. By intuition, the study selected membership of farmer-based organizations (FBOs) as an instrument to address the issue of model identification. Farmers' access to extension services can potentially be influenced by FBO membership. This is because FBOs have become the main conduit of information dissemination process, and agricultural extension agents can get information to farmers through FBOs as it is easier to reach many farmers at the same time. Thus, the study conceptualized that membership of FBO is a potential predictor of access to extension services but may not have correlation with the error terms of Eq. (7) and Eq. (8). Membership of FBOs has been used as an instrument for many impact studies such as [38–40]. The study also established the statistical validity of the FBO membership as an instrument through the application of falsification test recommended by Ref. [41]. The results of the falsification test indicated that FBO significantly predict access to extension services ($Chi = 58.07$; $p = 0.000$). However, FBO is redundant in explaining adoption of each of the components of SWC. The *Chi* values and probabilities for crop rotation, minimum tillage, contour ploughing, and manure application are as follows: $Chi\ (1) = 0.68\ (0.408)$; $Chi\ (1) = 0.02\ (0.881)$; $Chi\ (1) = 0.02\ (0.932)$; and $Chi\ (1) = 0.07\ (0.796)$, respectively .

2.2. Data and descriptive statistics

2.2.1. Data

This study relied on the baseline survey under the Africa Research in Sustainable Intensification for the Next Generation (Africa RISING, 2015) project conducted in Northern Ghana by International Food Policy and Research Institute (IFPRI). About half of Ghana's land area is in the northern part, and has a single rainy season that lasts from May to October. The survey was conducted in the former three regions (northern, upper west and upper east regions), now five regions (Savannah, North east, northern, upper east and upper west regions). The main source of livelihoods for the inhabitants of the three northern regions is agriculture (crop and animal production). The majority of farming households cultivate crop (legumes, legumes, fruits and vegetables, roots and tubers), livestock (including poultry), trees and shrubs in a mixed farming systems.

A multi-stage sampling procedure was used to collect data from the farming households in the study areas. First, three districts were randomly selected from each region. The survey covered Wa west, Nandowli and Wa east in the Upper west region, while districts in the Northern region include Tolon/Kumbugu, Savelegu and West Mamprusi districts. For Upper east region, the data was collected in Talensi-Nabdam, Bongo and Kassena-Nankena districts. Second, a proportional sampling was used to select the number of respondents from the districts in each region. In all, the survey was conducted on 447, 615, and 222 agricultural households in Upper west, Northern and Upper east regions of Ghana, respectively. Thus, the total sample size used was 1284 farming households. The data was collected through face-face interview using a well-structured questionnaire. The questionnaire captured variables such as farmer socio-economic characteristics, farm characteristics, use of farming practices, social capital such as farmer organizations, household assets ownership and farmers' access to supply-side variables such as extension access, credit access, etc. Agriculture is the primary source of income for the vast majority of people, and the majority of households cultivate crops such as cereals; legumes; roots; and tubers.

2.2.2. Descriptive statistics

As indicated earlier, SWC practices include farmers' practice of crop rotation, minimum tillage, contour planting, and application of manure. Table 2 summarizes profile of the farming households' adoption of SWC practices. About 66.7, 64.4, 19.6, and 25.1% of the farming households that had access to extension services practiced crop rotation, contour planting, minimum tillage, and manure application, respectively. For those farming households that did not access extension services, 63.2, 68.1, 19.7, and 17.7% practiced crop rotation, contour planting, minimum tillage, and manure application, respectively. Fig. 1 gives a pictorial view of the adoption of SWC practices for access and non-access to extension services.

Moreover, the study included a number of control variables in its empirical model. These variables include household demographic characteristics (gender, age, marital status), socioeconomic characteristics (primary occupation, engagement in non-farm economic activities, membership of FBO, access to agricultural credit), and farm-specific characteristics (farm size under cultivation, experience of soil erosion on farm plots). The inclusion of these variables in the empirical specification was in line with empirical literature on access to extension services, adoption of SWC and impact evaluation (e.g., Ref. [1,5,6]).

For farmers who had no access to extension services, about 85% of them are males, while those who had access to extension services, about 83% of them are male. However, there is no significant difference between these two groups. On average, there is a significant difference between the marital status of those who had access to extension services and those respondents who did not access extension service. In general, the respondents are within the active age bracket (average range of 47–48 years), have crop production as their primary source of livelihood. About 35% are engaged in non-farm business, few had access to agricultural credit facility and have relatively small farm sizes (less than 2 ha). Moreover, the proportion of farmers with access to extension who are members of FBO (0.44) is significantly higher than those who did not access extension service and are members of FBO (0.22). The study also included variables such as crop diversification index (CDI) and livestock diversification index (LDI), which measures the extent of households' asset ownership. The study used margalef index to generate CDI and LDI indices. The margalef index was used because of its ability to discriminate and its compatibility with other diversity indices, as well as capturing a wide range of crop and animal species. Higher values of the Margalef index imply increased system diversity, while lower values indicate decreased system diversity. An index of zero means that there are very few crop species per land area or few animals per population. Table 1 shows that farming households who had access to extension services have significantly greater values of CDI and LDI than farming households who did not access extension services. Thus, access to extension resulted in a greater system diversification.

Lastly, food security status of the farming households was included in the empirical specification. Food security status was measured by household dietary diversity score (HDDS) using twelve food groups: cereals, root and tubers, vegetables, fruits, legumes, nuts and seeds, meat, fish and eggs, milk, oil and fats, sweets and sugars, and, spices and drinks. Thus, the HDDS ranges from 0 to 12, with greater values indicating consumption of many food groups, which translate into an improved food security status. From the results, those farming households who had access to extension services had a significantly better food security status than those with no access to extension services.

