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Factors Influencing the Adoption of Agricultural Practices in Ghana's Forest-Fringe Communities

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Abstract: Two-thirds of rural Ghanaians are farmers, and farming is almost the only income source for Ghana's forest-fringe communities. Some farmers adopt some agricultural practices to augment their operations while others do not. We examined the factors that influence farmers' adoption and intensity of adoption of agricultural practices, namely, chemical fertilizers, pesticides, herbicides, improved seeds, animal manure, and crop rotation. We surveyed the agricultural systems and livelihoods of 291 smallholder households in forest-fringe communities and developed a multivariate model (canonical correlation analysis) to test the degree to which social, economic, and institutional factors correlate with adoption and intensity of adoption of the above practices. We found that 35.4% of the farmers do not adopt any of the practices because they perceive them to be expensive, not useful, and difficult to adopt. The rest (64.6%) adopt at least one of the practices to control weeds, pests and diseases, and consequently increase crop yields. Our results indicate that farmers that perceive the aforementioned practices to be more beneficial, cultivate multiple plots, and have access to extension services adopt more of the practices. Farmer age and distance to source of inputs negatively correlate with adoption and intensity of adoption of agricultural practices. Almost two-thirds each of adopters and non-adopters do not have access to agricultural extension services and this could pose threats to the sustainability of the forest reserves within and around which the farmers cultivate. Educating farmers on agricultural practices that are forest-friendly is critical in the forest-fringe communities of Ghana. The correct application of practices could double outputs and minimize threats to forests and biodiversity through land-sparing.

Keywords: farming systems; agricultural education; farm intensification; forest-fringe communities; rural Ghana

1. Introduction

Agriculture employs over 70% of Ghana's rural workforce and almost all residents of forest-fringe communities are farmers [1]. Many of these farmers have their farms within and at the fringes of forest reserves officially protected and managed by the Forestry Commission of Ghana for conservation and/or production [2]. Farming practices such as the use of agricultural inputs influence the economic welfare of farmers [3,4]. Farmers adopt practices to control weeds, pests and diseases, and improve crops yields and outputs [5,6]. However, when these practices (e.g., application of herbicides and pesticides) are adopted within forest frontiers, they may adversely affect tree species that are naturally regenerating, beneficial insects, and other living organisms that contribute to the richness of the forests' biodiversity [7–9]. Agricultural practices such as legume-crop rotation and intercropping, and the application of organic manure, help enrich the soil and increase crops yields with minimal negative agro-ecological impact [10–12]. Farmers' adoption of agricultural

practices is however contingent on a range of factors such as land tenure, access to inputs and extension services, and the farmers' perceptions of such practices [13–16].

Farming practices such as slash-and-burn cultivation and incorrect application of agricultural inputs at forest frontiers are one of the major causes of deforestation and forest degradation in Ghana [17–19]. Slash-and-burn with continuous mono-cropping has led to degraded and infertile soils—a major constraint to increased agricultural productivity [19–21]. The use of fertilizers, herbicides and pesticides has improved agricultural productivity but with some negative environmental impacts including soil compaction, salinization, and acidification, and damage to indigenous flora and fauna [5–8]. Adoption of forest-friendly agricultural practices at forest frontiers in Ghana could play an important role in improving agricultural productivity and forest protection.

Farming practices are intrinsically linked both to the scale of agricultural activities and the goal of farming, whether subsistence or commercial. For instance, rice farmers in Northern Ghana who implement row-planting in addition to the use of improved seeds and agro-inputs tend to produce higher yields for markets e.g., [12,14,22]. Regardless of farm scale, research has demonstrated the importance of various agricultural intensification techniques to increase yields, restore soil quality, and enhance the resilience of smallholder farming systems. These techniques include legume-crop rotation and intercropping, conservation tillage, use of improved crop varieties and animal manure, soil and stone bands for soil and water conservation, and agroforestry for tree-friendly farming [23,24]. Some of these practices apply to specific contexts but they have been shown to be effective in improving yields and increasing outputs with minimal environmental disturbance when properly applied [21,23,24]. Here, we examine the factors influencing farmers' adoption of some agricultural practices in order to recommend approaches for sustainable agriculture in African forest-fringe landscapes.

2. Adoption of Agricultural Practices: A Conceptual Review

Here, we examine agricultural inputs and agricultural practice under the general term 'practices'. The inputs of interest are chemical fertilizers, pesticides, herbicides, improved seeds, and animal manure. Crop rotation is the practice identified with the aforementioned inputs.

In Ghana, researchers have documented the extent of farmers' adoption of various agricultural practices and their effects on soil fertility, agricultural productivity, food security and household incomes [12,18,25–31]. Some of these studies have demonstrated that the adoption of agricultural practices is influenced by farm size, the effectiveness and frequencies of agricultural extension services, farmer education, input availability, and distance to sources of inputs [14,16,25,29]. For instance, Kotu et al. [25] observed that most farmers are unwilling to travel long distances to purchase agricultural inputs, e.g., chemical fertilizers; hence, they continue with slash-and-burn farming. Others even do not have access to such inputs and as a result do not adopt innovative technologies [27,28]. Issahaku and Abdulai [30] and Zakaria et al. [26] observed that education of household head, access to extension and weather information, and membership of farmer-based organizations influence farmers' likelihood of adopting climate-smart agricultural practices. Zakaria et al. [26] further stated that the intensity of adoption of climate-smart practices depends on farmers' participation in capacity building programs, family labour, and access to agricultural insurance. Ehiakpor et al. [29] identified that the intensity of adoption of sustainable practices is influenced by farmers' access to agricultural credit, participation in field demonstrations, and farm size. Similarly, [31] found that the intensity of adoption of sustainable soybean production technologies in northern Ghana is determined by age, education, extension visits, mass media, and perception of adoption. Generally, farm characteristics, socio-economic, and institutional factors determine the agricultural practices a farmer adopts, while the intensity of adoption in a given place also reflects a farmer's motivation and capacity [32].

It is not only in Ghana that farmers adopt and intensify their adoption of new or existing practices for various reasons. For instance, smallholder farmers in Zambia and Kenya who own their farmlands tend to practice agroforestry and mixed cropping to sustain production, while conversely farmers with insecure land tenure tend to use chemical fertilizers to sustain production [33,34]. Faße and Grote [35] observed that experienced farmers in Tanzania employ crop diversification and agroforestry more than inexperienced farmers because the latter have little knowledge about farming techniques. Kassie et al. [36] found that households with short-lease land tenure adopt legume intercropping and chemical fertilization to increase short-term productivity, with the intensity of their adoption correlating with farm size, distance to farms, and availability of household labour. According to Kassie et al. [36], household size positively influences farmers' use of manure since collecting and transporting manure to farms is labor intensive.

