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Research article

Factors influencing adoption of integrated soil fertility management technologies by smallholder farmers in Ghana

Moses Kwadzo [a,*], Emmanuel Quayson [b]

[a] Department of Agricultural Economics and Extension, University of Cape Coast, Sasakwa Center, Cape Coast, Ghana
[b] Department of Agricultural Science, Aggrey Memorial Zion Senior High School, Accra-Cape Coast Highway, Cape Coast, Ghana

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ABSTRACT

This study examines smallholder farmers' adoption of both a full set of and multiple bundles of integrated soil fertility management technologies, and estimates the determinants of and assesses the relationship among adoption practices using the logistic model and multivariate probit model respectively. A cross-sectional survey was used to collect data from 300 smallholder farmers who benefitted from a sustainable food security and environmental health project in three districts in Ghana. Four ISFM technologies (zero or minimal tillage, inorganic fertilizer, leguminous crop, and crop rotation) serve as outcome variables. The result revealed that only 26.7% of the respondents adopted the full set of the ISFM technologies. Agroecological zone, a spatial variable has been found to significantly influence smallholder farmers adoption of the full ISFM technologies. One or more of the predictor variables, purpose of farming, land ownership, distance from house to the nearest input shop, access credit and agroecological zone, have been found to significantly influence the adoption of the multiple ISFM technologies. However, the computed correlation coefficients of the independent determinants show inconsistent significant values. The implication of this finding is that the adoption of multiple ISFM technologies cannot be estimated utilizing common determinants. Therefore, extension service in the region should focus on crucial factors that influence adoption of specific multiple ISFM technologies to maximize adoption options.

1. Introduction

More than 60% of the world population depends on agriculture for its livelihood (World Bank, 2014). In many developing countries such as Ghana, about 70% of the population engages in agriculture and related activities to supply food and raw materials and generate income (FAO, 2002; World Bank, 2014). Despite the importance of agriculture to socioeconomic development, the annual agricultural growth rate at the global level is only 2–4% (Zavatta, 2014). According to the FAO (2002) and the World Bank (2014), world agricultural production, especially crop yield, has declined in recent years. This situation is likely to threaten the sustainability of food supply to meet the growing global population (FAO, ECA & AUC, 2020). Many researchers point out that low agricultural productivity is directly linked to land and soil fertility degradation, particularly in developing nations (FAO, 2015; Tully et al., 2015). Most of rural population depends on agriculture for their livelihood in the sub-Saharan Africa (SSA). For more than three decades, the agricultural growth in the sub-region is stagnant with an annual growth rate below 2% (FAO, 2015). Gomiero and Rosen (2016) point out that diminishing soil fertility is the main cause of decreasing agricultural outputs in the sub-region.

In the past, smallholder farmers in developing countries practiced natural fallowing, which involved land rotation through shifting cultivation. Farmers cultivated a piece of fertile land for a few years, moving to another area when crop yields began to decline (Collinson, 2000; Ker, 1995). Over the past five decades, high population densities have rendered these fallowing practices unrealistic, and the current situation requires the introduction of sustainable agricultural strategies such as integrated soil fertility management (ISFM) (AGRA 2015; Aura, 2016). The ISFM is a technologies package that is seen as the most ideal in addressing the problem of environmental degradation and low agricultural productivity. The ISFM technologies can be grouped into inputs and practices. The farm inputs that are advocated to be used include fertilizer, improved seeds and herbicides while recommended conservation practices are no-tillage, crop residues, mulching, cover crops, intercropping and crop rotation. The farmer has the option to choose from a number of inputs and practices. Thus, the ISFM concept emphasized multiple combinations of these technologies (AGRA 2015; Aura, 2016;

* Corresponding author.
E-mail address: moses.kwadzo@ucc.edu.gh (M. Kwadzo).

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Bellwood-Howard 2014). Vanlauwe et al. (2015), however provides a slightly different definition to ISFM. According to Vanlauwe et al. (2015), ISFM is a bundle of soil fertility management practices that essentially embrace the use of fertilizer, organic inputs and quality germplasm, combined with the knowledge of adjusting these practices to local conditions, meant to improve nutrients utilization and crop productivity. Vanlauwe's ISFM concept emphasizes the use of a full set of technologies that consists of fertilizer, quality seed and organic matter with additional practices to optimize efficiency of nutrient use.