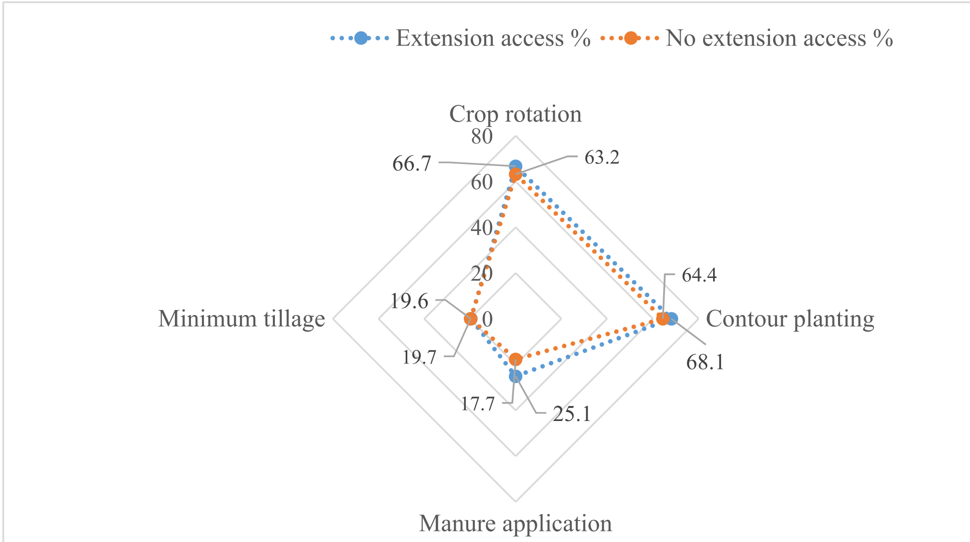

Fig. 1. Comparison of adoption of SWC practices for access to extension services.

3. Results and discussion

3.1. Determinants of soil and water conservation (SWC) practices

The MVP model was used to examine the complementarity or/and substitutability of the SWC practices, as well as the predictors of SWC adoption, and the results are illustrated in Tables 2 and 3. Table 2 shows the correlation matrix depicting the complementarity or/and subtitutability of the SWC components, while Table 3 shows the factors influencing the adoption of each SWC component. Table 2 shows that when the likelihood ratio test (LR) was used, the null hypothesis of independence between the adoption of SWC practices was significant at 1%. This implies that all of the correlation values between the SWC components are greater than zero. As a result, the null hypothesis that all components of the SWC are independent of one another is rejected, indicating that the implication of interdependency among the SWC components is supported. The correlation coefficient suggests that crop rotation and minimum tillage have a positive relationship, as determined by the simulated maximum likelihood estimate. Thus, farmers who practice crop rotation are more likely to practice minimum tillage. There was a negative correlation between crop rotation and manure application, as well as between crop rotation and contour ploughing. This suggests that farmers who practice crop rotation are less likely to apply manure on the farms and practice contour ploughing. Moreover, the practice of minimum tillage had a positive correlation with contour ploughing, which led to the conclusion that minimum tillage was more common among farmers who also practiced contour planting.

Similarly, there is a positive correlation between contour ploughing and application of manure. Farming households' likelihood of adopting all the four SWC practices together was based on the joint probabilities of success or failure. In Table 2, the likelihood of farmers adopting the four SWC practices is 22.8%, which means that households are unlikely to succeed in selecting all of the recommended practices at the same time by a margin of 77.2%. As predicted by the model, there was a 43.2, 59.9, 46.8 and 86.1% chance that farming households will practice crop rotation, minimum tillage, contour planting and application of manure, respectively. In comparison to minimum tillage, contour planting, and manure applications, the possibility of practicing crop rotation was low. This suggests that farmers were not interested in practicing crop rotation as compared to other SWC probably due to the difficulty in accessing land, which may be as a result of unregulated land tenure system in northern Ghana.

The coefficient estimates from the MVP are presented in Table 3. The independent variables hypothesized to influence adoption of SWC include gender, marital status, farm size, participation in non-farm economic activities, extension service, food security status, and farmers' experiencing erosion on their fields. The positive and significant influence of gender on crop rotation suggests that male-respondents were more likely to adopt crop rotation and minimum tillage compared with female-respondents. This may be because women have limited access to land, as crop rotation requires relatively larger parcel of land to plant different crops sequentially on the same plot. For example, when maize is planted on a piece of land and it is harvested, the farmer might plant beans to fix nitrogen. This means that the farmer requires another portion of land to plant maize in the same planting season. Since women do not have easy access to land as compared with men, they are most likely to be limited in the practice of crop rotation. Similarly, marital status of the respondents enhances the adoption of crop rotation and contour planting.

Land size under agricultural production is an important variable influencing the adoption of SWC in many pieces of empirical studies [42]. In this study, land size influence the likelihood of adoption of crop rotation, minimum tillage, contour planting and manure application. However, while land size show positive and significant correlation for crop rotation, minimum tillage and contour planting, it is negative for manure application. Thus, while farmers with larger farm sizes are more likely to practice crop rotation, minimum tillage, and contour planting, they are less likely to apply organic manure. Income from non-farm sources had a positive and significant effect on crop rotation, contour ploughing and manure application. This is probably because farmers with secondary sources of income from non-agricultural activities may have less liquidity constraints as income from non-farm activities could be used to finance farming activities such as labour to do contour planting, transportation and purchase of organic manure.

The role that extension services play in increasing both the general awareness of SWC techniques and the likelihood that individual farmers will choose to participate in SWC activities is significant. If farmers have access to information on different types of SWC techniques and how they should be used, as well as management of technology, this will directly lead to an increase in the adoption of SWC. The results of the study indicates that contact with extension services positively and significantly increases the adoption of all the SWC practices under study. Thus, farmers who receive SWC extension messages from extension agents are more likely to apply the SWC practices on their farm plots than those who do not interact with extension agents. As [43] noted, households with access to information about land degradation and soil conservation

Table 1
Summary profile of the sampled farming households.

