Gender and Agricultural Technology Adoption: Evidence from Integrated Crop-Livestock Management Practices (ICLMPs) among Men and Women Smallholder Farmers in Ghana

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Bright Owusu Asante[1, 2*], Isaac Koomson[2, 3], Renato A Villano[3], and Alexander Nimo Wiredu [4]

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Abstract

Integrated crop-livestock management practices (ICLMPs) play a vital role in ensuring food security and improved welfare for smallholder households but studies that focus on ICLMP adoption in Ghana (including its gender dimension) remain scant. This paper examines gender differences in the drivers and intensity of ICLMPs' adoption using farm-level data from 608 smallholder farmers in Ghana. Employing Multivariate Probit, Tobit regression models and dominance analytical procedures, we find that adoption of ICLMPs is generally influenced by non-farm income, extension contacts and nativity. While age, credit access, soil fertility, distance to markets, total value of assets and research contacts influence the intensity of ICLMPs' adoption among the men, intensity of adoption among women farmers is influenced mainly by household size. The dominance analyses showed that being a native of the community/village where one farms had the strongest influence in intensifying ICLMP adoption, with gender differences being evident regarding the relative influence of the other variables. Policies to enhance the adoption of ICLMPs in Ghana could be designed to focus on women farmers who have large farm assets, access to extension and are engaged in non-farm income-generating activities

Keywords: Gender, agricultural technology, adoption, integrated crop-livestock management practices, Ghana

JEL Codes: Q10, Q12, Q15, Q18

[1] *CSIR-Crops Research Institute, Kumasi, Ghana*
[2] *Network for Socioeconomic Research and Advancement (NESRA), Accra, Ghana*
[3] *UNE Business School, University of New England, Armidale, NSW, Australia*
[4] *International Institute for Tropical Agriculture (IITA), Nampula, Mozambique*

Introduction

Agriculture is a major sector of the Ghanaian economy, contributing about 20.3 percent of gross domestic product (GDP) (ISSER, 2016), and a major source of income and employment for most households. The sector provides employment for over 60 percent of the Ghanaian population and is a major foreign exchange earner (Government of Ghana, 2017; ISSER, 2016). In the wake of declining arable land area, coupled with increasing human population, the adoption of productivity-enhancing technologies plays a pivotal role in achieving sustainable agricultural growth. There is evidence of considerable productivity gaps in farming systems in African agriculture (Villano et al., 2019; Asante et al., 2019; Temoso at al., 2016; Asekenye et al., 2016). Smallholder agriculture faces substantial challenges, including limited or no access to modern inputs and technical assistance while having to deal with difficulties imposed by the increasing incidence of climatic variability (Harrison et al., 2016; Thornton et al., 2016; Whitfield, 2015).

Consequently, integrated crop-livestock farming has received significant attention from governments and development partners in Ghana and across sub-Saharan Africa over the past few decades (Herrero et al., 2007). It is considered one of the key mechanisms for boosting crop and livestock productivity sustainably and for addressing rural household food insecurity and poverty (Food and Agriculture Organization (FAO), 2010; Herrero et al., 2007). An integrated crop-livestock farming system includes the production of a combination of one or more crops with one or more livestock in a single production period. This farming system can enhance farmers' livelihoods by providing them with multiple or diversified income streams. It also provides them with funds for financing other farming activities. For instance, income from the sale of livestock may be used to finance cropping activities while sale of produce can be used to buy new breeds of livestock (Asante et al., 2017b).

The practice, where almost 90 percent of farmers produce a range of crops and livestock in an integrated system, is common in Ghana (MoFA, 2015). The main crop-livestock production enterprises consist of small ruminants (e.g., sheep and goats) in combination with crops, such as cereals (maize, millet, and sorghum) and legumes (peanuts, cowpea, and soybeans). Some crop-livestock production enterprises produce root and tuber crops, such as yam, cassava, cocoyam and sweetpotato. There are also crop-livestock enterprises with large ruminants, such as cattle, and non-ruminants, such as pigs and poultry (Karbo and Agyare, 2002). Producers tend to diversify their farm enterprises as a strategy to manage inherent production, marketing and income risks resulting from climatic, biophysical and market-related factors (Chavas and Di Falco, 2012).

In spite of its advantages, the system is characterised by low productivity resulting from inadequate use of improved technologies. To reverse this phenomenon, improved Integrated Crop-Livestock Management Practices (ICLMPs) were developed and have been promoted through the Sustainable Intensification of Crops-Small-Ruminant (SIIC-SR) project among smallholder farmers in Ghana since 2011. Improved agricultural technology adoption rates in the country are, however, low; thus, farmers are unable to fully benefit from such innovation. In the case of ICLMPs, the evidence of adoption is yet to be well documented. Moreover, evidence suggests that the rates of adoption of improved agricultural technologies differ among men and women (Gebre net al., 2019; Gichuki and Mulu-Mutuku, 2018; Croppenstedt et al., 2013; Ragasa, 2012; Peterman et al., 2010). The differences are explained by the variation in access to and demand for the factors of production and others, including improved production practices, improved crop varieties and innovations (Gebre net al., 2019; Croppenstedt et al., 2013).

Given the low adoption of improved technologies in integrated farming systems among smallholder farmers in Ghana, this paper contributes to the literature on gender and technology adoption by analysing the gender differences in the drivers of ICLMPs' adoption and its intensity among smallholder farmers in Ghana. Furthermore, it applies dominance analyses to assess the essential factor(s) to consider in promoting the adoption of ICLMPs in the midst of limited resources for policy considerations.

Review of factors influencing adoption of ICLMPs

Factors influencing agricultural technology adoption can be categorized into household factors, farm-level factors, factors that relate to the attributes of the technology and institutional factors (Geroski, 2000; Karshenas and Stoneman, 1995; Adesina and Baidu-Forson, 1995). Major household factors that are expected to influence adoption decision include age, gender, education and household size. Farm-level factors include farm size (Mwangi and Kariuki, 2015; Mignouna et al, 2011; Uaiene et al., 2009). Institutional factors include Farmer Based Organization membership, access to extension (Asante et al., 2017b; Kabunga et al., 2012).