Although agriculture remains the predominant economic activity in rural Ghanaian communities, the country's agricultural production is characterized by low yields (MoFA, 2019). According to CSIR (2018), poor agricultural crop production is largely attributed to the low organic matter content of Ghana's arable soils, which ranges from 0.00 to 5.63 percent. To address the challenge of land degradation in the country, the Ministry of Food and Agriculture (MoFA) has promoted ISFM projects in districts including Hohoe, Jasikan, and Kadjebi. These districts depend largely on agriculture, with 70% of their populations involved in agricultural activities (MoFA, 2019). Anecdotal evidence shows that farmers in these districts generally practice slash-and-burn agriculture, and do not apply inorganic fertilizer to maize crop (data not available). Concerns over these practices led MoFA to partner with AFRICARE, a non-governmental organization, to implement a sustainable food-security and environmental health project that trained smallholder farmers on ISFM technologies, including zero or minimal tillage, inorganic fertilizer, leguminous crop (organic input), and crop rotation. Maize was the project entering crop grown by all the project beneficiaries. While the benefits of ISFM technologies in improving soil fertility and agriculture production have been reported in literature, previous studies show that adoption of ISFM technologies remains low among smallholder farmers in developing countries such as Ghana (Fairhurst, 2012; Ollenburger, 2012).

Though MoFA's ISFM project activities have been carried out for more than five years in these three districts, data on ISFM adoption and practices are scant. With comparison to empirical work examining adoption of a single soil fertility management technology, few studies have examined factors that influence adoption of ISFM technologies (AGRA 2015; Aura, 2016; Bellwood-Howard 2014; Vanlauwe et al., 2015). The current study aimed to assess factors influencing adoption of ISFM technologies by smallholder farmers in the three districts in Ghana. Considering previous studies that show the adoption of ISFM technologies varies from one country to another, this study contributes to topical literature specifically within the Ghanaian context.

2. Materials and methods

2.1. Research design and study area

The current study employs a cross-sectional design, and was conducted in the three districts of Hohoe, Jasikan, and Kadjebi in the Oti and Volta Regions of Ghana. These regions are positioned along the eastern border of the country and share common boundaries with Greater Accra, Eastern, Brong-Ahafo, and Northern Regions (CWSA, 2020; GSS, 2014).

2.2. Study population and sampling techniques

The target population of the study included all individual farmers who live within the three districts and who participated in the ISFM technologies training project. These farmers belonged to different registered farmer-based organizations (FBOs) that had been receiving advisory services from MoFA. There were approximately 25 FBOs in each district, each consisting of an average membership of 20 farmers. In all, the study sample frame was 1200 farmers. The Krejcie and Morgan Table for population and sample size was used to determine the sample size for the study (Krejcie and Morgan, 1970). For a population of 1,200, a sample size of 291 is appropriate. Thus, a sample size of 300 was selected. A multi-stage sampling method was employed to choose the study sample. In the first stage, 10 FBOs were randomly selected from the registered farmer group organizations in each district. The second stage involved random sampling of 10 registered farmers from each of the sampled FBOs. This sampling technique and procedure resulted in 100 individual smallholder farmers in each of the three districts ($n = 300$), from the sample frame population of 1200. While the researcher was not required to obtain ethical approval to conduct this study, permission was nevertheless obtained from the research participants prior to data collection and subsequent publication. The data collected by means of a structured questionnaire administered with the assistance of MoFA field staff who were not part of the ISFM project team. Data collected included individual or household characteristics, institutional factors, farm characteristics, farming systems, and implementation of ISFM technologies and practices.

2.3. Dependent variables

The concept of ISFM emphasizes the use of a full set of ISFM technologies or multiple ISFM technologies by the smallholder farmers (AGRA 2015; Aura, 2016; Vanlauwe et al., 2015). The criterion variable, adoption of ISFM technologies, is operationalized in two different ways as the likelihood of a farmer using the full set of ISFM technologies or multiple bundles of ISFM technologies (zero or minimal tillage, inorganic fertilizer, legume crop, and crop rotation).

2.4. Explanatory variables

A review of technology adoption literature reveals that individual attributes (e.g., age, gender, education, household size, farmer main occupation and main purpose of farming), institutional features (e.g., land ownership, extension services, farm based organization membership, and distance from farmer's residence to central input shop), and farm characteristics (e.g., farm size, farm land fertility status, extend of land degradation and agroecological zone of the farm) can influence farmers' adoption of a given ISFM bundle (Kassie et al., 2015; Teklewold et al., 2013).

2.5. Model specification and data analysis

Data was analyzed using univariate, bivariate and multivariate analyses. In order to predict factors determining adoption of the full set of the SFM technologies and multiple bundles of the ISFM technologies by the smallholder farmers, binary logistic model and multivariate probit model were utilized respectively.