Variables	Description	Extension Access	No extension Access	P-values
		Mean (SD)	*Means (SD)*	
Crop rotation	1 = if household practice crop rotation	0.667 (0.472)	0.632 (0.483)	0.200
Contour Planting	1 = if household practice contour planting	0.681 (0.466)	0.644 (0.479)	0.163
Manure application	1 = if household apply manure on farms	0.251 (0.434)	0.177 (0.382)	0.002[a]
Minimum tillage	1 = if household practice minimum tillage	0.196 (0.397)	0.197 (0.398)	0.968
Gender	1 = if household head is a male	0.854 (0.353)	0.832 (0.374)	0.280
Marital status	1 = if household has spouse	0.758 (0.201)	0.728 (0.258)	0.023[b]
Age	Age of the household head in years	48.125 (14.235)	47.037 (15.065)	0.191
Primary occupation	1 = if crop production is the primary occupation	0.794 (0.079)	0.781 (0.117)	0.172
Farm size under cultivation	Farm size under crop cultivation in hectares	1.556 (1.657)	1.627 (1.594)	0.446
Experienced erosion on farm plots	Farmer experienced erosion in the last five years	0.221 (0.416)	0.244 (0.430)	0.339
Engagement in non-farm employment activities	1 = if household engage in non- farm employment	0.349 (0.477)	0.308 (0.462)	0.125
Credit access	1 = if household accessed credit	0.194 (0.292)	0.181 (0.279)	0.226
Membership of farmer group	1 = if household head is a member of a farmer-based organization (FBO)	0.435 (0.494)	0.223 (0.416)	0.000[a]
Crop diversification index (CDI)	Diversified crops (continuous variable)	1.848 (1.159)	1.729 (1.146)	0.073[c]
Livestock diversification index (LDI)	Diversified livestock (continuous variable)	0.559 (0.385)	0.479 (0.348)	0.000[a]
Food security status (HDDS)	Household dietary diversity score (continuous)	8.444 (1.802)	7.943 (1.997)	0.000[a]

a, b and c denote significance at $p < 0.01$, $p < 0.05$ and $p < 0.1$, respectively. SD denote standard deviation.

activities may perceived SWC practices to be profitable because they are better informed of the problem and practices. The results are in line with other previous studies (e.g., Refs. [44–46]) that found a positive and significant influence of agricultural extension services on adoption of SWC practices. The results further demonstrated that CDI have no significant influence on all the SWC practices except for manure application. This could be because most households in northern Ghana cultivate more than a single crop and rear more than a single animal species, and this provide them the opportunity to collect plant and animal biota to make organic compost for soil fertilization [47]. Thus, the more diversified a farming household is in terms of crop production, the more likely it is to apply organic manure. Similarly, LDI influence farmers' probability of practicing minimum tillage and manure application in a positive direction. However, LDI have negative and significant effect on the likelihood of farming households adopting contour ploughing. Crop and livestock diversification promotes integrated crop-livestock farming systems where farming households used fecal of their livestock to fertilize their crop land, while the animals are used for soil traction. Crop-livestock diversification also allow farmers to diversify their resources, maintain sustainable crop and animal production, combat poverty and improved food security [27,37,48,49]. In addition, food secure households are more likely to practice crop rotation but less likely to adopt minimum tillage, and contour ploughing.

Table 2
Correlation matrix of SWC adoption.

	Crop rotation	Minimum tillage	Contour planting	Manure application
Crop rotation	1	0.261 (0.049)[a]	−0.344 (0.044)[a]	−0.011 (0.052)
Minimum tillage		1	0.106 (0.049)[a]	0.056 (0.054)
Contour planting			1	0.061 (0.052)
Manure application				1
LR test				
Chi2 (6) = 84.98				
Prob>Chi = 0.000				
Joint probability (Success)	0.228 (0.001)[a]			
Joint probability (Failure)	0.127 (0.002)[a]			
Linear Predictions				
Crop rotation	0.432 (0.012)[a]			
Minimum tillage	0.599 (0.010)[a]			
Contour ploughing	0.458 (0.014)[a]			
Manure applications	0.861 (0.015)[a]			
a denote significance at p < 0.01				

3.2. Results from the full information maximum likelihood (FIML)

This section discusses the FIML estimates for each component of SWC practices, including the selection equation (Eq. (6)) and the determinants of regime 1 (Eq. (7)) and regime 2 (Eq. (8)). Column 2 of Table 4 highlights the factors influencing access to extension services, whereas columns 3–10 identified the factors influencing SWC practices: crop rotation (CR), minimum tillage (MT), contour ploughing (CP), and manure application (MA), in both regimes. According to the model diagnosis, there is a positive relationship between the error term of extension access and the CR for extension access (CR = 1) [*Rho_1 = 0.100 (0.003)*] and for non-access to extension services (CR = 0) [*Rho_0 = 0.768(0.129)*], implying that farmers with access to extension services are subject to some level of self-selection bias. Furthermore, the error term in the extension access equation is positively correlated with minimum tillage for both farming households with access to extension (MT = 1) [*Rho_1 = 0.629 (0.280)*] and those without access to extension (MT = 0) [*Rho_0 = 0.549 (0.242)*], whereas the error term in the extension access equation is negatively correlated with the contour ploughing equation for those with and without access to extension. Similarly, for access and non-access to the extension, there is a negative relationship between the error term of extension access and the manure application. The negative relationship between the selection equation's error terms (extension access) and the outcome equations (SWC practices) suggests that farming households who did not have access to extension services self-selected themselves out of the use of the services because they did not perceived the benefits. Furthermore, the *Wald test* of independent equations rejects the null hypothesis of joint independence. For both regimes, there is thus a joint dependence between the selection equation and each of the outcome equations.

Table 4 (column 2) reports the findings of the factors hypothesized to influence access to extension services. Farmers' access to extension

Table 3
Determinants of adoption of soil and water conservation practices.