The age of the farmer has been found to have either positive or negative effect on technology adoption. Older farmers are assumed to have gained knowledge and experience over time, and are able to evaluate technical information better than younger farmers. They are therefore more likely to adopt improved technologies (Asante et al., 2014; Mignouna et al, 2011). In some cases, age has also been found to have a negative relationship with adoption of technology (Ogada et al., 2014; Uduji and Okolo-Obasi, 2018; Adesina and Baidu-Forson, 1995). The intuition is that as farmers grow, they tend to be more risk averse and this decreases their interests in long term farm investments, which include technology adoption while younger farmers are typically risk-loving and are more willing to try new technologies. Also, the link between age and technology adoption depends on the type of technology such that smart-technologies (e-based) are more appealing to younger farmers. However, regardless of the relationship, there is always a threshold beyond which age will have the opposite effect on adoption.

Level of education has been found to have a positive relationship with the adoption of technology among farmers. Farmers with higher number of years of schooling tend to have a much higher probability to adopt new technology as compared to those with lesser or no formal education. (Gao et al., 2018; Mponela et al., 2016; Dontsop Nguezet et al., 2013; Uaiene, Arndt and Masters 2009; World Bank 2007). The more educated a farmer is, the easier it is for the farmer to understand, analyze and respond to technology, and also search for technological advancements and its benefits to maximize production. Education is thus expected to have a positive relationship with adoption of ICLMPs.

Many authors have reported a positive relationship between Research and Extension services on technology adoption among farmers (Dontsop Nguezet et al., 2013; Akudugu et al. 2012; Mignouna et al. 2011; Uaiene et al., 2009). Based on the innovation-diffusion theory, contact with extension agents and research institutions is expected to have a positive impact on ICLMP technology adoption. Extension agents act as intermediaries between the researchers of the technology and users of that technology which helps to reduce transaction cost of disseminating information about a new technology to a large heterogeneous population of farmers which increases the potential adoption rates (Genius et al., 2010).

Contextual issues

The main contextual basis of this paper include agriculture, technology adoption and gender. Gender plays an important role in agriculture. It influences the economic and social roles played by men and women (comprising men and women, boys and girls) in society including their roles in agriculture. For instance, in rural households, participation in agriculture is one of the major activities. Over the years, the role of women farmers in agricultural households in sub-Saharan Africa is focused on producing to meet the food needs of households (Dennery, 1996; Bortei-Doku, 1990; Ngome and Foeken, 2012). In addition to this traditional role, females are providing labour to support cash crops production in the farm households. However, in recent times, due to agricultural modernization and availability of markets, females are gradually drifting from producing solely for household consumption to participating in cash crop cultivation. It also implies differences in the extent to which men and women adopt improved agricultural technology, hence, the need to consider gender differences in the development and dissemination of improved agricultural technology. In Ghana, most smallholder farmers are into integrated crop-livestock farming for food, nutrition and income security strategy. Consequently, improved technologies such as the ICLMPs is essential to sustainably improve the overall productivity of this farming system. In order for farmers and their households to obtain the full benefits of these practices, the gender dynamics in adoption of these practices needs to be fully understood. This study seeks to address this gap in the extant literature by investigating differences in the adoption of these improved practices and the determining factors.

Methodology

Data and study area

The data used in this study was collected from smallholder crop-livestock producing households in the Forest-Savannah Transition agroecological zone because of its unique and conducive environment for producing diverse crops and livestock species (Ghana Districts Repository, 2018). Farming systems in this zone are predominantly food crops and livestock production. It is an important area for producing major commercial staple crops such as maize, cassava, groundnut, cowpea and yam, while goats and sheep are the main livestock raised in these districts (MoFA, 2016). The zone is characterised by bimodal rainfall patterns with average annual rainfalls ranging from between 1,300–2,200mm which is generally erratic. The average temperatures are about 28°C, with low temperatures mostly experienced during the major rainy season between June and July. Major farming systems include mixed farming, mixed cropping and monocropping (MoFA, 2016). Agricultural production in this zone is rain-fed with little irrigation infrastructure. The zone is among the leading producers of most local food staple crops. Major livestock systems include cattle, goats, sheep, pigs and poultry (including chicken, duck, guinea fowls and turkeys). The livestock husbandry systems are generally free range[5] and mainly dominated by female producers (MoFA, 2016).

Sampling technique

Multi-stage sampling procedure was adopted to select the respondents for the study. First, the forest-savannah transition agroecological zone and the two districts, Atebubu-Amantin (A-A) and Ejura-Sekyedumase (E-J), were selected purposively. These districts were selected based on their high livestock density, high potential for crop-livestock integration, high levels of poverty and proximity to existing good livestock-practice centres. In addition, agriculture

[5] This is a livestock husbandry system where the animals are allowed to go out to feed on their own at the early hours of the day and return to their shed when night falls.

plays a vital role in these districts, employing about 70 per cent of the labour force. These districts are characterised by a high small ruminant population density and a high potential for crop-livestock integration (MoFA, 2010). From each of the two districts 12 communities were randomly selected. For each community, a minimum of 25 households[6] were randomly selected for the study. In all, a total of 608 farm household were involved in the study. We commenced data collection by interviewing key informants in each community, followed by discussions with a community-level focus group.

Definition and measurement of key variables

ICLMPs consist of a number of practices that are integrated in nature, hence, applicable mostly in an integrated farming systems context. These practices are not mutually exclusive hence a farmer can adopt either one or all of the practices at a time (with equal probabilities). Specifically, and in this paper, The ICLMPs comprise storage of crop residue; the use of feed residue to feed livestock; tethering of livestock; supplementary feeding; the use of faecal matter from livestock as manure; the use of tetracycline; access to and use of improved pasture; use of dual-purpose cowpea and groundnut. A randomly selected farmer is said to adopt an ICLMP if he/she is using any of the specified technologies, thus, the ICLMPs are not a package but rather individual practices. Accordingly, the rate of adoption of any of the ICLMPs refers to the number of farmers adopting a given practice per the total number of farmers. We define intensity of ICLMP adoption as the number of practices adopted by a randomly selected farmer. We operationalise gender by using men and women, thus, sex disaggregated data is collected and used to capture gender. Subsequently, gender differences refer to the differences in adoption and determinants between men and women integrated crop-livestock farmers.

[6]Generally, the head of household is interviewed, however, in situations where the head is unavailable or wishes to delegate a member to speak on behalf of the household, information relating to the household head and the entire household are obtained from such representative.

Analytical framework

To understand and analyze the ICLMP adoption decisions, we use the multivariate probit model and apply the Tobit regression model to estimate the intensity of ICLMP adoption.