However, the issue surrounding the Ghanaian studies reviewed above is that none of them considered the locations of farms to determine whether the practices adopted could conflict with the surrounding landscapes and the possible resolutions that could be offered. Research sites were generally arable lands used for subsistence and commercial farming, not designated as forest reserves, and where sometimes there are almost no forest. Farmers in forest-fringe communities in Ghana however cultivate within and around forest reserves that are officially protected [37–39]. Evidence shows that these farmers often rely on the forests as land banks for agricultural production when their existing farmlands become infertile [37,40].

According to Acheampong et al. [17], agricultural expansion between 1986 and 2015 caused 78% of the deforestation in the forest reserves of the Ashanti region. The underlying factors were that, first, before the demarcation of the areas as forest reserves, human settlements and farms already existed within the forests [39]. The Forestry Commission of Ghana allowed the settlers and their farms to remain in the reserves with their boundaries delineated to prevent further encroachment into the reserves. Population growth and weak enforcement of forest protection laws led to the expansion of the farms into the reserves. Second, a majority of the inhabitants interplant their food crops with tree crops for cash and depend on natural soil fertility to increase output. According to these farmers, when the tree crops form a canopy, they encroach more of the forest in the search for fertile land to cultivate their food crops [17]. Since the tree crops are the main source of income for the farmers, after about two years of cultivating the newly cleared land, they will interplant their food crops with tree crops.

This continuous conversion of protected forestlands to agriculture reduces forest cover and biodiversity, limits the provision of ecosystem services, and contributes to climate change [17,41–43]. The adoption of certain high-yielding agricultural practices by farmers in forest-fringe communities may enhance agricultural sustainability and forest conservation. This is possible via a presumed 'land-sparing' effect whereby higher yields on existing plots diminish the need to convert surrounding forests [44]. We explore the factors influencing the adoption and intensity of adoption of the agricultural practices listed above at forest frontiers of Ghana and offer possible recommendations for agriculture and forest sustainability.

3. Materials and Methods

We surveyed 291 farmers in forest-fringe communities of the Ashanti region of Ghana (Figure 1) to obtain data on their farming operations. We used the farmers' cropping patterns and inputs to identify the agricultural practices they adopt. We used the farmers' perceptions to identify the rationale for adoption and non-adoption of the practices. We then examined the extent to which socio-economic, institutional, and farm factors influence farmers' adoption of agricultural practices.
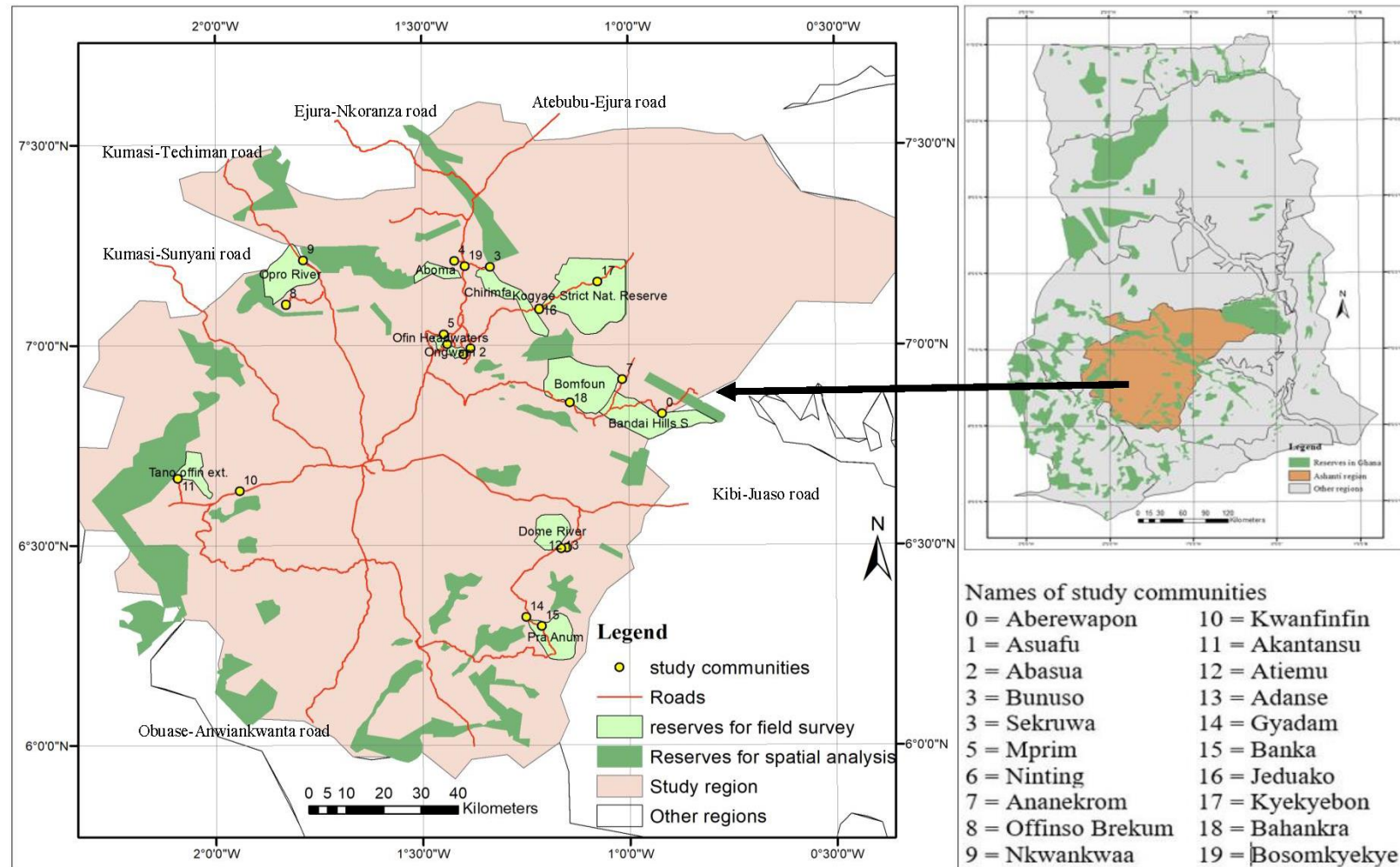
Figure 1. The Ashanti region of Ghana and its forest reserves. Source: [2].