Variables	Crop rotation		Minimum tillage		Contour ploughing		Manure	
	Coeff.	*SE*	*Coeff.*	*SE*	*Coeff.*	*SE*	*Coeff.*	*SE*
Gender	0.323[a]	0.106	0.244[c]	0.128	0.138	0.108	0.079	0.118
Marital status	0.515[a]	0.167	−0.218	0.186	0.339[b]	0.169	−0.168	0.185
Age	0.309	0.451	−0.112	0.696	−0.286	0.498	−0.346	0.737
Age square	−0.160	0.323	−0.017	0.356	0.054	0.329	0.080	0.360
Primary occupation	0.047	0.409	−0.394	0.421	0.184	0.420	−0.850[b]	0.395
Farm size under cultivation	0.052[a]	0.012	0.058[a]	0.010	0.016	0.010	−0.043[a]	0.014
Non-farm employment	0.208[a]	0.081	0.095	0.087	0.240[a]	0.081	0.237[a]	0.087
Credit access	0.111	0.139	0.021	0.148	−0.031	0.135	−0.015	0.150
FBO membership	0.074	0.081	0.030	0.088	0.101	0.081	0.076	0.090
Extension service	0.401[a]	0.084	0.260[a]	0.094	0.298[a]	0.085	0.182[a]	0.091
Crop diversification index (CDI)	−0.080	0.102	−0.116	0.113	0.216	0.105	0.807[a]	0.113
Livestock diversification index (LDI)	−0.010	0.034	0.123[a]	0.037	−0.074[b]	0.034	0.172[a]	0.036
Food security status (HDDS)	0.101[a]	0.021	−0.060[b]	0.023	−0.170[a]	0.022	−0.020	0.023
experience erosion on farm plots	0.353[a]	0.093	0.208[a]	0.096	0.630[a]	0.097	0.508[a]	0.094
Constant	−2.710	4.621	−0.711	5.070	1.225	4.712	−0.510	5.166

a, b, and c denote significant at $p < 0.01$, $p < 0.05$ & $p < 0.1$, respectively. Coeff. and SE implies coefficient and standard errors, respectively.

Table 4
Determinants extension services and SWC adoption for beneficiaries and non-beneficiaries.

Variables	*Extension*	*CR = 1*	*CR =* 0 MT *= 1*		*MT = 0*	*CP = 1*	*CP = 0*	*MA = 1*	*MA = 0*
	Coeff.	*Coeff.*	*Coeff.*	*Coeff.*	*Coeff.*	*Coeff.*	*Coeff.*	*Coeff.*	*Coeff.*
Gender	−0.001	0.319[a]	0.135	0.294[c]	0.186	0.007	0.227	0.146	0.069
	(-0.107)	(0.110)	(0.148)	(-0.160)	(-0.450)	(-0.143)	(-0.207)	(-0.122)	(-0.166)
Marital status	0.288[c]	0.190	0.303	0.143	−0.255	−0.012	−0.425	−0.223	0.605[b]
	(-0.166)	(-0.180)	(-0.220)	(-0.280)	(-0.253)	(-0.266)	(-0.259)	(-0.224)	(-0.259)
Age	1.721	−2.151[a]	−1.232[a]	0.179	−0.287	−0.915	−0.371	1.728	−0.979[b]
	(-2.362)	(0.670)	(-0.098)	(-1.530)	(-0.729)	(-1.629)	(-0.245)	(-3.096)	(-0.473)
Age square	−0.196	−0.541	0.535	−0.300	0.005	0.160	0.059	−0.216	0.648
	(-0.311)	(-0.350)	(-0.410)	(-0.460)	(-0.494)	(-0.476)	(-0.559)	(-0.406)	(-0.459)
Primary occupation	0.526	0.051	−0.288	−0.110	−0.307	−1.567[b]	−0.192	0.118	−0.123
	(-0.377)	(-0.380)	(-0.458)	(-0.590)	(-0.532)	(-0.631)	(-0.611)	(-0.568)	(-0.529)
Farm size under cultivation	−0.025	0.109	0.113[b]	0.153	0.068[c]	−0.123	−0.051	0.083[b]	−0.032
	(-0.024)	(-0.030)	(0.042)	(0.040)	(0.038)	(-0.043)	(-0.056)	(0.031)	(-0.037)
Experience erosion on farm plots	−0.126	0.344[a]	0.349[b]	0.211	−0.021	0.533[a]	0.509[a]	0.606[a]	0.608[a]
	(-0.087)	(-0.100)	(-0.122)	(-0.120)	(-0.141)	(-0.120)	(-0.149)	(0.124)	(0.147)
Non-farm employment	0.117	0.171	−0.034	0.176[c]	0.069	0.174	0.289[c]	0.201[c]	0.105
	(-0.078)	(-0.090)	(-0.110)	(0.100)	(-0.135)	(-0.111)	(0.159)	(0.101)	(0.128)
Credit access	−0.047	0.067	0.256	−0.130	0.074	0.217	0.521[c]	−0.059	0.103
	(-0.131)	(-0.150)	(-0.198)	(-0.180)	(-0.224)	(-0.177)	(0.301)	(-0.151)	(0.214)
CDI	0.071[b]	−0.061	−0.049	0.118[b]	0.168[a]	0.163[a]	0.173[b]	−0.081[b]	−0.132[b]
	(0.035)	(-0.040)	(-0.046)	(0.050)	(0.054)	(0.048)	(0.067)	(-0.041)	(-0.050)
LDI	0.277[b]	−0.111	−0.371[b]	−0.090	0.100	0.952[a]	0.436[c]	0.093	0.057
	(0.101)	(-0.110)	(-0.141)	(-0.140)	(-0.181)	(0.157)	(0.224)	(-0.131)	(-0.171)
Food security status (HDDS)	0.089[a]	−0.111	−0.143[a]	0.094[a]	0.087[b]	−0.023	−0.055	−0.199[a]	−0.159[a]
	(0.020)	(-0.020)	(-0.027)	(0.030)	(-0.033)	(-0.033)	(-0.040)	(-0.027)	(-0.030)
FBO membership	0.633[a]								
	(-0.076)								
Constant	−5.387	−6.811	8.911	−6.76	0.036	1.343 (−0.983)	−0.550 (−8.026)	−1.237	1.214 (0.520)
	(-4.473)	(-5.060)	(-5.81)	(-6.71)	(-6.963)			(-0.923)	
Rho_1		−0.100[a]		0.629[b]		−0.969[a]		−0.709[a]	
		(0.003)		(0.280)		(-0.326)		(-0.229)	
Rho_0			−0.768[a]		0.549[b]		−0.399[a]		−0.629[a]
			(-0.129)		(0.242)		(-0.104)		(-0.200)
LR test of independent. Eqs. (Chi2)		28.5[a]		6.83[b]		26.9[a]		11.59[a]	