The multivariate probit model

Such adoption decisions as that for ICLMPs are inherently multivariate in nature. The decision to adopt one ICLMP is influenced by the decision to adopt another because in reality, farmer's consider information on several other practices in deciding to adopt a particular practice. A randomly selected farmer is likely to adopt a particular ICLMP if the benefits obtained from adopting is greater than that not-adoption. Following Kassie et al. (2013) and Mulwa et al. (2017), the decision to adopt an ICLMP is modelled within a random utility framework. Let's consider an i^{th} farmer faced the decision to adopt a j^{th} ICLMP where i=1,2,3……., N; and j=1,2,3….., J, i.e. j= storage of crop residue (*SR*); use of crop residue as livestock feed (*FR*); tethering of livestock (*T*); supplementary feeding (*SF*); the use of faecal matter as manure (*F*); the use of tetracycline (*TC*); use of dual-purpose cowpea(*DC*) and use of dual-purpose groundnut (*DG*). Let P^* denote the difference between the utility from adoption (U_{iA}) and the utility from non-adoption (U_{iN}) of an ICLMP, such that a farmer in household i will choose to adopt the farm management practice if $P^* = U_{iA} - U_{iN} > 0$. Subsequently, the net benefit from the adoption of ICLMPs is a latent variable, which is determined by observed household, institutional, and farm-level factors characteristics (X_i), and the error term (ε_i) as follows:

$$P_{ij}^{*} = X_{i}^{'}\beta_{j} + \varepsilon_{i} \quad (1)$$

Subsequently, the two utilities are unobservable but can be expressed for each ICLMP as a function of observable components in the latent variable specified as:

$$P_{ij} = \begin{cases} 1 & \text{if } P_{ij}^{*} > 0 \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

where P_{ij}^{*} is a latent variable which represents the observed and unobserved preferences associated with the j^{th} ICLMP, and P_{ij} represents the binary dependent variables. X_{ik} denotes a set of household and farm-specific characteristics, as well as institutional variables. A_{ik} represents plot characteristics to account unobserved heterogeneity. β_k and α_k are parameters to be estimated. ε_k represents the multivariate normally distributed stochastic error term (Wooldridge, 2003). In the multivariate probit model with the possibility of adopting multiple ICLMPs, the error terms jointly follow a multivariate normal distribution (MVN) with zero conditional mean and variance normalized to unity, i.e. $(u_{SR}, u_{FR}, u_{T}, u_{SF}, u_{F}, u_{TC}, u_{DC}, u_{DG}) \approx \text{MVN}(0, \Omega)$, and the covariance matric Ω is given by

$$\Omega = \begin{bmatrix} 1 & \rho_{SRFR} & . & \rho_{SRDG} \\ \rho_{FRSR} & 1 & . & . \\ . & . & 1 & \rho_{DCDG} \\ \rho_{DGSR} & . & \rho_{DGDC} & 1 \end{bmatrix} \quad (3)$$

where ρ represents the pairwise correlation coefficient of the error terms with regards to any two of the estimated adoption equations of the ICLMPs. Subsequently, the off-diagonal elements (e.g. ρ_{FRSR}, ρ_{SRFR}) in the covariance matrix represents the correlation between the stochastic components of the different *ICLMPs* adopted (Mulwa et al. (2017). The non-zero value of these correlations in the off-diagonal elements supports the appropriateness of the use of the multivariate probit model.

The Tobit model for Intensity of ICLMP Adoption

Apart from the possibility of adopting a single ICLMP, we are also interested in estimating the intensity of farmers' adoption of ICLMPs because the instantaneous decision to adopt any of the ICLMPs is not entirely adequate in understanding ICLMP adoption decisions among smallholder farmers. Although the two decisions can be made separately, given the multiple nature of the ICLMPs and hence the fact that the decision to adopt is addressed in the Multivariate probit frameworks, this paper assumes that farmers' instantaneous decision to adopt and the decision on the number of ICLMPs to adopt are made jointly. Based on this assumption, a randomly selected farmer who decides to adopt ICLMPs will adopt at least one of the nine *practices* and hence assigned a value of 1. A non-adopter will not adopt any of the nine *ICLMPs* and hence assigned a value of 0. Let y denote the number of ICLMPs adopted by the farmers. Therefore, $y = 0,1,2,3,...,N$ and is defined as the count of the number of *ICLMPs* adopted by a farmer.

Following Cameron and Trivedi (2010), the relationship between the observed y and the unobserved latent variable y_i^* is expressed as:

$$y_i^* = X_i'\beta + \varphi_i, \quad i = 1,2,3,......N \tag{4}$$

where $\varphi_i \sim N(0,\sigma^2)$, and X_i denotes the $(K \times 1)$ vector of exogenous and fully observed regressors. If y^* were observed, we would estimate (β,σ^2) by OLS in the usual way, however, this is not the case. The relationship between he observed variable y_i and the latent variable y_i^* is specified as;

$$y = \begin{cases} y^* & \text{if } y^* > L \\ L & \text{if } y^* \leq L \end{cases} \quad (5)$$

The probability of an observation being censored is given by:

$$\Pr(y^* \leq L) = \Pr(X_i'\beta + \varphi_i \leq L) = \Phi\left\{L - X_i'\beta / \sigma\right\}, \quad (6)$$

where $\Phi(.)$ is the standard normal cumulative distribution function. The truncated mean of expected value of the y for noncensored observations is thus presented as:

$$E(y_i \mid X_i\, y_i) = X_i'\beta + \sigma \frac{\phi\{(X_i'\beta - L)/\sigma\}}{\Phi\{(L - X_i'\beta)/\sigma\}} \quad (7)$$

Where $\phi(.)$ is the standard normal density.

Following Wiredu et al (2012), the Tobit model for examining the intensity of adoption of ICLMPS is empirically specified as:

$$E(ICLMP_{num_i}) = \alpha + X_i'\beta + \gamma_i$$

where $ICLMP_{num_i}$ is the number of ICLMPs adopted by a famer and X_i is a vector of individual-, household- and farm-level determinants of ICLMP adoption. γ_i is a random error term. The full list of explanatory variables used in estimating the Probit and Tobit models for the binary and number of ICLMPs adopted, respectively, have been defined with their A Priori signs in Table 1.

Dominance analysis

As a follow-up to the intensity analysis, it is prudent to engage in relative analysis to identify the variable that has the highest influence on the intensity of farmers' adoption of ICLMPs. To do this, we employ dominance analysis that helps to decompose the contribution of the explanatory variables to the coefficient of determination (R^2) after several subsampled models that follow a step-wise process (Azen and Budescu, 2003; Budescu, 1993; Koomson, Annim, and Peprah, 2016; Nathans, Oswald, and Nimon, 2012). The advantage of dominance analysis is that it ranks the variables based on their proportional contribution to the overall dominance statistic.