3.1. Study Area

The Ashanti region (Figure 1) occupies 24,389 km^2, about 10% of Ghana's land area and is located between longitudes 0.15° W and 2.25° W, and latitudes 5.54° N and 7.46° N [45]. The region has mean annual rainfall of 1,270 mm and two rainy seasons: April-August and September-November. The region contains 58 of the 256 forest reserves in Ghana. We chose this region for the study because it has a high deforestation rate and the northern part of the region is transitioning from forest vegetation to savannah woodlands [2].

Recent research shows that farming is a major cause of deforestation and forest degradation in the region [17]. As described by Acheampong et al. [17], the forest extent within the region's forest reserves declined by 33.2% since 1986, with more than two-thirds of such degradation attributable to the expansion of annual crop farms and tree crop plantations. Of 291 farmers surveyed, about one-fifth hold farms within the forest reserves while half are within 5 km of reserve boundaries. All the farmers are slash-and-burn semi-subsistence cultivators. The prevalence of slash-and-burn has contributed to forest degradation within and around the forest reserves in the region.

3.2. Sample Size Selection and Data Collection

The forest reserves in the Ashanti region have the most forest-fringe communities in Ghana and over 70% of the residents in these communities are farmers [2,45]. We selected 10 of the 58 forest reserves in the region at random and sampled communities that are within 3 km from the 10 reserves. Although the standard distance used by the Forestry Commission of Ghana for a forest-fringe community is 5 km [46], we chose to use 3 km to capture the communities that were closest to the reserves. This sampling frame contained 192 communities. We selected two communities at random for each of the 10 reserves considered in our survey (See Table A1). The total households for the 20 sampled communities was 4202, of which 2942 (70%) were estimated to be farmer households at the time of the survey [45]. From this 2942 farmer households, we randomly sampled 291, entailing a 5% error margin (95% confidence of estimated values) for our survey (See Appendix A) [47]. The 291 sampled farm households were distributed proportionately among the 20 sampled communities based on the estimated total number of farm households in each community.

We carried out a household survey from March to June 2018 to collect data on farmers' perceptions for adopting or not adopting some agricultural practices using survey questionnaires. The practices we identified from our survey are the use of fertilizers, herbicides, pesticides, animal manure, improved seeds, and crop rotation. All the farmers practice slashing-and-burning before cultivation so we did not consider slash-and-burn as a potential practice to be adopted. Crop rotation was considered as a practice because it is an alternative means of adding inputs (e.g., natural nitrogen fertilizers) to the soil yet not all farmers practice it.

Data on farmers' age, education, household labour, labour hired, and distance to sources of inputs, access to extension services, farming system, land tenure, and plots per farmer were the socio-economic, institutional, and farm variables collected to determine the extent of their influence on the adoption of the agricultural practices identified (Table 1). We ensured that farmers surveyed in each community were randomly distributed across their respective communities. Only one farmer was surveyed in each house and household (some communities had compound houses with more than one farm household) to avoid pseudo-replication.

Table 1. Descriptive statistics of variables investigated and the statistical values of the quantitative variables calculated by the authors

Factors of Adoption	Variables Measured/Identified	Categories	Mean Value	Standard Deviation	Mean Difference	*t*-Values	Description of Variables
Socio-economic	Age	Adopters	46.98	14.83	−2.209	−3.628	Age of the famer (e.g., 58 years)
		Non-adopters	50.61	12.53			
	Education	Adopters	6.840	4.45	0.890	0.471	Level of education the farmers completed
		Non-adopters	6.37	4.06			
	Household size	Adopters	4.30	2.39	1.049	0.293	Number of people in a farmer's household
		Non-adopters	4.01	2.06			
	Household labour	Adopters	1.74	1.24	−0.020	−0.003	Household members working with the farmer
		Non-adopters	1.75	1.13			
	Number of hired labour	Adopters	3.90	3.64	1.996	0.839	Farm labourers the farmer hires per cropping season
		Non-adopters	3.06	2.97			
	Distance to source of inputs	Only adopters	11.13	17.51			Distance (in km) to main source of input
Institutional	Access to extension services						Extension officers' visit to community
Farm characteristics	Farming system						Mixed cropping, mono cropping, mixed and mono cropping
	Land tenure system						The landholding status of the farmer (e.g., own, lease)
	Number of farm plots	Adopters	1.66	0.98	3.039	0.315	Number of plots the farmer is currently cultivating
		Non-adopters	1.35	0.76			
	Number of practices adopted	Only adopters	1.24	1.24			Complementary practices a farmer adopts at a time
Perceptions for adoption							Reasons why the farmers adopt the practices
Perceptions for non-adoption							Reasons why the farmers do not adopt any practice

Distance to source of inputs refers to the number of kilometers a farmer has to travel to purchase their preferred input. This distance is based on the most preferred location that the farmer purchases inputs. Extension officers visit farming communities to provide agricultural education. We asked farmers if an extension officer visited their community during the previous or the current cropping season. We did not ask the frequency of visits.

Farming system refers to how the farmers cultivate, whether they mix their crops on their farmlands (mixed cropping), grow only one crop on all their lands (mono cropping), or mix crops on one land and grow only one crop on another land (mixed and mono cropping). The farmers were asked about their perceptions for adopting the practices. For the purpose of quantitative analysis, all adopters were assigned the value of one (1) while non-adopters were assigned zero (0). Reasons for not adopting any practice were also obtained from the non-adopters. This was used for descriptive analysis only.

3.3. Data Analyses Techniques

The data on farming practices the farmers adopt and the perceptions for adoption and non-adoption were first descriptively analysed and related to the farming operations of the respondents. We used the multivariate technique, canonical correlation analysis (CCA), to assess the relationship between adoption and intensity of adoption of agricultural practices and a set of adoption factors, namely, age, education, household size, household labour, hired labour, access to extension services, number of farm plots, land tenure, distance to sources of input, and perception for adoption. We adopted this technique to limit the probability of a type 1 error [48] by performing one statistical test on the same predictors for the two dependent variables (adoption and intensity of adoption) instead of running separate univariate models. We relied on Wilks' test of significance to assess the significance of the full model and the proportion of the variance explained by the variable sets [49]. We then tested the hierarchical arrangements of the canonical covariates for statistical significance through the dimension reduction analysis. This was done to determine whether only the first canonical covariate or both are worthy of interpretation. We adopted a cut-off correlation of 0.30 to determine the variables that contribute significantly to the relationship between the adoption variables and the factors of adoption [50]. We checked the data for normality, linearity, and absence of multi-collinearity for the purpose of the multivariate analysis, specifically the correlation analysis. The data were generally normally distributed and when they were not, they were log transformed to approximate normality [51]. Multi-collinearity was not problematic [52].