CR, MT, CP and MA denote crop-rotation, minimum tillage, contour ploughing and manure application, respectively. a, b and c denote significant $p < 0.01$, $p < 0.05$ & $p < 0.1$, respectively. Coeff. denotes coefficient and values in the parenthesis are standard errors.

service was influenced by factors such as marital status, crop and animal production diversification (as measured by the CDI and LDI, respectively), food security status, and FBO membership. Farmers with a high level of crop and animal production diversification demand the attention of extension agents for managerial and technical advice on most practices in farm management. Thus, it is not surprising that these farmers will constantly seek extension services. Similarly, food secure farming households are more likely than food insecure farming households to access extension services. This could be because food secure households either produce more food for household consumption or have enough income to buy more food, and the desire of these households to continue feeding their household members may increase their motivation to seek extension services to help them increase their food production. Another important factor is FBO membership, which enhances the probability of farmers participating in extension service programmes. This could be due to the fact that FBO has become an important communication channel for disseminating information among farming households. During group meetings, farmers discuss innovative ideas ranging from farm production to marketing, which may encourage them to participate in extension programmes [16,37].

The second step of the ESR is provided in Table 4 columns 3–10, which estimates the determinants of farmers' adoption behaviour of SWC practices for each regime. According to the findings, men who have used extension services are more likely to practice crop rotation and minimum tillage than women who have used extension services. Gender, on the other hand, had an effect on these two SWC practices among people who did not have access to extension services. Age has a negative effect on crop rotation adoption for those who had access to extension service and those who did not, and it also has a negative influence on manure application for farmers who accessed extension services. In terms of farm size, it influences the likelihood of adopting crop rotation and minimum tillage for non-access to extension services but raises the likelihood of adopting manure application for farmers who had access. Manure application is an example of a nature-based solution (NBS) that is being advocated internationally, and Ghana is no exception. As a result, extension officers are teaching FBO in many rural communities on how to prepare and use organic manure. Furthermore, having bigger agricultural landholdings improve the likelihood of adopting crop rotation and minimum tillage by farmers with no-access to extension services, and increases the likelihood of adopting manure application by farmers who had access to extension services. Except for minimum tillage, there is also a positive and significant association between farmers who have experienced erosion on their farm plots and adoption of all SWC practices for both group of farmers.

Furthermore, extension service recipients who also engage in non-farm economic activities are more likely to practice minimum tillage and manure application. Non-recipients of extension services who are involved in non-farm economic activities, on the other hand, are more likely to practice contour ploughing than non-recipients who are not involved in any non-farm economic activity. Many empirical studies [6,34,50] have predicted that access to agricultural credit has a favourable and significant influence on farmers' agricultural technology adoption decisions. However, in this study, agricultural credit enhances the likelihood of contour ploughing adoption only for farmers who did not receive extension service. Crop diversification as proxy by CDI enhances the likelihood of implementing minimum tillage and contour ploughing for both groups of farming households that receive extension services and those that did not. However, the CDI reduces the possibility of using manure for both extension service recipients and non-recipients. This is in contrast to the *a priori* expectation that diversification of crop output will enhance the likelihood of farmers using organic manure as they plant diverse varieties of crops. The findings also show that livestock diversification reduces the likelihood of practicing crop rotation for non-recipients of extension services but enhances the likelihood of using contour ploughing for both extension service recipients and non-recipients. This could be because farmers who keep a lot of animals may also have donkeys that can be used for contour ploughing; hence, save money for other farm expenditures. Furthermore, food secure households who did not receive extension assistance are less likely to practice crop rotation and manure application. Farming households that received extension services, on the other hand, were more inclined to implement minimum tillage and less likely to use organic manure.

3.3. Impact of extension services on SWC adoption: average treatment effects

Table 5 summarizes the causal effects of extension services on SWC adoption as described by Ref. [37] and given by equations (4a)–(5a). The average treatment effects on the treated (ATT) for crop rotation, manure application, and contour ploughing are 0.526, 0.178, and 0.362, respectively. These values imply that, for example, among agricultural households that receive extension services, they are about 52.6 percentage points more likely to practice crop rotation than if they did not receive extension services (the counterfactual case). Farming households that used extension services increased their chances of applying manure, and contour ploughing by 17.8, and 36.2 percentage points, respectively, than they would have if they did not receive the services.

Table 5
Average impact of extension services on adoption of SWC practices.

Soil & Water Conservation Practices	ATT	ATU
Crop rotation	0.525 (0.004)[a]	0.366 (0.007)[a]
Minimum tillage	−0.333 (0.004)[a]	−0.171 (0.003)[a]
Manure application	0.178 (0.004)[a]	0.088 (0.005)[a]
Contour ploughing	0.362 (0.004)[a]	0.271 (0.006)[a]

a denotes significance at $p < 0.01$. Values in the parenthesis are standard errors.