Applying the general dominance analyses, the standardized dominance statistics is expected to add up to one. It is worthy to note that there are other dominance approaches, but we use the general dominance because of its peculiar advantage of reporting the ranking variables. The number of subset models estimated for the full model is 16,383 whilst that of the male and female models are both 8,191. Table 1 presents the definition of the variables used in the ICLMP adoption models and their a priori expectations. The same set of variables are used in the intensity and dominance analyses.

Table 1: Variable definition and a' priori signs

Variables	Definition	A priori sign†
Age	Age of the farmer in years	+/-
Years of Schooling	Years of schooling in years	+
Gender	1 if the farmer is male; 0 otherwise	+/-
Credit Access	1 if the farmer has access to credit; 0 otherwise	+
Household Size	The total number of people within a household	+
Non-farm Income	Income generated from non-farm economic activities	+
Research Contacts	I if the farmer had contacts with research; 0 if otherwise	+
Total Asset Value	The total value of asset that the farmer has in GHC	+
Soil Fertility	1 if the farmer perceived his soil to be fertile; 0 if otherwise	+
Market Distance	The distance from the farm gate to the nearest market in km	-
Extension	1 if the farmer had contact with extension; 0 otherwise	+
Native	1 if the farmer is a native of the community; 0 otherwise	+
IC-L Diversity Index	The crops-livestock diversity index; 1 if specialised and 0 diversified.	+
A-A District	1 if the farmer is a is from the A-A district; 0 otherwise	+/-

†The signs +, -, and +/- signifies a positive, negative or mixed effect of the factor on ICLMP adoption, respectively.

Results and discussions

Characteristics of sampled farmers

Table 2 presents the characteristics of sampled farm households involved in the study. Overall, the results indicate that 76.8 percent of the farmers adopted one or more ICLMPs. However, this varied substantially, being greater among women (84.4%) than men (74.0%). In all, the sampled farmers consisted of 73.52% men with 26% of them being men. A typical farmer adopted an average of about four ICLMPs, however, this was significantly greater for male farmers. In general, the average age of farmers was 44 years, indicating that majority of the farmers are adults with the women farmers having a significantly higher age (45 years) as compared to 42 years for the men. Years of formal schooling was significantly low as the average years of formal education is four (4) years for the full sample. With regard to credit access, 80.1% of the men had access to credit as compared to 77.6% for women. However, this was statistically insignificant across the two categories. Generally, because men are heads of households, they tend to have control of household resources which is often used as some form of collateral in obtaining credit for farming activities. However, investigations from the field indicates that input credits are the major form of credit available to the farmers. Most household decisions are highly influenced by males and hence tend to be favoured by society in terms of access to credit as compared to female farmers.

The average differences in household size and non-farm income were both significant among the men and women at 1% significant level. Women were found to have larger household size (10) as compared to men (8). However, generally household sizes across the farms were found to be relatively high compared to the national average of 4.0 (GSS, 2014). In relation to non-farm income, 89.4% of the men had a non-farm income source whereas 74.9% of the women had a non-farm income source. This can be attributed to the patriarchal advantage that men have over women in the allocation of resources within society and ends up leaving men with more resources to be able to diversify their economic activities more. Differences in research contacts and extension contacts were also statistically significant.

Table 2: Summary Characteristics of Sampled farmers by sex

Variables	Full (608)		Men (N=477)		Women (161)		*p*-value	Test Results[7]
	Mean	SD	Mean	SD	Mean	SD		
Adoption of ICLMPs *(%)*	76.8	2.6	74.0	2.1	84.4	2.9	0.000	2.70***
No. of ICLMPs (*No.*)	4.0	2.0	4.0	2.0	3.0	2.0	0.000	3.42***
Age *(Years)*	44	14	42	12	45	15	0.043	-2.03**
Gender (%)	73.5	44.2	—	—	—	—	—	—
Years of schooling *(Years)*	4.0	5.0	3.0	4.0	4.0	5.0	0.001	-3.31***
Credit access *(%)*	78.3	41.3	80.1	40.0	77.6	41.7	0.511	0.66
Household size *(N)*	9.3	5.1	7.7	3.8	9.7	5.4	0.000	-4.36***
Non-farm Income *(%)*	78.8	40.9	89.4	30.8	74.9	43.4	0.000	3.90***
Research contacts *(%)*	56.9	49.6	64.0	48.2	54.4	49.9	0.035	2.12**
Total assets value *(GHC)*	6022	1691	6652	1875	4276	1005	0.126	-1.53
Soil fertility (%)	82.7	37.8	84.5	36.3	82.1	38.4	0.496	0.68
Market distance (*Km*)	3.5	2.7	3.2	1.9	3.6	3.0	0.058	-1.90**
Extension contact *(%)*	67.9	46.7	74.5	43.7	65.5	47.6	0.036	2.10**
Native *(%)*	46.7	49.9	57.1	49.6	43.0	49.6	0.002	3.11***
IC-L diversity index	0.42	0.18	0.44	0.19	0.41	0.17	0.072	1.80*
A-A district *(%)*	49.7	50.0	36.6	48.3	54.4	49.9	0.000	-3.89***

†The asterisks, ***, **, and *, indicate significance at the 0.1%, 1% and 5% levels, respectively

Generally, 56.9% of farmers had contacts with research institutions while 67.9% of the sample had contacts with extension agents. This is not surprising because of the closeness of extension agents to the farmers compared with research. Additionally, research institutions are mandated to develop and make new technologies available to farmers via the extension agents. The average value of total assets in the full sample was GHC 6,022, with men having relatively higher than women. In general, 82.7% of the farmers perceived their soil to be fertile for production but the proportional difference in this perception was not significant between men and women. By inference, a greater proportion of the lands in the study areas

[7] The binary or categorical variables were tested with the Chi-square test of ANOVA, while difference in continuous or count variables between the two groups were tested using the t-test.

are fertile and adequate to support agricultural activities. The distance from the farm gate to the nearest market was 3.5km on the average and is significantly different at 1% for men and women farmers. With residential status, 57.1% of the men were natives of their respective communities as compared to 46.7% of the women who were natives. This variation can be associated to women leaving their family homes to settle with their husbands/partners in different localities. The integrated crop-livestock diversity is significantly higher among men than women implying that, generally, men farmers tend to diversify their integrated crop-livestock production than women. This could be the quest for reducing risks through alternative livelihood sources to address the various household needs.