4. Results

We identified six main agricultural practices that some farmers in the forest-fringe communities of the Ashanti region complement with slash-and-burn. These are chemical fertilizers, pesticides, herbicides, improved seeds, animal manure, and crop rotation. While 64.6% of the farmers adopt at least one of the practices, 35.4% have some reservations that discourage them from adoption of any practice. Out of the 103 farmers that rely only on slash-and-burn, 44.7%, 28.2%, and 13.6% perceive that the above complementary practices are expensive, not useful, and difficult to work with, respectively. There are other secondary reservations as well (such as 'not allowed' = 7.8%, and 'no more supplies' = 5.8%). The majority of these 103 non-adopters (76.7%) do however practice inter-cropping to hedge against the failure of a given crop, and 72.4% of these mixed croppers perceive the aforementioned agricultural practices as not useful. Most of these mixed croppers admitted that they do not need to rely on inputs for increased production because the residues from their crops add nutrients to the soil—a statement that is technically true but short sighted, given that nutrients are progressively leached in the absence of fallowing.

Various land tenure systems exist in the forest-fringe communities. We have categorized them into three—private land (own land), leased land, and forest reserve (Table 2), based on the responses the farmers gave concerning how they obtained the land. Private land is the land that the holder owned through gifting, share cropping to land sharing ar-

rangements, inheritance, and outright purchase. Leased land is that which the farmer rents for a period of time and pays the rent by either cash or other crop sharing arrangements. Reserve land is a degraded land in the forest reserve that the foresters apportion to farmers in need of land but require the farmers to interplant their food crops with trees supplied by the foresters.

Table 2. Descriptive statistics of the farmers and their farming practices. * The number of farmers that adopt at least one agricultural practice is 188. The total for the categorized perceptions for adoption is 224 farmers because some farmers gave more than one response. The percentage is however out of 188 to reflect the responses against the number of farmers that adopt the practices. ** 'None' refers to the farmers who do not adopt any of the practices but rely solely on slash-and-burn. The percentage for 'none' is out of the total farmers.

Categorical Variables	Categories	Number of Farmers	Percentage
Main practices adopted	Use of herbicides	45	15.5
	Legume-crop rotation	28	9.6
	Use of improved seeds	12	4.1
	Use of organic manure	4	1.4
	Use of inorganic fertilizers	83	28.5
	Use of pesticides	16	5.5
	None	103	35.4
Perceptions for adoption *	Controls pests	10	5.3
	Increases yield	91	48.4
	Makes farming easy	84	44.7
	Controls weeds	39	20.7
	** None	103	35.4
Land tenure system	Leased land	68	23.4
	Own land	190	65.3
	Forest reserve	33	11.3
Farming system	Mixed cropping	194	66.7
	Mono cropping	74	25.4
	Crop rotation	6	2.1
	Mixed and mono cropping	17	5.8
Access to extension services	No	187	64.3
	Yes	104	35.7
Total farmers (N)		291	100.0

The majority (75.7%) of the non-adopters own their farmlands, while 10.7% and 13.6% farm on leased land and reserve land, respectively. Out of the 46 non-adopters who own their farmlands, 76.1% perceive the agricultural practices as expensive. These farmers reported that their farming operations do not yield enough income to purchase inputs. Data on incomes were however difficult to obtain from farmers. Finally, 78.6% of the non-adopters who perceive the practices to be difficult to apply own their farmlands. Probing further, we found that these farmers have not attempted to apply any of the practices before; hence, the farmers only perceive adoption to be overly difficult to attempt, suggesting a crucial role for further agricultural extension.

According to the reserve-land farmers who secured their farmlands from forestry officials, one condition of their land acquisition was that they would apply no chemical agricultural input (e.g., herbicides, pesticides) because these inputs adversely affect the survival and growth of the young trees planted amidst food crops. Land tenure and associated farming systems therefore have effects on the likelihood of farmers adopting complementary agricultural practices. Other farmers however have some reasons for adopting various agricultural practices in the study area.

The mean distance from the communities to the nearest central markets where the farmers sell their produce and purchase agricultural inputs is 11 km. Twelve of the 20 study communities have agro-chemical shops from which inhabitants can purchase agricultural inputs. Almost all (18) of the communities have information centers that relay various information, including that on agriculture, to their members. Eleven of the 20 communities had extension service visits at least before our survey. It is however worth mentioning that according to our study, adoption or non-adoption of complementary agricultural practices is not based on a community's nearness to central markets, availability of agro-chemical shops and information centers in community, operation of periodic markets in community, or any other characteristic of a community. This is because each community had a mix of adopters and non-adopters based on the farmers' perceptions and some other probable factors which are elaborated in the succeeding sections.

Adoption and Intensity of Adoption of Complementary Agricultural Practices

Chemical fertilizer application is the main practice that 44.1% of the 188 adopters have applied, followed by the use of herbicides (23.9%) and the practice of legume-crop rotation (14.9%). Pesticides use (8.5%), the use of improved seeds (6.4%), and the application of organic manure (2.1%) are the other practices adopted (Table 2).

We conducted canonical correlation analysis to evaluate the multivariate-shared relationship between social, institutional and farm factors and adoption and intensity of adoption of agricultural practices. The analysis produced two canonical covariates with squared canonical correlations (R_c^2) of 0.716 and 0.094 for canonical variates 1 and 2, respectively (Table 3). The test statistics of the multivariate model adopting Wilks' Lambda criterion ($\lambda = 0.257$, $F(20,552.00) = 26.791$, $\rho < 0.001$) indicate that the full model is statistically significant and that the model explains 74.3% ($1 - \lambda$) of the variance shared between the two sets of variables. The dimension reduction analysis for canonical variates 1 to 2 ($F(20,552.00) = 26.791$, $\rho < 0.001$) and 2 to 2 ($F(9,277.00) = 3.198$, $\rho < 0.005$) indicate that both functions are statistically significant (Table A2). However, given the R_c^2 effect of each function (71.6% and 9.4%) of shared variance for canonical variates 1 to 2 and 2 to 2, respectively), the first canonical variate is more noteworthy of interpretation although the second function is still significant for interpretation.

Table 3. Canonical solutions for adoption and intensity of adoption of agricultural practices for canonical variates 1 and 2. Note: Structure coefficients (r_s) greater than I.30I are underlined. Communality coefficients (h^2) greater than 45% are underlined. Coef = standardized canonical function coefficient; r_s = structure coefficient; r_s^2 = squared structure coefficient; h^2 = communality coefficient.