The heartbeat for government policymakers and other stakeholders in the field of sustainable agriculture is to understand what the benefits of extension services would be on adoption of these SWC practices among farmers who did not receive extension services if they had. This is determined by the average treatment effect on the untreated (ATU). The ATU estimated from the ESP are 0.366, 0.088 and 0271 for crop rotation, manure application and contour ploughing. If farmers that did not access extension service had done so, it would have led to about 36.6 percentage points more likely to adopt crop rotation. Similarly, for the farming households that did not access extension services, they would have increased the probability of adopting manure application and contour ploughing by 8.8 and 27.1 percentage points had they benefited from extension services. Thus, those farming households that did not access extension services would have been better if they did.

However, for minimum tillage, the negative sign indicates that extension reduces the probability of adoption by 33.3 percentage points for farming households with access to extension services and 17.1 percentage points for those who did not. That is, farmers who had access to extension services would have been better-off in terms of the probability of adopting minimum tillage if they had not, and those who did not access extension services would have been worse-off if they had received extension services. This is a cause for concern because minimum tillage keeps the soil cold and damp, which helps to preserve soil fertility. However, in northern Ghana, hoeing or ploughing with a tractor or drought animals is a frequent and long-standing activity. Farmers usually remove residue from the land's surface and use it as fodder for livestock or/and a supply of fuel wood. As a result, the soil is typically dry for about half a year before the start of the planting season. As a consequence, smallholder farmers who engaged in residue removal must till the soil to facilitate seed planting. Moreover, according to the descriptive statistics in Table 1, only 19.6% of farmers with access to extension services practice minimum tillage, whereas 19.7% of those without access to extension services do. The importance of residue to smallholder farmers, which resulted in a fraction of them adopting minimum tillage, may have had a detrimental impact of extension access on the adoption of minimum tillage. The negative impact of extension service could also be attributed to insufficient extension agents, who were most likely not involved in the information dissemination concerning minimum tillage.

The positive and the significant impact of extension services on adoption of SWC practices is in line with the study's *a priori* expectation. This is partly because extension service is the primary conduit through which smallholder farmers receive information on agricultural innovation and management practices. The agricultural extension agents are usually in direct contact with the farmers at the community levels. The results of the study also corroborate with other previous studies. For example, Makate et al. [51] observed a positive and significant impact of extension services on adoption of climate-smart agriculture. Moreover, Anang [15] observed a positive impact of extension services in Ghana on adoption of improved rice varieties. Similarly, Wossen et al. [11] observed a positive and significant impact of extension services on the adoption of improved cassava varieties among Nigerian farmers, and that the non-recipient of extension service would have had a higher probability of adopting than they did have they receive the services.

4. Conclusions and policy recommendations

The paper used a data set collected in northern Ghana to contribute to the body of literature in three key areas: (i) access the complementarities or/and subtitutabilities as well as the determinants of SWC practices; (ii) examine factors influencing farmers' access to agricultural extension services; and (iii) estimate the causal effect of extension services on adoption of SWC practice. The MVP was used to investigate simultaneous and/or substitutition adoption, as well as the predictors of SWC practices. The ESP model was used to account for self-selection bias that may be caused by observed and unobserved household factors in the impact of extension services on the adoption of SWC practices.

The study indicated that farmers had limited access to agricultural extension services. Focusing on the development of farmer-led groups is critical for boosting access to agricultural extension and ensuring that information reaches farmers. Specifically, the study recommend that the farmer-to-farmer approach to extension service delivery should be strengthened at the community levels. The farmer-to-farmer extension is a complementary method that involves farmers sharing knowledge about agricultural practices with one other. The extension directorate of the Ministry of Food and Agriculture, Ghana, can adopt the volunteer farmer-trainer approach to extension service delivery being implemented by some projects in Africa, such as East Africa Diary Development project, where volunteer farmers were trained and used to share knowledge on farm practices in their own communities. This approach can be effective because these volunteers understand the local conditions, culture and practices, and are trusted by their peers and hence have the abilities to pass on new information on farming practices.

The empirical findings reveal that there were complementarities in adoption across the SWC practices, implying that adoption of one SWC practice is contingent on adoption of another. This implies that any intervention programme that influences the adoption of a SWC practice is likely to have a knock-on effect on the adoption of other SWC practices. Thus, farm-level policies that support, say, crop rotation should also support other SWC activities like manure application to enable diverse mitigation methods against the negative effects of climate change. Farmers' participation in non-farm income, crop and livestock diversification were also found to positively influence the adoption of SWC practices. It is therefore recommended that rural farming households be encouraged to diversify their farm income into other non-farm income activities and, as a result, increase their financial ability to embrace climate-smart practices such as SWC. Crop-livestock diversification techniques should also be included in agricultural programmes to encourage the use of SWC and other farm management practices.

Generally, access to extension services had a substantial impact on the adoption of SWC practices. Farmers who had access to extension services had a higher probability of adopting three of the SWC practices (crop rotation, contour planting and manure application) than they would have had if they had not accessed extension services. In addition, farmers who did not benefit from extension services would have had a higher likelihood of adopting three of the SWC practices than they have in their non-beneficiary state. The study reaffirmed extension services' contribution to farmers' adoption of innovations and indigenous farm management techniques. Furthermore, the fact that farmers who did not access extension services would have been better-off in terms of SWC adoption if they had, implies that some factors are impeding access to extension services. Over the years, extension services in developing nations such as Ghana have primarily been championed by the state, with extremely limited budgets for execution. However, a few private groups (e.g., ESOKO) also provide extension services to farmers. With growing ICT technologies, pluralistic extension service delivery that mixes government and private-sector-led approaches to extension operations is strongly recommended. This pluralism strategy will promote flexibility, foster demand-driven extension services, and reduce the government's budgetary burden. Nevertheless, this model must be closely monitored and assessed to ensure that the needs of limited-resource farmers, who provide the majority of Ghana's food supply, are satisfied, rather than focusing on commercial farmers.

Declaration of competing interest

The authors declare that there are no conflicts of interests among them in publishing this paper.