2.6. Binary logistic model

A logistic regression is a suitable test model to predict the likelihood of an event. The dependent variable is dichotomous. The predictor variables can be either categorical or continuous, or a mix of both. The likelihood of occurrence of an event can a value from 0 to l (Pallant, 2013). Using the binary logistic regression, we estimate factors influencing the likelihood of the respondents to adopt the full ISFM technologies using Statistical Packages for the Social Sciences (IBM SPSS version 25). Maize being the project entering crop was grown by all the project beneficiaries. The respondents were coded “1” for adopting the full set of ISFM technologies (zero or minimal tillage, inorganic fertilizer, legume crop (organic input), and crop rotation) at the same time, otherwise ‘0.’

2.7. Multivariate probit (MVP) model

The ISFM concept encourages the use of multiple bundles of a given ISFM technologies by farmers so as to address a number of agricultural challenges. A multivariate probit (MVP) model is useful for jointly estimating several correlated binary outcomes. In contrast, the ordinary probit model considers only one binary dependent variable (Kassie et al., 2015). The MVP model, therefore, helps to overcome problems or weaknesses associated with the univariate probit model (Dougherty, 2011).

The general specification for the MVP is (Cappellari and Jenkins, 2003; Greene, 2000)

$$yim^* = \beta m + xim + \mathcal{E}im,\ m = 1,2 \ldots 4 \quad (1)$$

$$yim = 1\ if\ yim^* > 0,\ 0\ \text{otherwise} \quad (2)$$

where

yim_* is a dormant variable that relates to the choice of a practice m.

βm represents a vector of parameters.

xim is an observed characteristic found in linear relation with yim* .

Ɛim is the stochastic error term,

yim are manifest binary variables which specify whether a farmer used a particular technology.

To predict the relative contribution of factors influencing the probability of adoption a mix of ISFM technologies, univariate and multivariate probit analyses were carried out using STATA 13.0.

3. Discussion of results

The descriptive statistics of the demographic features of the surveyed farmers are presented in Table 1.

3.1. Age

Older farmers have been found to have greater experience of production practices and to have accumulated more physical capital. However, older farmers also tend to be more risk averse, as well as susceptible to declines in physical energy. Consequently, the influence of age on technology adoption is ambiguous (Kassie et al., 2015). The mean age of respondents in this study was 43.34 years.

Table 1. Descriptive statistics of the socio-demographic characteristics of surveyed farmers.

Variables	Frequency	Percentage
Age (years)		
More than 45	135.0	
Mean	43.34	45.0
Gender		
Male	160	53.3
Female	140	47.7
Main occupation		
Farming	278	92.7
Other than farming	22	7.3
Main purpose of farming		
Commercial	234	78
Subsistence	66	31
Education		
No formal education	31	10.3
Primary school	35	11.7
Junior high/middle school	192	64.0
Senior high secondary school	30	10.0
Tertiary education	12	4.0
Household size		
Mean	6.42	
Land ownership	91	30.3
Obtained credit	67	22.3
Get extension service	300	100
Farm based organization membership	300	100
Distance from house to the nearest input shops (Km)		
Mean	15	
Farm size (hectares)		
Less than 1	186.9	62.30
Less than 2	264.0	88.00
Mean	.96	
Farmland being degraded	157	52.3
Extent of farmland degradation		
No/low	112	37.3
Moderate	164	54.7
High	24	8.0

3.2. Gender

A smallholder farmer may opt to adopt ISFM technologies regardless of his or her gender status because other production resources such as ownership of farmland may influence his decision to use such technologies. Thus, the nature of the relationship of gender to the likelihood to adopt a new technology is ambiguous. In this study, gender is coded 1 if the respondent is male, otherwise 0. About 53.3% of respondents were male.

3.3. Main occupation

Literature on small-enterprise development posits that smallholder entrepreneurs will devote most of their time and labor to develop farm enterprises if these are their main occupation, rather than representing extra income activities (FAO, 2011; Kahan, 2012*)*. The surveyed respondents were asked to indicate their main occupation with these response categories: a = farming; b = formal employment; c = vocational employment; d = others. A dummy variable was set for farmer's main occupation. Farmers whose main occupation was farming were coded '1'; otherwise, '0.'

3.4. Main purpose of farming

The purpose of farming is to produce food for family consumption and/or to generate profit. Agribusiness enterprise enables farmers to increase their income and raise living standards. Respondents were asked to indicate their main purpose for farming, with these response categories: 1 = commercial or income generation, and 2 = household food security. About 93% of respondents indicated that their main purpose of farming is commercial.