Variable	Canonical Variate 1			Canonical Variate 2			h^2(%)
	Coef	*r_s*	*r_s^2 (%)*	*Coef*	*r_s*	*r_s^2 (%)*	
Adoption of complementary agricultural practices	0.521	<u>0.855</u>	73.11	1.069	<u>0.519</u>	26.89	<u>100.00</u>
Number of practices adopted	−0.617	<u>−0.899</u>	80.80	1.017	<u>0.438</u>	19.20	<u>100.00</u>
R_c^2			71.6			9.4	
Age of farmer	0.034	0.167	2.80	−0.451	<u>−0.422</u>	17.81	20.62
Education	0.041	−0.002	0.00	0.162	0.113	1.27	1.27
Household size	0.025	−0.070	0.49	0.020	−0.030	0.09	0.59
Household labour	−0.059	−0.058	0.34	−0.082	−0.164	2.70	3.04
Labour hired	−0.083	−0.238	5.67	0.069	0.072	0.52	6.19
Agricultural extension visits	0.098	0.078	0.60	0.658	<u>0.713</u>	50.77	<u>51.37</u>
Number of farm plots	−0.126	<u>−0.307</u>	9.44	0.312	<u>0.316</u>	10.01	19.45
Land tenure	0.042	0.238	5.68	0.103	−0.179	3.21	8.88
Distance to input	0.063	<u>−0.713</u>	50.78	−0.635	<u>−0.356</u>	12.67	<u>63.45</u>
Perception for adoption	−0.983	<u>−0.978</u>	95.64	0.351	−0.006	0.00	<u>95.65</u>

The coefficients and proportions of variance explained in the first pair of canonical variates show that both adoption and intensity of adoption of complementary agricultural practices correlate with the canonical variate (Table 3). The first pair of canonical variates

indicate that farmers that have fewer number of farm plots (−0.31), have to travel long distances to purchase inputs (−0.71), and that have negative perceptions about complementary agricultural practices (−0.98) do not adopt any complementary agricultural practices (0.855). On the other hand, possession of more farm plots (−0.31), short distances to sources of inputs (−0.71), and positive perception about complementary agricultural practices (−0.98) influence adopters to increase the number of practices they adopt (−0.899). The second pair of the canonical variates indicates that adopters (0.519) increase the number of practices they adopt (0.438) when they have access to agricultural extension services (0.713) and cultivate more than one plot (0.32) but do not adopt or decrease intensity of adoption as they age (−0.422) and also with long distance to sources of inputs (−0.356). The farmers that adopt one, two, three, four, and five practices at a time represent 43.6%, 33.0%, 13.3%, 8.0%, and 2.1%, respectively of the 188 adopters. No farmer adopts all the six practices.

The 188 adopting farmers had various perceived factors that motivate them to adopt the complementary agricultural practices. We have categorized all the varied reasons for adoption into four main perceptions based on the main themes that emanated from farmers' responses to the survey (Tables 2 and 4). Despite the diverse reasons, the highest priority motive for the farmers to adopt the practices is to increase yield. Similar to the non-adopters, the majority of the farmers that adopt the agricultural practices mainly to increase yield are mixed croppers (60%), followed by mono croppers (33.3%). Additionally, the majority of these farmers own their farmlands followed by those who cultivate on leased plots. The obvious reason for these similarities is that the main land tenure systems in the study area are owner-occupied land and leased land while the main farming systems are mixed cropping and mono cropping.

Table 4. Categorized perceptions for adoption based on farmers' responses. * The number of farmers that adopt at least one agricultural practice is 188. The total for the categorized perception for adoption is 224 farmers because some farmers gave more than one response. The percentage is however out of 188 to reflect the responses against the number of farmers that adopt the practices.

Motivation	Responses from Farmers Indicating the Categories	Number of Farmers *	%
Controls pests	Control pests; help control pests and increase yield; help prepare my farm and drive pests away, etc.	10	5.3
Increases yield	Clear the weeds and pest and also increase yield; get more yield; help increase yield and prepare land; I do this to get more yield; I need more produce, etc.	91	48.4
Makes farming easy	Good for my work; help in my farm and increase yield; help in my farm and to control weeds and pest; prepare my farms for cultivation; to work faster and easier, etc.	84	44.7
Controls weed	Easy destruction of the weeds; help do away with weeds to prepare the land; I do not use labourers to weed the farm. I plough the land first and when the weeds start growing, the labourers spray it; it helps to increase the size of the land when there is no hired labour available to weed	39	20.7
Total farmers that adopt at least one agricultural practice		188	

As aforementioned, the first canonical variate demonstrates that positive perceptions (−0.98) emanating from the need to improve yield and control weeds, pests, and diseases (Table 4) are the main motivational factors that increase the number of practices a farmer adopts (−0.90). According to the farmers, application of these practices makes their

farming operations easier. Some adopters stated that adopting more of the practices results in harvesting more outputs on a relatively smaller plot compared to farming with no complementary inputs. However, a comparative analysis between the adopters and non-adopters revealed that the adopters farm on larger plots. For instance, while 54.8% of the adopters have their total farm sizes larger than 2 ha and the rest with plots sizes smaller than 2 ha, 40.8% of the non-adopters have same. The adopters however harvest almost three times the outputs of the non-adopters. Data collected from maize growers for instance indicated that while adopters of complementary agricultural practices harvest averagely 19 bags of maize per hectare, non-adopters harvest averagely eight bags.

Both canonical variates show that multiple-plot farmers (−0.31 and 0.32 for functions 1 and 2, respectively) tend to intensify their agriculture through adopting more practices at a time (−0.90 and 0.44 for functions 1 and 2, respectively). Cereals (maize, rice) farmers constitute 40.4% of the multi-plot adopters followed by tree crops growers (28.2%) and tubers cultivators (18.1%). According to some of the multi-plot farmers, they are able to control weeds, pests and diseases and increase crops yields at the same time using complementary agricultural practices. Cross-referencing the number of farm plots cultivated with the main practice adopted indicated fertilizer application dominating all the categories of farmers except those who cultivate three plots where herbicides usage is the main practice followed by legume crop rotation (Table A3).

According to the second canonical variate, access to agricultural extension services has a strong positive correlation (0.71) with both adoption (0.52) and number of practices adopted (0.44). While 64.6% of the farmers adopt at least one of the practices, only 35.6% had access to extension services at the time of the survey. These adopting farmers could not explain why extension agents generally do not visit their communities. The same farmers stated that they instead rely on their own knowledge and that of other adopters to apply the agricultural practices they have adopted.