ICLMP **adoption rates**

Figure 1 presents the adoption rates for the various ICLMPs across sampled households. The Figure shows that improved pasture is the most highly adopted practice by nearly 90% of the farmers. This is because of the importance of pasture for livestock production particularly during the dryer periods of the year which has debilitating impacts on livestock production. Additionally, other practices which were highly adopted included the use of animal droppings as manure (72%), the use of dual-purpose groundnuts cowpea (70% and 68%, respectively) and storage of crop residue (52%). The results imply that generally, there is high adoption rates of ICLMPs among smallholder farmers in Ghana. This points to the fact that indeed ICLMPs play essential role in sustainable integrated crop-livestock production in Ghana.

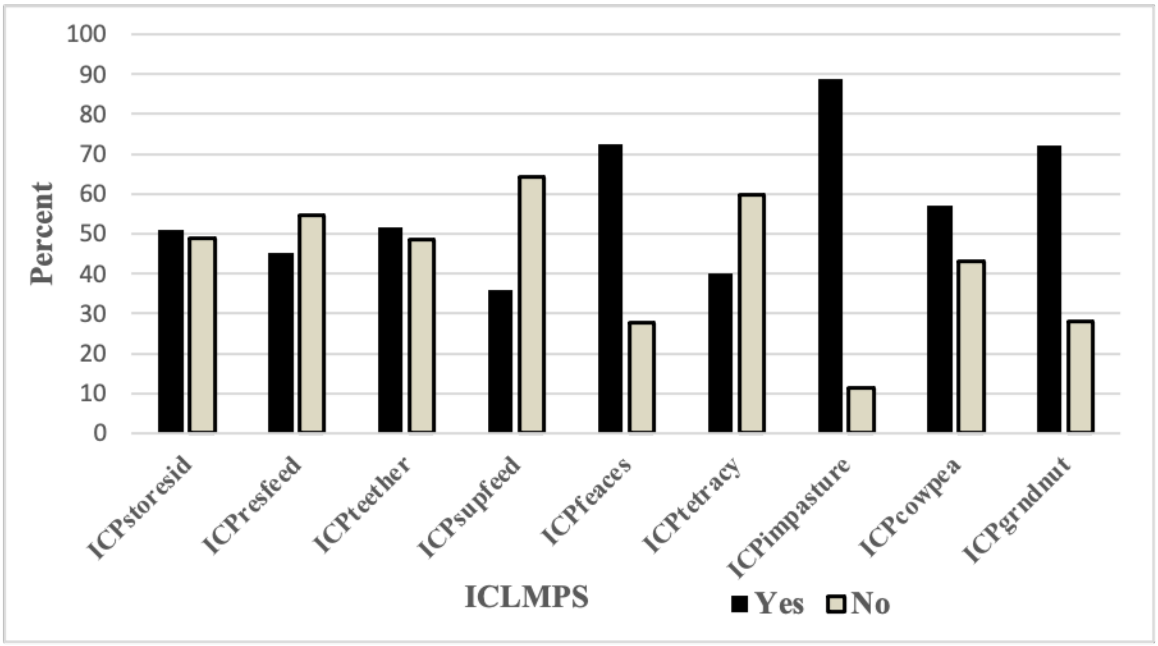

Figure 1: Adoption rates for each ICLMP

Factors influencing the adoption of individual ICLMPs among integrated crop-livestock farmers in Ghana

Table 3 presents the multivariate probit estimates of the factors influencing the adoption of individual ICLMPs among Integrated Crops-livestock farmers in Ghana. The key individual ICLMPs adopted are storage of crop residue, use of feed residue, tethering, supplementary feeding, use of faecal matter as manure, use of tetracycline, improved pasture, use of dual-purpose cowpea and use of dual-purpose groundnut. The positive effect of age on adoption of supplementary feeding of livestock implies that, older farmers are more likely to practice supplementary feeding compared to younger ones. This is not surprising because obtaining feeds for livestock in such an extensive system is quite involving hence, supplementary feeding tends to be a relatively easier option for older farmers. This is consistent with Asante et al. (2014) and Mignouna et al. (2011) who found older farmers to adopt improved crop technologies. Years of formal schooling attained by the farmer significantly and positively influenced the adoption of storage of crop residue to feed livestock, supplementary feeding and use of dual-purpose cowpea. Educated farmers are able to decipher the benefits of technologies faster and are able to search and decide which technologies will optimally benefit their production activities when adopted (Farid et al., 2015). Furthermore, gender was found to influence five (5) out the nine (nine) technologies (ICLMPs); storage of crop residue, use of feed residue as manure, supplementary feeding, use of tetracycline medication, and adoption of dual-purpose cowpea. The result shows that women farmers are more likely to adopt ICLMPs than men. This finding however, is contrary to findings of Kabunga et al. (2012) and Donkoh et al. (2014) who found a higher likelihood of adoption of improved crop technologies for men. Our result differs because it focusses mainly on integrated crop-livestock system which more women tend to be interested in due to its food security implications on the household compared to men.

The results further show that, farmers who had access to credit were more likely to store crop residue and also practice tethering of livestock. Household size was also found to positively influence the adoption and use of storage of crop residue, feed residue and tethering but had a negative influence on use of pasture. Farmers with larger household members have access to more family labour to cultivate larger fields which enables the accumulation of high quantities of crop residue to feed livestock hence, reducing their interest in searching for and using pasture for their livestock. Similar findings have been found in previous studies where adoption of improved technologies correlated with household size (Teklewold et al., 2013; Kassie et al., 2015). Non-farm income had a negative and significant influence on tethering and use of faecal matter from livestock as manure at the 1% and 10% significant levels respectively. This implies that with access to non-farm income, farmers are able to purchase and use adequate quantities of chemical fertilizers and hence decrease the use of manure.

There was a positive and significant relationship between use of storage of crop residues; use of feed residues; supplementary feeding; use of faecal manure and total value of farmers' assets. Farmers with more assets tend to be more stable and also capable of having access to resources hence are more likely to adopt more ICLMPs to improve their overall farm productivity. The income effect from increased asset value triggers an improvement in farmers' ability to pay for ICLMPs. This outcome is possibly a response phenomenon which is informed by farmers' strategic decisions taken to avoid or reduce financial and opportunity costs of travelling long distances to access inputs. When a farmer is a native of the community, he/she resides in, it is associated with a higher likelihood of adoption of storage of crop residues, use of feed residue, supplementary feeding and dual-purpose cowpea cultivation.