References

[1] R. Tol, The economic impacts of climate change, J. Rev. Environ. Econ. 12 (1) (2020). https://doi.org/10.1093/reep/rex027.
[2] A. Jalloh, G.C. Nelson, T.S. Thomas, R.B. Zougmoré, H. Roy-Macauley, West African Agriculture and Climate Change: a Comprehensive Analysis, Intl Food Policy Res Inst, 2013.
[3] H. Mensah, B.J.J.o.A. Ibrahim, Sustainability 10, Alternate solutions towards sustainable irrigated agriculture in Ghana: Review of literature, 2017, 1.
[4] F.A. Armah, J.O. Odoi, G.T. Yengoh, S. Obiri, D.O. Yawson, E.K.J.M. Afrifa, a.s.f. g. change 16, Food security and climate change in drought-sensitive savanna zones of Ghana, 2011, pp. 291–306, 3.
[5] FAO, Climate-smart Agriculture: Sourcebook, 2013.
[6] A. Belachew, W. Mekuria, K. Nachimuthu, Factors influencing adoption of soil and water conservation practices in the northwest Ethiopian highlands, J. Int. Soil Water Conserv. Res. 8 (1) (2020) 80–89.
[7] M. Asnake, A. Heinimann, Z. Gete, H. Hurni, Factors affecting the adoption of physical SWC practices in the Ethiopian highlands, J. Int. SWC Resour. 6 (1) (2018) 23e30.
[8] C. Kessler, Decisive key-factors influencing farm households' soil and water conservation investments, J. Appl. Geograph. 26 (1) (2006) 40–60.
[9] G. Issahaku, A. Abdulai, Adoption of climate-smart practices and its impact on farm performance and risk exposure among smallholder farmers in Ghana, Aust. J. Agric. Resour. Econ. 64 (2) (2020) 396–420.
[10] T. Wossen, T. Berger, S. Di Falco, Social capital, risk preference and adoption of improved farm land management practices in Ethiopia, J. Agric. Econ. 46 (1) (2015) 81–97.
[11] T. Wossen, T. Abdoulaye, A. Alene, M.G. Haile, S. Feleke, A. Olanrewaju, V. Manyong, Impacts of extension access and cooperative membership on technology adoption and household welfare, J. Rural Stud. 54 (2017) 223–233.
[12] P. Antwi-Agyei, K. Amanor, J.N. Hogarh, A.J. Dougill, Predictors of access to and willingness to pay for climate information services in north-eastern Ghana: a gendered perspective, J. Environ. Dev. 37 (2021), 100580.
[13] M. Blum, F. Cofini, R.J.R. Sulaiman, FAO, Agricultural Extension in Transition Worldwide: Policies and Strategies for Reform, 2020.
[14] S. Manteaw, B. Folitse, J. Anaglo, S. Mahama, Mingle, The dynamics of agricultural extension delivery along the value chain: assessment of agricultural extension activities of MMDAs in Ghana, Ghana J. Agric. Sci. 55 (2) (2020) 70–85.
[15] B.T. Anang, S. Bäckman, T.J.S.A. Sipiläinen, Adoption and income effects of agricultural extension in northern Ghana, J. Sci. Afr. 7 (2020) e00219.
[16] M. Suvedi, R. Ghimire, M. Kaplowitz, Farmers' participation in extension programs and technology adoption in rural Nepal: a logistic regression analysis, J. Agric. Educ. Ext. 23 (4) (2017) 351–371.
[17] R. Ghimire, H. Wen-Chi, R.B. Shrestha, Factors affecting adoption of improved rice varieties among rural farm households in Central Nepal, J. Rice Sci. 22 (1) (2015) 35–43.
[18] B.E. Swanson, R. Rajalahti, Strengthening Agricultural Extension and Advisory Systems, 2010.
[19] A. Siddiqui, Z. Mirani, Farmer's Perception of Agricultural Extension Regarding Diffusion of Agricultural Technology, Pakistan Journal of Agriculture: Agricultural Engineering Veterinary Sciences, 2012.
[20] M.N.B. Agbarevo, N. Benjamin, Farmers' perception of effectiveness of agricultural extension delivery in cross-river state, Nigeria, IOSR J. Agric. Vet. Sci. 2 (6) (2013) 1–7.
[21] P. McNamara, J. Dale, J. Keane, O. Ferguson, Strengthening pluralistic agricultural extension in Ghana, J Modernizing extension advisory services discussion paper, USAID (2014).
[22] K. Davis, E. Nkonya, E. Kato, D.A. Mekonnen, M. Odendo, R. Miiro, J. Nkuba, Impact of farmer field schools on agricultural productivity and poverty in East Africa, J. World Dev. 40 (2) (2012) 402–413.
[23] A. Abdulai, W.J.L.e. Huffman, The adoption and impact of soil and water conservation technology, An endogenous switching regression application 90 (1) (2014) 26–43.
[24] A. Teshome, J. De Graaff, M.J.E.m. Kassie, Household-level determinants of soil and water conservation adoption phases: evidence from North-Western Ethiopian highlands, Afr. Econ. Hist. 57 (3) (2016) 620–636.
[25] N. Mango, C. Makate, L. Tamene, P. Mponela, G.J.I.S. Ndengu, W.C. Research, Awareness and adoption of land, soil and water conservation practices in the Chinyanja Triangle, South. Afr. 5 (2) (2017) 122–129.