While perceptions for adoption, number of farm plots cultivated, and access to agricultural extension services increase the intensity of adoption, two other factors are on the contrary—age of a farmer, and distance to sources of agricultural inputs. The second canonical variate demonstrates that the age of a farmer (−0.42) negatively correlate with adoption and number of practices a farmer adopts. Further enquiry into the ages of the adopters revealed that 35.6% are over 50 years old. Out of this, 52.2% adopt only one practice while 28.4% adopt two practices at a time. Ideally, these farmers (>51 years) should be using more agricultural inputs to boost productivity because age might reduce their physical capacity. Yet our results indicate that the more farmers age, the lesser the number of complementary practices they adopt.

Agricultural inputs play vital roles in farming. However, the distance a farmer has to travel to purchase these inputs (−0.36) reduces adoption and for the farmers adopting, the intensity of their usage. We identify that distance to sources of inputs (−0.71) in the first canonical covariate positively correlates with the number of practices adopted (−0.90). This interpretation is however questionable considering the small standardized coefficient of distance to input (0.06) perhaps resulting from a multi-collinearity issue. Nevertheless, interpretation is still valid for the second canonical covariate. The majority of the adopters travel less than 20 km to purchase agricultural inputs. For instance, all the farmers that adopt five practices purchase their inputs within 5 km of their residence. A third (66.7%) of those that adopt four practices, 72% of those that adopt three practices, 67.7% of adopters of two practices, and 70.7% of one practice adopters travel within 20 km to purchase their inputs. This implies that shorter distance to sources of inputs correlates positively with increased adoption of agricultural practices. Eight of the fringe communities have access to agrochemical shops that supply inputs to the farmers. According to the adopters in these communities, purchasing inputs from shops in their communities is easier and preferable to shops outside of their communities.

5. Discussion

The majority of the farmers in the study area adopt various intensification techniques, a result observed in other studies [13,53,54]. Non-adopters in the study harvest averagely about half the yields of the adopters. The cost of the practices as well as other institutional factors (e.g., lack of access to extension services or lack of supply from the government) is the main constraining factor for the non-adopters [13]. According to these farmers, they do not have any other source of income, aside from crop sales, and they only sell crops that are in excess of their subsistence needs. Although significant proportions of the harvested produce are sold (Table 5), some of the non-adopters stated that the incomes from sales are not enough to meet household expenditure and purchase agricultural inputs.

Table 5. Percentage of harvested produce of major crops cultivated by non-adopters. Note: Some of the non-adopters have tree crops (cocoa, cashew, orange) as their major crops. These farmers were excluded from the calculations since their crops are not for direct domestic consumption and were processed in factories. The calculations were based on 'Total farmers (food crops growers)'.

Proportion of Harvested Produce Consumed	Percentage Farmers
Consumed all	16.0
Consumed below 50%	77.3
Consumed 50% and beyond	6.7
Total farmers (food crops growers)	75
Tree crop growers	28
Total farmers (all non-adopters)	103

Non-adoption of complementary agricultural practices is not unique in farming communities in Ghana [37], but it is a critical issue in forest-fringe communities. Although some practices such as the use of herbicides and pesticides pose threats to forest health, their correct and moderate application in addition to organic manure, crop rotation, inorganic fertilizers, and improved seeds could minimize their impacts on the forest environment while improving farm productivity and subsequent livelihood improvement. This is based on two presumptions. First, a land-sparing scenario where we presume that farmers who meet their subsistence needs on a smaller land through intensification will not desperately encroach the forest for increased agricultural production [44]. This can be more achievable through motivations given to the farmers by the Forest Services Division of Ghana for not encroaching the forest. Evidence shows that farmers in forest-fringe Ghana are willing to forgo exploitation of forest resources if they are compensated [54]. Our suggestion is not in a form of compensation but motivational packages for practicing forest-friendly agriculture. Second, strengthening forest protection strategies so that profit-maximizing farmers may not be able to expand their farms into the adjoining forests after adopting the yield-enhancing practices. Access to non-farm jobs through investments in small-scale enterprises and flexible agricultural loans (such as low interest rates) to farmers may also reduce the total reliance on farming for survival and enhance farmers' capacity to intensify agriculture, with similar land-sparing effects [55]. Improved access to non-farm incomes and agricultural loans in Ethiopia for instance has enhanced farmers' access to technical, mechanical and capital inputs to sustain agricultural production, culminating in significant economic returns and food security [53,54].

5.1. Promoting Complementary Agricultural Practices Is Critical for Improved Productivity

Although 64.6% of the farmers are adopters of complementary agricultural practices, 64.3% of all the farmers do not have access to extension services. A third of both adopters and non-adopters lack access to extension services. Meanwhile, our results indicates that access to agricultural extension services (0.71) has strong correlation with both adoption (0.52) and intensity of adoption of agricultural practices (0.44) (Table 3). Agricultural extension agents in Ghana educate farmers on best farming practices such as how to use

modern inputs, sustain soil fertility, control pests and diseases, and increase crops yields. However, the extension agents are not able to reach all farming communities due to limited resources and poor road infrastructure in remote areas [37]. According to some adopters with no access to extension services, they obtain knowledge through farmer-to-farmer diffusion, a process that yields quality results if the giver has the correct information [56,57]. While correct application of agricultural practices through effective extension services could double or even triple outputs, wrong application of inputs can cause damage to crops, human health, and biodiversity [13,23,58,59]. Without access to adequate knowledge and improved technology, farmers are likely to continue with farming practices that results in little or no improvement in productivity.

Some studies e.g., [14,60] indicate that the age of farmers positively influence their intensification of agriculture. This is contrary to what was revealed in our regression results. The older farmers in the study area prefer to use less inputs in their farming operations (Table 3). This is not unusual. Older farmers are found to be less trusting of new technologies and/ or management practices. They are often resistant to change and prefer to continue with what is well tried and tested [61–63]. The majority of the older farmers (Above 50 years old: 71.6% of adopters and 83.7% of non-adopters) own their farmlands. The majority of these older farmer land owners (75.0% of adopters and 87.8% of non-adopters) operate on one plot. According to both of our canonical variates (Table 3), the likelihood of these one-plot farmers adopting more practices is less than average [15], let alone for non-adopters to start practicing any agricultural innovation. However, effective diffusion of information about the benefits of yield-enhancing practices may influence older farmers to appreciate the need to complement their activities with inputs as they age [14,60].