3.5. Education

Formal education is a huma cn development factor that increases individuals' capability to acquire and apply new information. It suggests that individual farmers who obtain high education are more likely to use new technologies. Education was measured as accomplishment of a specific level of formal education. About 86% of the respondents had no or low formal educational attainment, which was defined as up to middle or junior high school level.

3.6. Household size

The variable household size is a proxy for labor availability. It is assumed that a larger household size will make more labor available to adopt a new technology, which may require the farmer to carry our labor-intensive activities. It is expected that a farmer with a large household will readily adopt new technologies (Kamau et al., 2014). The mean household size of the respondents is 6.42 persons.

3.7. Land ownership

Land ownership has been found to influence a farmer's likelihood to invest in agricultural technologies such as ISFM (Kamau et al., 2014). Because investment in some farming technologies may take a long time to realize their benefits, individual land ownership will encourage the adoption of such technologies. Land ownership is measured as a categorical variable and was coded 1 if the respondent owns farmland, otherwise, 0. Just over 30% of the respondents reported that they owned farmlands.

3.8. Credit

Farmers' ability to obtain financial resources. On the other hand, financial constraints inhibit the farmer's ability to purchase farm inputs such as inorganic fertilizer or quality seeds. Consequently, farmers who readily obtained credit will more likely adopt ISFM technologies. A farmer with obtained credit is coded 1, otherwise, 0. Only 22.3% of respondents had gotten loan.

3.9. Agricultural extension

Agricultural extension is a non-formal education system that supports farm families through educational activities to improve their farming practices (Axinn, 1988). Hence, agricultural extension service tends to facilitate technology transfer. Farmers who benefit from extension service has a tendency to promote adoption of technologies. All the study respondents benefitted from extension service as part of ISFM technology training provided by the staff of MoFA.

3.10. Distance from house to input shop

The distance from the farmer's residence to a central input shop represents additional transaction costs to be incurred by the farmer. A long distance from the farmer's residence to a central input shop is negatively associated with to find agro-inputs, such as to inorganic fertilizer or improved seeds, as these also impose costs. Distance measured in kilometers. The average distance from house to central input shop was 15 km.

3.11. Group membership

A farmer's membership with a FBO provides him with the opportunity to obtain relevant information on farm inputs and operations. Additionally, FBOs present a stronger front that increase farmers bargaining power in the marketing arena (Kamau et al., 2014). All study respondents were members of FBOs that registered with MoFA for its advisory and training services, so can be considered farm group members.

3.12. Farm size

Farm size is the total farmland under cultivation. A larger land holding may inspire farmers to finance and adopt a new technology. Additionally, a small farm size may inspire the farmer to intercrop to maximize land used. Therefore, farm size may not influence the adoption of ISFM technologies in one specific direction in an empirical model. Farm size is measured in hectares. The average area of smallholdings was 0.96 ha.

3.13. Land fertility status

This is a measure of a respondent's perception of their farmland fertility status, indicating whether the farmer should address soil fertility status. A farmer who perceives their farmland as degraded is more likely to use the appropriate technology to restore soil fertility status. Respondents were to indicate whether their farmland was degraded. The responses are categorical, with 1 = yes and 0 = no. In total, 52.3% of respondents perceived their farmland to be degraded.

3.14. Extent of farmland degradation

Land degradation occurs in agroecological areas due to factors such as farming system and extent of land use. This variable measures the extent of farmland degradation. Respondents were asked to indicate the extent of degradation of their farmlands. This variable is an ordinal scale ranging from 1-3, where 1 = No or low degradation and 3 = high degradation.

3.15. Agroecological zone

Farmers residing in agroecological zone featuring degraded farmlands are more likely to adopt ISFM technologies. The spatial analysis of farmlands degraded within the study revealed that greater proportion of the farmers in Jasikan and Hohoe reported their farmlands to be degraded than those in Kadjebi (data not shown). In this study, Hohoe and Jasikan districts are reference agroecological areas with degraded farmlands and coded as agroecological zone 1 and agroecological zone 2 respectively.