These were significant at 1% significance levels with the exception of use of feed residue which was significant at the 5% significant level. The crops-livestock diversity index recorded a negative and significant influence on; use of feed residues, tethering, supplementary feeding and use of tetracycline. By implication, the adoption of these ICLMPs increase with diversified farmers and declines with farmers who are specialised.

Table 3: Multivariate probit estimates of the factors influencing the adoption of ICLMPs

VARIABLES	StoResid[§]	FeedResid	Teether	SupFeed	Feaces	Tetracy	ImPasture	DPcowpea	DPgrndnut
Age	0.0025	0.0005	0.0011	0.0035**	0.0002	0.0007	0.0004	-0.0001	0.0008
	(0.0015)[†]	(0.0015)	(0.0015)	(0.0014)	(0.0014)	(0.0015)	(0.0010)	(0.0010)	(0.0010)
Years of Schooling	0.0105**	0.0048	0.0064	0.0091**	-0.0008	0.0040	0.0008	0.0064**	-0.0007
	(0.0041)	(0.0042)	(0.0042)	(0.0040)	(0.0038)	(0.0041)	(0.0027)	(0.0029)	(0.0028)
Gender	-0.1079**	-0.1089**	-0.0375	-0.1091**	-0.0258	-0.1843***	-0.0518*	-0.1076***	-0.0050
	(0.0479)	(0.0471)	(0.0473)	(0.0449)	(0.0435)	(0.0470)	(0.0304)	(0.0328)	(0.0323)
Credit Access	-0.2440**	-0.1621	-0.2427**	-0.1068	0.0272	0.0036	-0.0536	0.1202	-0.0145
	(0.1179)	(0.1110)	(0.1115)	(0.1057)	(0.1025)	(0.1107)	(0.0716)	(0.0771)	(0.0760)
Household Size	0.0083**	0.0110***	0.0019	0.0019	0.0052	0.0080*	-0.0045*	0.0027	0.0021
	(0.0041)	(0.0041)	(0.0042)	(0.0039)	(0.0038)	(0.0041)	(0.0027)	(0.0029)	(0.0028)
Non-farm Income	-0.0433	-0.0684	-0.1998***	0.0252	-0.0803*	0.0635	-0.0339	0.0382	-0.0330
	(0.0497)	(0.0483)	(0.0485)	(0.0460)	(0.0446)	(0.0482)	(0.0312)	(0.0336)	(0.0331)
Research (CSIR-CRI)	0.0718*	0.0465	0.0416	0.0792**	-0.0083	-0.1045***	0.0413	0.0135	-0.0214
	(0.0400)	(0.0399)	(0.0401)	(0.0380)	(0.0369)	(0.0398)	(0.0257)	(0.0277)	(0.0273)
Total Asset Value	0.0023*	0.0028**	0.0008	0.0029**	0.0029***	0.0023*	0.0003	0.0002	0.0003
	(0.0013)	(0.0012)	(0.0012)	(0.0011)	(0.0011)	(0.0012)	(0.0008)	(0.0008)	(0.0008)
Soil Fertility	0.0930	0.1556	0.0886	0.1123	0.0234	-0.0422	0.0350	-0.0530	-0.0386
	(0.1124)	(0.1044)	(0.1049)	(0.0994)	(0.0964)	(0.1041)	(0.0673)	(0.0726)	(0.0715)
Market Distance	0.0086	0.0120*	0.0069	0.0030	0.0093	-0.0063	-0.0044	0.0072	0.0072
	(0.0074)	(0.0073)	(0.0073)	(0.0069)	(0.0067)	(0.0072)	(0.0047)	(0.0050)	(0.0050)
Extension	0.1147*	0.1443**	0.1733***	0.1375**	-0.0333	0.0558	0.0338	-0.0549	-0.0312
	(0.0663)	(0.0655)	(0.0658)	(0.0624)	(0.0605)	(0.0654)	(0.0423)	(0.0455)	(0.0449)
Native	0.1453***	0.0970**	0.0359	0.1224***	-0.0145	-0.0177	0.0270	0.6826***	0.6144***
	(0.0400)	(0.0403)	(0.0405)	(0.0384)	(0.0372)	(0.0402)	(0.0260)	(0.0280)	(0.0276)
IC-L Diversity Index	0.0058	-0.2253**	-0.3510***	-0.2038*	-0.1074	-0.1881*	-0.0581	0.0539	-0.0835
	(0.1113)	(0.1101)	(0.1106)	(0.1049)	(0.1016)	(0.1098)	(0.0710)	(0.0765)	(0.0754)
Atebubu-Amantin District	0.0871**	0.0812**	-0.1048**	-0.0836**	0.0349	-0.0703*	-0.1031***	-0.1421***	0.1060***
	(0.0411)	(0.0411)	(0.0413)	(0.0391)	(0.0379)	(0.0410)	(0.0265)	(0.0285)	(0.0281)
Wald Chi-square (14)	45.64***								
Observations	608								

[illegible] chi2(36) = 498.337 Prob > chi2 = 0.0000

[§]The estimates are the marginal effects of the variables. [†]Figures in parenthesis denote standard errors. The asterisks, ***, **, and *, indicate significance of the marginal effects at the 0.1%, 1% and 5% levels, respectively. **StoResid**: storage of crop residue; **FeedResid**: use of crop residue as livestock feed;

Teether: tethering of livestock; **SupFeed**: supplementary feeding; **Feaces**: the use of faecal matter as manure; **Tetracy** the use of tetracycline; **Impasture**: use of improved pasture; **DPcowpea**: use of dual-purpose cowpea, **DPgrndnut**: use of dual-purpose groundnut.

Determinant of intensity of adoption of ICLMPs among men and women farmers in Ghana

The Tobit estimates of the determinants of intensity of adoption of ICLMPs among men and women farmers are presented in Table 4. The results show that generally the adoption of a number of ICLMPs is determined by age, education, gender credit access, household size, non-farm income, total value of assets, extension, being a native of the resident community, crop-livestock diversity, being in the District dummy. While higher likelihoods of intensified adoption are experienced with respect to age, years of schooling, household size, total value of assets, credit access, , extension, being a native of the community, crop-livestock diversity and gender, lower likelihoods of intensified adoption are associated with non-farm income and being in the A-A district. On the full sample, the age of the farmer is significant at the 5% level. This implies that older farmers intensify their adoption of ICLMPs more than the younger ones. Older farmers are assumed to have gained knowledge and experience over time and are able to evaluate technology information better than younger farmers (Chirwa, 2005; Mignouna et al, 2011; Kariyasa and Dewi, 2011).