[26] S. Kagoya, K.P. Paudel, N.L.J.E.m. Daniel 61, Awareness and adoption of soil and water conservation technologies in a developing country: a case of Nabajuzi Watershed in Central Uganda, 2018, pp. 188–196, 2.
[27] A. Mekuriaw, A. Heinimann, G. Zeleke, H.J.I.s. Hurni, w.c. research 6, Factors influencing the adoption of physical soil and water conservation practices in the Ethiopian highlands, 2018, pp. 23–30, 1.
[28] C. Mulwa, P. Marenya, M. Kassie, Response to climate risks among smallholder farmers in Malawi: a multivariate probit assessment of the role of information, household demographics, and farm characteristics, J. Clim. Risk Manag. 16 (2017) 208–221.
[29] T. Ojo, L. Baiyegunhi, A. Salami, Impact of credit demand on the productivity of rice farmers in South West Nigeria, J. Econ. Behav. Stud 11 (1) (2019) 166–180.
[30] S. Asfaw, F. Di Battista, L. Lipper, Agricultural technology adoption under climate change in the Sahel: micro-evidence from Niger, J. Afr. Econ. 25 (5) (2016) 637–669.
[31] G. Danso-Abbeam, L.J. Baiyegunhi, Adoption of agrochemical management practices among smallholder cocoa farmers in Ghana, Afr. J. Sci. Technol. Innov. Dev. 9 (6) (2017) 717–728.
[32] K. Thinda, A. Ogundeji, J. Belle, T. Ojo, Determinants of relevant constraints inhibiting farmers' adoption of climate change adaptation strategies in South Africa, J. Asian Afr. Stud. 56 (3) (2021) 610–627.
[33] H. Teklewold, M. Kassie, B. Shiferaw, G. Köhlin, Cropping system diversification, conservation tillage and modern seed adoption in Ethiopia: impacts on household income, agrochemical use and demand for labor, J. Ecol. Econ. 93 (2013) 85–93.
[34] L.O. Bello, L.J. Baiyegunhi, G.J.E.o.I. Danso-Abbeam, Productivity impact of improved rice varieties' adoption: case of smallholder rice farmers in Nigeria, Econ. Innov. New Technol. J. 30 (7) (2021) 750–766.
[35] M.G. Wordofa, J.Y. Hassen, G.S. Endris, C.S. Aweke, D.K. Moges, D.T.J.A. Rorisa, F. Security 10, Adoption of improved agricultural technology and its impact on household income: a propensity score matching estimation in eastern Ethiopia, 2021, pp. 1–12, 1.
[36] K.M. Wonde, A.S. Tsehay, S.E.J.H. Lemma, Training at Farmers Training Centers and its Impact on Crop Productivity and Households' Income in Ethiopia: A Propensity Score Matching (PSM) Analysis, 2022 e09837.
[37] M. Lokshin, Z. Sajaia, Impact of interventions on discrete outcomes: maximum likelihood estimation of the binary choice models with binary endogenous regressors, STATA J. 11 (3) (2011) 368–385.
[38] B. Shiferaw, M. Kassie, M. Jaleta, C.J.F.p. Yirga, Adoption of Improved Wheat Varieties and Impacts on Household Food Security in Ethiopia vol. 44, 2014, pp. 272–284.
[39] G. Issahaku, A.J.I.s. Abdul-Rahaman, w.c. research 7, Sustainable land management practices, off-farm work participation and vulnerability among farmers in Ghana: Is there a nexus?, 2019, pp. 18–26, 1.
[40] G. Danso-Abbeam, L.J. Baiyegunhi, M.D. Laing, H.J.F.S. Shimelis 13, Food security impacts of smallholder farmers' adoption of dual-purpose sweetpotato varieties in Rwanda, 2021, pp. 653–668, 3.
[41] S. Di Falco, M. Veronesi, M. Yesuf, Does adaptation to climate change provide food security? A micro-perspective from Ethiopia, Am. J. Agri. Econ. 93 (3) (2011) 829–846.
[42] A. Belachew, W. Mekuria, K. Nachimuthu, Factors influencing adoption of soil and water conservation practices in the northwest Ethiopian highlands, J. Int. Soil Water Conserv. Res. 8 (1) (2020) 80–89.
[43] C.Y. Tizale, The Dynamics of Soil Degradation and Incentives for Optimal Management in the Central Highlands of Ethiopia, University of Pretoria, 2007.
[44] M.J.D.W. Erkie, Asessment of Farmers' Awareness and Adoption on Soil and Water Conservation Practices: the Case of Borebor Micro Watershed, Addis Ababa University Addis Ababa, Ethiopia, 2016.
[45] A. Daniel, N.J.I.S. Mulugeta, W.C. Research, Factors influencing adoption of SWC practices: the case of Wereillu woreda (district), South Wollo zone, Amhara region, Ethiopia 5 (4) (2017) 273–279.
[46] G. Mohammed, D. Yan, H. Wang, A. Basaznew, C. Mersha, A. Genanew, Determinant factors influencing crop production and adoption of SWC practices in Semein Mountain National park, Ethiopia, Int. J. Environ. Sci. Nat. Resour. 13 (2) (2018), 555858.
[47] G. Danso-Abbeam, G. Dagunga, D.S. Ehiakpor, A.A. Ogundeji, E.D. Setsoafia, J. A. Awuni, Crop–livestock diversification in the mixed farming systems: implication on food security in Northern Ghana, J. Agric. Food Secur. 10 (1) (2021) 1–14.
[48] W. Mekuria, K. Mekonnen, Determinants of crop–livestock diversification in the mixed farming systems: evidence from central highlands of Ethiopia, J. Agric. Food Secur. 7 (1) (2018) 1–15.
[49] B.O. Asante, R.A. Villano, G.E. Battese, Evaluating complementary synergies in integrated crop-livestock systems in Ghana, Int. J. Soc. Econ. 47 (1) (2020) 72–85.
[50] E.A. Boahen, Effects of fertilizer adoption on household welfare: the case of cereal farmers in Ghana, J. Energy Nat. Resour. Manag. 8 (1) (2022) 9–16.
[51] N. Mango, B. Zamasiya, C. Makate, K. Nyikahadzoi, S.J.D.S.A. Siziba 31, Factors influencing household food security among smallholder farmers in the Mudzi district of Zimbabwe, 2014, pp. 625–640, 4.