Age is not the only factor that reduces the intensity of farmers' adoption of agricultural intensification. Long distance to sources of inputs is another factor that discourages farmers to intensify agriculture [16,22,25]. Positive perception and motivation towards adoption of inputs through effective extension services may attract suppliers to use mobile supply services in the farming communities. Improvement in rural road networks will reduce transportation cost and enhance access to, and distribution of agricultural inputs. Improved roads lead to the use of more inputs resulting in higher yields, better market integration by enabling smallholders to transport a larger proportion of their harvested produce to the market, and commercialization of farms without necessarily expanding farm size [37,64]. Forming farmer-based organizations will also be an effective means to access agricultural inputs in bulk for distribution among the members. This will reduce the retail and transportation costs incurred by individual farmers to access agricultural inputs. Farmer-based organizations are not only helpful in procuring bulk inputs, they also aid in securing good prices for agricultural produce marketed by members and accessing agricultural financial credits. Farmer-based organizations are known to play important roles in the farming operations of members [65–69].

The application of inputs is not the only agricultural practice that improves farm productivity. Legume-crop rotation is a less expensive alternative and is effective with both economic and environmental benefits. Legumes improve the soil through nitrogen fixation that boosts the yields of crops, reduces diseases, weed and insect population, and increases soil-carbon content [70–72]. Retaining the residues of legumes on the land enriches the soil [21]. These attributes of legumes increase crop yields especially maize [21,24,56]. Legume-crop rotation is the third most adopted practice and 51.9% of the farmers in the study area grow maize. Educating farmers about the benefits of legume-maize rotation should enhance adoption of the practice.

5.2. Adopting Complementary Agricultural Practices Around Forests Is a Contested Issue

Out of the 103 non-adopters, 65.1% of them expand their farms to increase food crop production and 28.4% and 14.9% of these farmers have their plots within the reserve and less than 1 km from the reserves, respectively. The likelihood that these farmers will

encroach the adjoining forests for fertile land is high [40,73,74]. Non-adoption of complementary practices (especially soil enrichment techniques) by farmers who farm within and at the fringes of forest reserves is a threat to the sustainability of the reserves. Application of soil-enrichment techniques at Ghana's forest frontiers together with reinforcing activities towards forest protection is one of the remedies to reduce forest encroachment and degradation. Adoption of inputs such as pesticides and herbicides especially in forest reserves could have negative impacts on the forest ecosystem and biological diversity. The farmers however need these inputs to enhance their farming operations to improve upon their livelihoods without necessarily expanding their farms. The priority of the farmers is yield improvement but this should not be at the expense of forest health. Forest and biodiversity conservation is crucial for improved provision of ecosystem services and reduction in climate change effects [41–43,75,76]. The work of extension agents through extensive education could help reduce the negative impact of agricultural inputs on the forest environment.

Our findings indicate that education, by means of agricultural extension services, is the main method through which a farmer gets knowledge about agricultural inputs. However, extension services are poor in the study area and Ghana as a whole due to inadequate resources (e.g., funds, motorbikes) and poor rural road networks that make it difficult for extension agents to travel to the remote places. Various agricultural development policies in Ghana have documented the above as the challenges facing extension services delivery in Ghana [77–79]. This leaves farmers with no other option than to practice what they think is correct for them.

The Forest Services Division of Ghana has forest rangers in each forest district to patrol the various forest reserves. With the limited resources available for extension services, a possible option could be a joint force between the Forest Services Division and the District Agricultural Development Unit of Ghana to have a combined training program on forest-friendly agricultural practices for both extension agents and forest rangers. Collaboration between forestry and extension officers to educate farmers on agricultural practices that increase yields and outputs will, first, help sustain the forest reserves around and within which the input adopters cultivate. Second, the education may influence the non-adopters to start using forest-friendly complementary practices when they have the capacity to do so instead of expanding farms into adjoining forest areas to increase production and subsequently cause forest degradation.

The intervention should not end with the combined education strategy. Agricultural inputs subsidies and small loans with flexible payments and low interest rates could be made available to needy farmers who are willing to intensify their agriculture. Food security, rural poverty reduction, and forest sustainability are three key foci of the Sustainable Development Goals (SDGs) [80]. Without subsidizing agricultural inputs and making agricultural loans available to smallholders, subsistence cultivation with low outputs will continue. Smallholders will continue to produce for household consumption and the surplus sold can only support household expenses with no extra income for farm innovation. Poor farmers seeking fertile land for food crops cultivation will have no choice than to encroach the forest reserves.

6. Conclusions

Complementary agricultural practices are important elements in farming due to the overall benefits that can be earned when properly applied. Farmers who adopt these practices enrich the fertility of their farmlands while reaping the benefits of higher yields. Perhaps of more importance for semi-subsistence farmers in Ghana and other developing countries is the adoption of soil enrichment technologies by farmers in forest frontiers. These farmers mostly rely on forests as fertile land banks for agricultural production. Adopting complementary agricultural practices could reduce the pressure on forest conversion for agriculture while at the same time enriching the farmers' lands for increased agricultural production. The agricultural practices identified in this study have both

economic and environmental benefits. One way to optimize these benefits is to educate farmers on the best way to adopt the practices to ensure agricultural and environmental sustainability.

Our survey of 291 farmers in the Ashanti region of Ghana showed that 64.6% of the farmers adopt one or more complementary agricultural practices to control weeds, pest and diseases and enhance soil fertility with the ultimate goal of increasing farm outputs. We acknowledge that the adoption of practices such as herbicides and pesticides use are sometimes detrimental to the forest when not properly applied. However, their moderate use together with the use of fertilizers, organic manure, and crop rotation enrich the soil for increased production. This may reduce the need to expand farms to increase production and thereby encroach the forest. Some 35.4% of the farmers have some perceptions (e.g., costly, not useful, and difficult to use) about these practices that in effect demotivate them to adopt. Effective farmer-extension education towards the adoption of agricultural-enhancing practices is critical to change the perceptions of the non-adopters, motivate them to adopt these practices, and consequently restore the fertility of existing farmlands to increase agricultural outputs. Overall, this may help improve food security and livelihoods of the farmers with minimal effect on the environment. Further research is however required to investigate and understand the effect of each of the practices on the economic welfare of the farmers and the sustainability of the forest landscape.

The complimentary agricultural practices under study have been part of Ghana government's agricultural modernization policies since 1997 [76,80–83]. The adoption of improved seeds and planting materials for crops survival and the application of inorganic fertilizers for increased outputs in particular have been pursued by the government of Ghana for decades. The promotion of these practices together with other improved agricultural technologies have mainly been through extension services delivery although not highly effective due to resource scarcity and other challenges. Promoting the adoption of the studied complementary agricultural practices is therefore in line with Ghana's agenda of transforming its agricultural sector in a sustainable manner [84].