The results further show that years of schooling is significantly influenced the number of ICLMPs adopted. Implying that more years of formal schooling is associated with adoption of more ICLMPs. This findings corresponds with that of Mariano et al. (2012) and Chirwa (2005) when they examined the factors affecting adoption of modern rice technologies. Farmers with more years of schooling farmers are better able to apply the knowledge applied and hence, adopt more practices to address potential challenges in production. Additionally, access to credit had significant impacts on the number of ICLMPs adopted.

Table 4: Tobit[8] estimates of the determinant of intensity of adoption of ICLMPs among men and women smallholder farmers in Ghana

Variables	Full		Men		Women	
	Coeff	ME	Coeff	ME	Coeff	ME
Age	0.0103**	0.0094**	0.0101*	0.0090*	0.0061	0.0059
	(0.0051)	(0.0047)	(0.0059)	(0.0053)	(0.0098)	(0.0095)
Years of Schooling	0.0425***	0.0389***	0.0418***	0.0373***	0.0103	0.0100
	(0.0138)	(0.0126)	(0.0157)	(0.0141)	(0.0275)	(0.0268)
Gender	0.7463***	0.6826***	—	—	—	—
	(0.1651)	(0.1514)	—	—	—	—
Credit Access	0.6903*	0.6314*	0.6352	0.5672	0.7421	0.7237
	(0.4105)	(0.3763)	(0.4520)	(0.4046)	(1.0440)	(1.0185)
Household Size	0.0368**	0.0337**	0.0475***	0.0424***	0.0191	0.0186
	(0.0159)	(0.0145)	(0.0167)	(0.0149)	(0.0366)	(0.0357)
Non-farm Income	-0.3322**	-0.3038**	-0.2448	-0.2186	-0.6670	-0.6504
	(0.1668)	(0.1526)	(0.1778)	(0.1587)	(0.4170)	(0.4068)
Research (CSIR-CRI)	0.1590	0.1454	0.0172	0.0154	0.3877	0.3781
	(0.1402)	(0.1284)	(0.1659)	(0.1481)	(0.2574)	(0.2502)
Total Asset Value	0.0149***	0.0136***	0.0109**	0.0097**	0.0402***	0.0392***
	(0.0054)	(0.0050)	(0.0050)	(0.0045)	(0.0099)	(0.0096)
Soil Fertility	0.4311	0.3943	0.6338	0.5659	-0.3456	-0.3370
	(0.4037)	(0.3692)	(0.4509)	(0.4028)	(0.9239)	(0.9009)
Market distance	0.0378	0.0345	0.0292	0.0261	0.0763	0.0744
	(0.0240)	(0.0219)	(0.0252)	(0.0225)	(0.0698)	(0.0680)
Extension	0.6407***	0.5860***	0.4499*	0.4017*	1.2634**	1.2319**
	(0.2228)	(0.2045)	(0.2402)	(0.2152)	(0.6129)	(0.5969)
Native	1.2412***	1.1353***	1.0078***	0.8999***	1.4681***	1.4315***
	(0.1400)	(0.1284)	(0.1649)	(0.1474)	(0.2627)	(0.2590)
IC-L diversity index	1.1262***	1.0301***	0.6726	0.6006	1.8949***	1.8477***
	(0.4114)	(0.3769)	(0.4901)	(0.4385)	(0.6383)	(0.6203)
Atebubu-Amantin District	-0.2864**	-0.2619**	-0.5734***	-0.5120***	0.4253	0.4147
	(0.1432)	(0.1302)	(0.1652)	(0.1457)	(0.2680)	(0.2621)
Constant	2.9274***		2.1428***		3.7253***	
	(0.4379)		(0.4603)		(0.8649)	
Pseudo R^2	0.0690		0.0563		0.1195	
F test	14.84***		9.27***		8.60***	
Linktest: hat: P>|z|=	0.001		0.029		0.005	
hatsq: P>|z|=	0.532		0.777		0.473	
Observations	608		447		161	

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1 ME: Marginal Effect

Farmers who had access to credit intensified their adoption of ICLMPs and this because most technologies require some amount of capital investments to be very effective. Access to credit stimulates technology adoption (Mwangi and Kariuki, 2015) hence, to enhance adoption of ICLMPs, there is the need to design of credit packages that are meet the needs of

8 Testing for model specification using the link test, we see that across all models, the _hat and _hatsq are significant and insignificant respectively. This means that we fail to reject the null hypothesis that the model is correctly specified.

farmers (Muzari *et al*., 2013). Household size has a negative relationship with the intensity of ICLMP adoption.

Access to extension services have been found to be key factor in intensification of technology adoption by farmers (Mignouna et al. 2011; Genius *et al*., 2010; Uaiene *et al*., 2009). Extension contacts was found to be significant in the number of ICLMPs adopted by the farmers. Frequent extension contacts encourages the intensified adoption of ICLMPs as farmers receive training in good agricultural practices which enhances both the awareness and adoption of the practices. Sulo et al. (2012) also reported a positive and significant association between technology adoption and extension services among women farmers in Kenya. The results further suggests that farmers engaged in non-farm income activities tended to adoption less ICLMPs. This is because such farmers tend to spend more of their time engaging in non-farm income activities they tend to have less time to engage in other integrated farming activities which will demand the adoption of relevant ICLMPs to enhance productivity.

The result further shows that farmers who are natives of communities they reside and produce are more likely to intensify their adoption of ICLMPs. Natives are most likely to have access to bigger farmlands hence, are able to dedicate portions of their land to try new technologies. Many studies have reported a positive relation between farm size and adoption of agricultural technology (Chirwa, 2005; Uaiene et al., 2009; Mignouna et al, 2011). Further, natives are more likely to share positive outcomes of use of ICLMPs among themselves and motivate one another to intensify their adoption. Gender plays a very vital role in the technology adoption process. Men farmers were seen as being more likely to intensify their adoption of ICLMPs than women. This results conforms with Kabunga et al. (2012) who found that, men adapt agricultural technology easier than women. In most African communities, men are heads of the household and hence are the primary decision makers, subsequently, they tend to have more access and control over vital production resources than women due to socio-cultural values and norms (Mignouna et al., 2011).

Integrated crop-livestock diversity positively influenced the number of ICLMPs adopted by the farmers for both the full and subsamples. Farmers who are more diversified into integrated crop-livestock production tend to have keen interest and areas for applying more ICLMPs in their production activities and hence increasing their probability of adopting more ICLMPs to enhance their overall farm productivity (Asante et al., 2017a).