3.16. Pattern of surveyed farmers adopting various ISFM technologies

The ISFM technologies considered in this study are zero or minimal tillage, inorganic fertilizer, leguminous crop, and crop rotation. Zero or minimal tillage is the reduction in the number of times a farmland is tilled during a cropping period using an orthodox tillage method (Eitelberg et al., 2015). Inorganic fertilizer has been seen as a major solution to solving soil nutrient deficiency that causes falling crop yield. Inorganic fertilizer, such as NPK and ammonia, help to improve essential nutrient supply to the soil for high crop performance (Bationo et al., 2018; Vanlauwe et al., 2015). The growing of leguminous crops such as cowpea allows the smallholder farmers to increase organic content of their soil. The practice of growing leguminous crops is advantageous where land is limited, allowing crops such as cowpea to fix substantial amounts of atmospheric nitrogen into the soil as part of the crop fallow (Arslan et al., 2014). Crop rotation is a cropping strategy that involves the growing of dissimilar crops in a precise order on the same farmland. It encourages the growing of crops with different characteristics that use the soil nutrients sequentially to sustain the productivity of the cropping system, and in addition, reduces crops infestation by destructive pests and diseases (Teklewold et al., 2013).

Table 2 presents the different combinations of ISFM technologies adopted by the farmers. Only 12.99% of the smallholder farmers used only one of the four ISFM technologies, while 30.32% of the surveyed farmers adopted and used combinations of two ISFM technologies. Almost 22% of the smallholder farmers who used the zero or minimal tillage also applied inorganic fertilizer and crop rotation. About 29% and 27% of the smallholder farmers adopted and used combinations of three

Table 2. Proportion of farmers adopted different bundles of the ISFM technology.

Possible ISFM technologies combination	Frequencies of farmers	% of farmers
Only “zero/minimum tillage”	19	6.33
Only “inorganic fertilizer”	12	4.00
Only “leguminous crop”	0	.00
Only “crop rotation”	8	2.66
“Zero/minimum tillage” and “inorganic fertilizer”	46	15.33
“Zero/minimum tillage” and “leguminous crop”	32	10.33
“Inorganic fertilizer” and “leguminous crop”	1	.33
“Inorganic fertilizer” and “crop rotation”	13	4.33
“leguminous crop” and “crop rotation”	0	,00
“Zero/minimum tillage” and “inorganic fertilizer” and “leguminous crop”	1	.33
“Zero/minimum tillage” and “inorganic fertilizer” and “crop rotation”	66	21.99
“Zero/minimum tillage” and “leguminous crop” and “crop rotation”	9	3.00
“inorganic fertilizer” and “leguminous crop” and “crop rotation”	11	3.66
All four	80	26.66
None of the four	2	.66
Total	300	100.00

and all the four of the ISFM technologies, respectively. Results show that the smallholder farmers used various bundles of ISFM technologies that they considered relevant. This points to the benefits farmers might be deriving through such combinations of ISFM technologies. The farmers' adoption of zero or minimal tillage may be attributed to the fact that, in minimal tillage, soil disturbance is kept to a minimum, while in zero tillage, no soil disturbance occurs, thereby reducing soil degradation (Zavatta, 2014**)**. The farmers reported practicing crop rotation by using leguminous crops with other crops. Prolonged planting of the same type of crop tends to deplete specific nutrients in the soil. The farmers surveyed noted that they rotated cowpea with maize, or in a few instances with cassava (data not shown). The use of nitrogen-fixing legumes such as cowpea helps to improve soil fertility, and prevents the reoccurrence of pests and diseases on the farm (Vanlauwe et al., 2015).

3.17. Complementarities and substitutionarity of ISFM technologies

Considering the varied bundles of ISFM technologies adopted by the farmers, it is likely that the farmers' use of one particular ISFM technology correlates with the adoption of other ISFM technologies. As presented in Table 3, pair-wise correlation coefficients across the residuals of the multivariate probit model were computed after the influence of the observed factors were accounted for. The binary correlation coefficients measure the correlation between the different technologies (Dougherty, 2011; Greene, 2000). The positive sign of the correlation coefficients proposes that the farmer adoption of one particular technology will likely lead to the implementation of one or more other technologies. The negative sign connotes substitutionarity between the two associated technologies. The results show that most of the ISFM technologies are complements. In this model, it appears that farmers who adopt zero or minimum tillage tend also to adopt inorganic fertilizer or leguminous crop. Furthermore, farmers who adopt inorganic fertilizer tend also to adopt crop rotation or leguminous crop. Inorganic fertilizer and crop rotation are substitutes. Many of the pair-wise correlation coefficients of the residuals of the ISFM technologies adoption are significant, confirming the suitability of the model and that new technology adoption is not mutually exclusive.

3.18. Econometric results

3.18.1. Determinants of the adoption of the full set of ISFM technologies

Adoption of ISFM is operationalized as the likelihood of the smallholder farmers adopting all the four ISFM technologies ((zero or minimal tillage, inorganic fertilizer, leguminous crop, and crop rotation) at the same time. Maize being the project entering crop was grown by all the project beneficiaries. The descriptive statistics shows that 80 (26.7%) of respondents adopted all the four technologies at the same time.