We acknowledge that our research is limited to the assessment of the factors of adoption treating all the identified practices as a combined component and that we failed to investigate the extent to which the factors affect each of the identified practices. We chose this method to provide a broader overview of factors of adoption and intensity of adoption in order to make generalized recommendations for agricultural development and forest sustainability. Since the adoption of complementary agricultural practices around forest reserves is a critical and contested issue, further research is required to investigate the factors affecting the adoption of each of the practices, the social, economic, and environmental costs and benefits associated with each of the practices, and the effects of adoption on outputs and income of the farmers. These will provide a more concrete rationale for the adoption of forest-friendly agricultural practices within forest-fringe communities while not compromising the conservation of the forest reserves.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of James Cook University, Australia (application ID: H7199; approval date: 12/12/2017).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Appendix A

Table A1. Sampled reserves, communities and farmers used for the study. Source: GSS 2014; RMSC, 2016; Author's construct, 2018

Sampled Reserves	Sampled Communities	Total Households	Farm Households	Sampled Farmers
Offin Headwaters	Mprim	252	177	17
	Ninting	364	254	25
Tano Offin	Akantansu	155	109	11
	Kwanfinfini	121	84	8
Chirimfa/Aboma	Bunuso	116	81	8
	Bosomkyekye	172	121	12
	Sekruwa	138	96	10
Ongwam II	Kruwi/Abasua	199	139	14
	Asuafo	196	137	14
Bomfuom/Bandai Hills	Ananekrom	206	144	14
	Bahankra	84	59	6
	Abiriwapon	93	65	6
Kogyae	Jeduako	518	363	36
	Kyekyebon	450	315	31
Dome River	Adansi	269	189	19
	Atiemo Nkwanta	58	41	4
Pra Anum	Banka	265	186	18
	Gyadam	109	77	8
Opro River	Offinso Brekum	172	121	12
	Nkwankwaa	265	186	18
Total		4202	2942	291

Sample size computation
$s = [z2*N*P (1 - P)/[e2*(N - 1) + z2*P (1 - P)]$, where:
s = sampled farmers;
N = total farmers in the study area
z = standard score at specific significant level;
P = probability of selecting a farmer
e = error margin
$s = [1.962*2942*0.7 (1 - 0.7)/[0.052*(2942 - 1) + 1.962*0.7 (1 - 0.7)] = 291$ farmers.

Table A2. Results from the multivariate model using canonical correlation analysis.

Effect Within Cells Regression Multivariate Tests of Significance (S = 2, M = 3, N = 137)					
Test Name	**Value**	**Approximate F**	**Hypothesis DF**	**Error DF**	**Significance of F**
Pillai's	0.80988	18.84993	20.00	554.00	0.000
Hoteling's	2.62201	36.05263	20.00	550.00	0.000
Wilks'	0.25749	26.79126	20.00	552.00	0.000
Roy's	0.71576				
Eigenvalues and Canonical Correlations					
Root No. (Can. Var)	**Eigenvalue**	**%**	**Cumulative %**	**Canonical correlation**	**Squared correlation**
1	2.51811	96.03725	96.03725	0.84602	0.71576
2	0.10390	3.96275	100.00000	0.30680	0.09412
Dimension Reduction Analysis					
Roots	**Wilks λ**	**F**	**Hypothesis DF**	**Error DF**	**Significance of F**
1 to 2	0.25749	26.79126	20.00	552.00	0.000
2 to 2	0.90588	3.19792	9.00	277.00	0.001
Standardized Canonical Coefficients for Dependent Variables					
	Variable			**Function 1**	**Function 2**
	Adoption of complementary agricultural practices			0.52117	1.06913
	Number of practices adopted at a time			−0.61672	1.01701
Correlations between Dependent and Canonical Variables					
	Adoption of complementary agricultural practices			0.85507	0.51852
	Number of practices adopted at a time			−0.89889	0.43818
Standardized Canonical Coefficients for Covariates					
	Covariate			**Canonical Variable 1**	**Canonical Variable 2**
	Age of farmer			0.03365	−0.45148
	Education			0.04146	0.16205
	Household size			0.02497	0.01953
	Household labour			−0.05938	−0.08151
	Labour hired			−0.08343	0.06948
	Agricultural extension visits			0.09807	0.65847
	Number of farm plots			−0.12618	0.31219
	Land tenure			0.04173	0.10286
	Distance to input			0.06264	−0.63517
	Perception for adoption			−0.98288	0.35084
Correlations between Covariates and Canonical Variables					
	Covariate			**Canonical Variable 1**	**Canonical Variable 2**
	Age of farmer			0.16747	−0.42203
	Education			−0.00247	0.11283
	Household size			−0.07035	0.03009
	Household labour			−0.05810	−0.16433
	Labour hired			−0.23812	0.07198
	Agricultural extension visits			0.07758	0.71255
	Number of farm plots			−0.30718	0.31642
	Land tenure			0.23825	−0.17909
	Distance to input			−0.71260	−0.35593
	Perception for adoption			−0.97798	−0.00644

Table A3. Number of farm plots the farmers cultivate and main agricultural practice adopted.

Number of Farm Plots	Categories	Main Agricultural Practice Adopted						Total Farmers
		Weed Control	Legume-crop Rotation	Improved Seeds	Organic Manure	Fertilizer	Pest Management	
1	Count	30	11	8	2	59	9	119
	% within number of farm plots	25.2%	9.2%	6.7%	1.7%	49.6%	7.6%	100.0%
	% of Total	16.0%	5.9%	4.3%	1.1%	31.4%	4.8%	63.3%
2	Count	4	7	1	0	11	3	26
	% within number of farm plots	15.4%	26.9%	3.8%	0.0%	42.3%	11.5%	100.0%
	% of Total	2.1%	3.7%	0.5%	0.0%	5.9%	1.6%	13.8%
3	Count	10	7	3	1	6	3	30
	% within number of farm plots	33.3%	23.3%	10.0%	3.3%	20.0%	10.0%	100.0%
	% of Total	5.3%	3.7%	1.6%	0.5%	3.2%	1.6%	16.0%
4	Count	1	3	0	1	7	1	13
	% within number of farm plots	7.7%	23.1%	0.0%	7.7%	53.8%	7.7%	100.0%
	% of Total	0.5%	1.6%	0.0%	0.5%	3.7%	0.5%	6.9%
Total farmers	Count	45	28	12	4	83	16	188
	% within number of farm plots	23.9%	14.9%	6.4%	2.1%	44.1%	8.5%	100.0%
	% of Total	23.9%	14.9%	6.4%	2.1%	44.1%	8.5%	100.0%

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