Our results further suggest gender differentials in the factors influencing the intensity of adoption of ICLMPs. For instance, age, years of schooling and household size had significant influences on the intensity of ICLMPs adoption among the men only while, integrated crop-livestock diversity is the only variable that had a significant influence on the intensity of adoption among women only. All factors that were significant among the males were also significant in the full model. Considering the significance of ICLMP in enhancing overall farm productivity, particularly among smallholder farmers in Ghana, there is the need to mainstream gender-improved technology adoption interventions to increase productivity and income of farm households.

Relative effect/importance of the determinants of ICLMP adoption

The results of the dominance analysis for the determinants of ICLMPs are presented in Table 5. The results of the dominance analysis provide vital information relevant for policy considerations. It seeks to examine which of the factors has the highest influence on the intensity of adoption of ICLMPs and hence needs to be considered by policy makers to enhance the adoption of ICLMPs for increased productivity of smallholder farming in Ghana. Specifically, it addressed the important policy question that, in the midst of time and financial resource constraints, if government or development partners is to boost the intensity of adoption of ICLMPs, which of these variables is most important to consider to achieve that goal? The result shows that across the full and gender subsamples, being a native of the land, where one farms, has the strongest influence in intensifying ICLMP adoption. This implies that in general, dissemination campaigns that mainly target natives or designing native-centred programmes will yield the greatest influence in intensifying the ICLMP adoption. This has implications on improving land tenure to boost investor confidence among farmers and hence increase ICLMP adoption. The results further show that besides being a native of the community a farmer farms, other factors such as gender, crop-livestock diversification, total value of assets, total household size, research and extension (*in order of importance*) have strong effects on influencing the intensity of ICLMP adoption and hence, needs to be considered in enhancing the adoption of ICLMPs among smallholders in Ghana.

However, in the men's sample, in terms of influence on intensity of ICLMP adoption, being a native is followed by household size, total value of assets, soil fertility and extension. In the women' s sample, apart from nativity, intensity of ICLMP adoption is highly influenced by crop-livestock diversification, total value of assets, extension, non-farm income and research. These findings suggest that, in order to increase the intensity of adoption of ICLMPs among men farmers, the dissemination campaigns should target farmers with large household sizes, those who own some household assets and have contacts with extension, while among women farmers such efforts should be targeted at farmers who are into crop-livestock production, have larger amount of household assets, have contacts with extension and research and are engaged in non-farm income generating activities.

Table 5: General dominance statistics for relative effect of the drivers of intensity of ICLMP adoption

	Full		Men		Women	
ICLMP	Standardized Domin. Stat.	Rank	Standardized Domin. Stat.	Rank	Standardized Domin. Stat.	Rank
Age	0.015	11	0.034	9	0.002	13
Years of schooling	0.032	8	0.047	6	0.018	10
Gender	0.113	2	—	—	—	—
Credit access	0.019	10	0.030	10	0.022	8
Household size	0.055	5	0.129	3	0.005	12
Non-farm Income	0.015	12	0.018	11	0.034	5
Research (CSIR-CRI)	0.013	14	0.004	13	0.026	7
Total assets value	0.061	4	0.058	4	0.129	3
Soil fertility	0.025	9	0.055	5	0.007	11
Market distance	0.013	13	0.016	12	0.019	9
Extension	0.054	6	0.044	7	0.069	4
Native	0.473	1	0.382	1	0.487	1
IC-L diversity index	0.064	3	0.036	8	0.154	2
A-A district	0.0464	7	0.150	2	0.030	6
No. of regressions		16,383		8,191		8,191
Number of Obs.		608		447		161
Overall Fit Statistic		0.056		0.046		0.08

Conclusions and Policy Implications

This paper examines gender differences in the rates and intensities of ICLMP adoption among 608 systematically sampled smallholder farmers in Ghana. The result shows differences in the rates and intensity of adoption of ICLMPs for men and women farmers. For instance, the rate of adoption of ICLMPs is 76.8% but is substantially greater for women (84.4%) than men (74.0%) farmers. Conversely, the intensity of adoption of ICLMPs was greater among men farmers. This indicates that there is greater likelihood for women to adopt the ICLMPs, however, women are unable to adopt many as compared to men probably but due to the dominant role of men in most household decision making processes. Furthermore, key individual ICLMPs adopted are storage and feeding of crop residue, tethering, supplementary feeding, use of faecal matter as manure, use of tetracycline, improved pasture, use of dual-purpose cowpea and groundnut. Major factors influencing the adoption of these individual ICLMPs are being a native of the residing community, years of schooling, gender, household size, extension and research, total value of assets and integrated crop-livestock diversification. Policies for enhancing the productivity of ICLMPs should be designed to target women farmers with larger household sizes. Furthermore, this process can be enhanced by promoting major ICLMPs such as storage and feeding of crop residue, tethering, supplementary feeding, use of faecal matter as manure, use of tetracycline, improved pasture, use of dual-purpose cowpea and groundnut.

However, the results further indicate a clear distinction in intensity of adoption and determinants among male and female farmers showing evidence of differences in the adoption of ICLMPs among men and women farmers. For instance, age, credit access, soil fertility, market distance, total value of assets, district and research contacts influenced the intensity of ICLMPs adoption among men farmers only, while household size influenced intensity of adoption among women farmers.

The results of the dominance analyses across the full sample and gender subsamples show that being a native of the land, where one farms, has the strongest influence on farmers' intensity of ICLMP adoption. An effective land registration system can help resolve this limitation. This will offer equal opportunities to access to land for both natives and non-natives and hence is likely to yield optimum results of enhancing the intensity of ICLMP adoption among farmers.

Furthermore, to increase the intensity of adoption of ICLMPs among men farmers, the dissemination campaigns should target farmers with large household sizes, those that own some household assets and those who have contacts with extension, while among women farmers such efforts should be targeted at farmers who are more diversified, have larger amount of household assets, have contacts with extension and research officers and are engaged in non-farm income generating activities. In order to account for differences in gender and ensure holistic benefits from the adoption of ICLMPs to farm households, this study recommends policies that targets male farmers who have credit, producing closer to markets, have substantial amount of farm assets and have contacts with extension and research, while, for female farmers the policy direction is to focus on those with large household sizes.

Considering the significance of ICLMP in enhancing overall farm productivity, particularly among smallholder farmers in Ghana, there is the need to mainstream gender into improved technology adoption interventions to enhance productivity and income within the entire household. This can be done by first profiling farmers to identify their specific gender needs before rolling out the intervention to ensure effective adoption of ICLMPs among male and female and sustainable improvement in productivity, incomes and food security.

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