3.18.2. Regression diagnostic

The logistic model does not assume a linear correlation between dependent and predictor variables. Nevertheless, the model is sensitive to multicollinearity (McCormick and Salcedo, 2017). Tolerance and Variance Inflation Factor (VIF) were calculated in order to test for multicollinearity among the predictor variables in the model as shown in Table 4. Following a number of regression diagnostics, the predictor variables with correlations than 0.60 were selected for the logistic modeling. The computed Tolerance values for the variables are high, with a range of .636–.974, showing an overall weak relationship among the predictor variables. These values confirm the absence of multicollinearity (McCormick and Salcedo, 2017).

A logistic model was run to examine the effects of the predictor variables on the likelihood that respondents would adopt the complete ISFM technologies. The model contained eight independent variables (gender, main occupation, main purpose of farming, land ownership, getting credit, distance from house to the nearest input shops, farmland being degraded, agrological zones-Jasikan and Hohoe). The model was statistically significant, $\chi2$ (9, N = 300) = 53.47, p < .000, signifying that the model was able to differentiate between farmers who adopted and did not adopt the full ISFM technologies. The Hosmer and Lemeshow value of a good-fit logistic model is expected to that be greater than .05 **(**McCormick and Salcedo, 2017**)**, and this is true for the model with its Hosmer and Leeshawn's value being .803. The model as a whole explained 23.8%) of the variance in adoption status, and correctly classified 73.7% of cases. (percentage accuracy in classification: PAC) (Pallant, 2013). Only three of the predictor variables, land ownership and agroecologicalzone, had been found to make a statistically significant influence to the model (Table 5).

Table 3. Correlation coefficients between ISFM technologies.

Combination of ISFM technologies	Correlation coefficient	Standard error
"Zero/minimum tillage" and "inorganic fertilizer"	.060	.119
"Zero/minimum tillage" and "leguminous crop"	.245*	.115
"zero/minimum tillage" and "inorganic fertilizer"	.115	.107
"Inorganic fertilizer" and "leguminous crop"	.029	.115
"Inorganic fertilizer" and "crop rotation"	-.017	.114
"leguminous crop" and "crop rotation"	.765*	.167

Correlation coefficients between the residuals from the multivariate probit equations.

* Indicate statistical significance at the 1% level.

Table 4. Collinearity statistics on predictor variables.

Variables	Tolerance	VIF
Gender	.973	1.027
Main occupation	.974	1.026
Main purpose of farming	.971	1.012
Land ownership	958	1.044
Obtained credit	.958	1.044
Distance from house to the nearest input shops	.913	1.095
Farmland degraded	.860	1.163
Agroecologicalzone1	.636	1.571
Agroecologicalzone2	.624	1.603

Table 5. Results of logistic model for the adoption of full ISFM technologies.

Independent Variables	*B* (S.E.)	Odds Ratio (B).	95% C.I. for EXP	
			Lower	Upper
Gender	.336 (.287)	1 .399	.797	2.496
Main occupation	364 (.620)	1.438	.427	4.851
Main purpose of farming	.204 (.324)	1.226	.650	2.314
Land ownership	-.858 (.339)	.424*	.218	.824
Obtained credit	.297 (.330)	1.345	.704	2.570
Distance from house to the nearest input shops	-.001 (.008)	.999	.982	1.015
Farmland being degraded	.093 (.312)	1.098	.595	2.024
Agroecologicalzone1	2.521 (.536)	12.445***	4.352	35.591
Agroecologicalzone2	2.479 (.524)	11.930***	4.269	33.337
Constant	-3.410			
-2Log-Likelihood	294.478			
N	300			
Pseudo R Square	.238			
Hosmer & Lemeshow	.803			
Goodness-of-Fit Prob > chi2	.000			
PCA	73.7			

Significant for coefficients: p*<.05; p**< .01; p***< .001.

Table 6. Results of probit models for the adoption of multiple bundles of ISFM technologies.

Variables	Zero or minimum tillage b (SE)	Inorganic fertilizer b (SE)	Leguminous crop b (SE)	Crop rotation b (SE)
Age	.004 (.009)	-.014 (.008)	.002 (.008)	.001 (.007)
Gender	.129 (192)	.120 (.187)	.058 (.167)	.007 (.167)
Main occupation	.295 (.344)	.219 (.333)	.362 (.355)	.042 (.295)
Main purpose of farming	.647**(.259)	-.186 (.185)	-.087 (.183)	-.073 (.183)
Education	.092 (.234)	.228 (.218)	-.273 (.202)	-.097 (.205)
Household size	.033 (.037)	.059 (.036)	-.002 (.032)	-.017 (.030)
Land ownership	-.661***(.205)	-.139 (.201)	-.240 (.185)	-.124 (.180)
Obtained credit	-.305 (.217)	.345 (.241)	.061 (.196)	.654***(.222)
Distance from house to the nearest input shops	.011 (.007)	.020**(.008)	-.000 (.000)	.007 (.006)
Farm size	.130 (140)	-.022 (.100)	-.088 (.093)	-.059 (.090)
Farmland degraded	.029 (.207)	-.123 (.197)	-.168 (.185)	.040 (.183)
Extent of farmland degradation	.127 (.161)	-.247 (.157)	.066 (.146)	.235 (.151)
Agroecologicalzone1	.407 (.256)	1.166***(.275)	1.086***(.248)	.628**(.226)
Agroecologicalzone2	.824***(.256)	.646**(.228)	1.096***(.241)	.800***(.220)
_cons	-.564 (.649)	.334 (.612)	-1.395 (.595)	.224 (.555)
N = 300 Wald chi2 (56) = 126.83*** Log likelihood = -553.38				
Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0: chi2 (6) = 42.56 Prob > chi2 = 0.0000				

Note. Regression coefficient is significant for coefficients: $p^* < .10$ $p^{**} < .05$; $p^{***} < .01$.

The strongest predictor of respondent's adoption of the full ISFM technologies is agroecologicalzone recording an odds ratio of 12.45 and 11.93 for Jasikan and Hohoe agroecological zones respectively. This indicated that farmers in Jasikan and Hohoe who adopted the full ISFM technologies are about 11 times more likely to adopt the full ISFM technologies than farmers in kadjebi, adjusting for all other variables in the model. Smallholder farmers in agroecological zones with degraded farmlands are more likely to adopt ISFM technologies (Assefa and Hans-Rudol, 2016; Lahmar et al., 2012). Greater proportion of the farmers in Hohoe and Jasikan reported their farmlands to be degraded than those in Kadjebi. This observation is not surprising since the two agroecological zones, Hohoe and Jasikan, are more populated and hence more likely to be degraded than those in Kadjebi **(**GSS, 2014**)**. In unexpected direction, land ownership has been found to have significant negative relationship with the adoption of the full ISFM technologies (Fosu-Mensah et al., 2012**)**. The finding could be attributed to the fact that cocoa is the main cash crop in the study area (MoFA, 2019). Because cocoa is a perennial crop, it is often grown by farmers who own lands. When the smallholder farmers own farmlands, they might more likely divert them to cocoa production.

3.18.3. Determinants of the adoption of ISFM technologies

Previous studies show that farmers do not always adopt a complete package of a technology even when extension service attempts to promote innovative technologies. They instead adopt a part or components of a recommended technology (AGRA, 2015; Aura, 2016; Mulwa et al., 2017). The probability of adopting a part or multiple bundles of the ISFM technologies is jointly estimated using multivariate probit. The likelihood ratio test is significant: χ^2 (6) = 42.56; ρ = 0.000. This implies the equations (models) are independent, and the use of MVP models is justified for capturing a wider effect than a single probit model. The significant null likelihood ratio tests for all the models suggest that the farmers jointly adopted multiple of the four ISFM technologies**.** The marginal effects of the explanatory variables were computed to predict the probabilities change in dependent variables as the independent variable changes. The values of the computed marginal effects are found to be same as the coefficient estimates (b) of the MPV models (data not shown). Previous studies have shown that technology adoption may be influenced by individual, institutional factors, and farm characteristics (Ashraf et al., 2014; Ghimire et al., 2015; Ndlovu et al., 2014; Rogers, 2003). The computed correlation coefficients of the independent determinants in the probit model show inconsistent significant relations to the adoption of the multiple ISFM technologies, zero or minimum tillage, inorganic fertilizer, leguminous crop and crop rotation (Table 6). Previous studies on ISFM technologies adoption have been found to show similar patterns of varying values of correlation coefficients for predictor variables (Arslan et al., 2014; Bonabana et al., 2016; Murendoa et al., 2016). One or more of the independent variables including purpose of farming, land ownership, distance from house to the nearest input shop, obtaining credit and agroecological zone have been found to significantly influence the adoption of the multiple ISFM technologies.

Smallholder farmers often engage in farming enterprise to produce enough for consumption and/or for sale. Most farmers in this study cited their main farming purpose as commercial. Interestingly, the main purpose of farming has a positive and significant effect on respondents' adoption of zero or minimal tillage**.** The farmers' likelihood to adoption the zero or minimal tillage may increase by 0.65 times due to their main purpose of farming. **A** farmer's engagement in any form of agriculture enterprise requires the management of various types of risk, such as soil degradation, or taking the opportunity to adopt innovative, yield-increasing technologies. The farmers were more likely to practice zero or minimum tillage to prevent soil erosion and thereby increases crop (Achterbosch et al., 2014).

Previous studies indicate that land ownership has a positive effect on a technology adoption (Fosu-Mensah et al., 2012). The results of the current study show significant negative associated between land ownership and the adoption of the zero or minimal tillage. The coefficient value of -0.66 for land ownership means farmers likelihood to practice zero or minimal tillage will decrease by 0.66 times. The unexpected negative coefficients could be explained by the fact that cocoa is the main cash crop in the study area (MoFA, 2019). Because cocoa is a perennial crop, it is often grown by farmers who own land. Most farmers in Ghana do not own farmland and therefore tend to grow arable crops including cereals and legumes. When the smallholder farmers own farmland, they may divert it to cocoa production. However, land preparation for cocoa production often involves heavy tillage including clearing of undergrowth, felling of trees and stumping. Thus, land ownership may cause farmers to divert to cocoa farming with less zero r minimal tillage. Many studies have reported a positive association between getting financial resource and technology adoption (Nhemachena et al., 2014; Tesfaye and Seifu, 2016). The result of the study shows positive significant correlation (0.65) between getting fund and adoption of maize-cowpea rotation. The positive significant correlation between getting fund and adoption of maize-cowpea rotation implies that farmers having fund would more likely increase their adoption of maize-cowpea rotation since they readily have money to purchase farm inputs including cowpea seed.

The coefficient for distance from house to the nearest input shop is 0.02 and has a significant positively correlation to the adoption and use of inorganic fertilizer. Ordinarily, the further the input shop from the farmer's house, the less the likelihood of the farmers adopting the new technologies, because of the extra transactional costs involved in doing so. The unexpected positive coefficient for distance from house to the nearest input shop could be explained by the fact that the study respondents often buy their agro-inputs from a specific shop called "One Shop Center". The "One Shop Center" is a special agro-input shops built by Africare in Hohoe and Jasikan districts for the farmers. Because the farmers own these shops, they are willing to travel any distance to buy inputs from these shops. Literature shows that the nature of agroecology can have a negative or positive effect on the adoption of ISFM technologies (Lahmar et al., 2012). It is expected that farmers in districts with farmland more relatively degraded are more likely to adopt the ISFM technologies. Most farmers in both Jasikan (Agroecologicalzone1) and Hohoe (Agroecologicalzone2) districts reported of their farmlands being degraded, compared to those at Kadjebi (data not shown). The econometric results show that farmers in Agroecologicalzone1 and Agroecologicalzone2 are more likely to adopt the zero or minimal tillage, inorganic fertilizes, leguminous crop and crop rotation.

Generally, the correlation coefficients of the probit model show that the adoption of the multiple ISFM technologies does not provide common determinants.

4. Conclusion

This paper assesses factors that affect the adoption of full and multiple ISFM technologies by smallholder farmers in three districts Ghana. The result revealed that only 26.7% of the respondents adopted the full ISFM technologies. This confirmed previous findings that farmers do not often adopt a complete package of a technology. Agroecological zone with its farmlands being degraded has been found to significantly influence farmers adoption of the full ISSFM technologies. Instead of adopting the full ISFM technologies, majority of the smallholder farmers adopted parts of the recommended technology. One or more of the independent variables including main purpose of farming, land ownership, distance from house to the nearest input shop, getting credit and agroecologicalzone have been found to significantly influence the adoption of the multiple ISFM technologies. The computed correlation coefficients of the independent determinants in the probit model show inconsistent significant relations to the adoption of the four ISFM technologies, zero or minimum tillage, inorganic fertilizer, leguminous crop and crop rotation (Table 6). Five out of six bundles of ISFM technology adoption options complement one other, since most of the correlation coefficients are positive. The implication of this finding is that the adoption of multiple ISFM technologies cannot be predicted using common determinants. Therefore, extension service in the region should focus on crucial factors that influence adoption of the multiple ISFM technologies and in addition emphasizes the complementarities between the technologies to widen farmers' adoption options.

Declarations

Author contribution statement

Moses Kwadzo: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Emmanuel Quayson: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data will be made available on request.

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The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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