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Impacts of Farmer Innovation Systems and Improved Agricultural Technologies on Rice Yield in Ghana

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ABSTRACT

To increase and bridge the differences in rice yield, many farmers have resorted to adopting farmer innovation systems and improved agricultural technologies. This study analysed the impact of adoption of farmer innovation systems and improved agricultural technologies on rice yield using multinomial endogenous switching regression. Nine-hundred and seven (907) rice farmers from Guinea Savannah Zone, Forest Savannah Transition Zone and Coastal Savannah Zone were used for the study. The study used both primary and secondary data. Membership of farmer-based organisations, rice farming experience and distance from farming communities to input markets increase farmers' adoption of only farmer innovation systems. Factors that increase farmers' probability of adopting only improved agricultural technologies are access to extension service, credit, improved seeds and contract farming. Farmers located in Coastal Savannah Zone have higher probability of adopting only improved agricultural technologies than their counterparts living in other agro-ecological zones. Age and access to input subsidy increase the probability of jointly adopting farmer innovation systems and improved agricultural technologies. Farmer Innovation Systems and improved agricultural technologies have heterogeneous impact on rice yield with adoption of only improved agricultural technologies having the highest impact followed by joint adoption of farmer innovation systems and improved agricultural technologies. It is important for stakeholders in rice subsector to champion the provision of improved rice seeds, the intensification of agricultural extension services and contract farming concept.

Key Words: *Farmer innovation systems, improved agricultural technologies, multinomial endogenous switching regression, treatment effect*

INTRODUCTION

The climatic and soil conditions of large proportions of the land in Ghana support rice production. Rice is grown in all the ten regions but the regions where rice is cultivated most are Greater Accra, Volta, Northern, Upper West and Upper East regions. Farmers producing rice use different methods. Due to the use of different Indigenous Farming Practices (*IFPs*), Farmer Innovation Systems (*FISs*) and Improved Agricultural Technologies (*IATs*) among farmers in the various agro-ecological zones as well as differences in environmental conditions, rice productivity has not been homogenous. In Ghana, some of the rice farmers still produce using indigenous practices. *IFPs* are the relatively unimproved older farming practices handed over to farmers by their fore parents or any other older family members or friends.

FISs and *IATs* have all emanated from *IFPs*. Farmer innovations are continuous processes which started long ago before scientific development of improved farming technologies (Biggs, 1981). For instance, over the years, farmers have tried to maintain varieties of crops with good characteristics (high yielding, disease resistant, drought resistant etc). The criteria and features used by the local farmers in the selection process are not documented and scientifically verified. Farmer innovations are crop specific even though some are universal and can be used in the production, storage and process of two or more crops. Meanwhile, *FISs* are relatively improved farming systems which are ingeniously developed by farmers with the aim of improving agricultural productivity, product quality or shorten maturity period. They include extensively modified or uniquely combined *IFPs* and/or *IATs* (Tambo and Wuscher, 2014). They are also defined as the combination of existing techniques or technologies in new ways in order to enhance their impact (Wills, 2012).

On the other hand, *IATs* are highly improved externally developed technologies by national or international research institutions. For rice, some of them have been developed by the research department of MoFA, Centre for Scientific and Industrial Research (Savannah Agricultural Research Institute, SARI; Soil Research Institute, SRI; and Crop Research Institute, CRI), FAO, International Rice Research Institute (IRRI) etc. Unlike *FISs* which are equally improved ways of increasing rice yield, vigorous efforts have been made to help farmers adopt *IATs* through project interventions, agricultural investment policy frameworks among others.

As noted by Abdulai and Huffman (2014), it is possible for farmers to increase the productivity of crops through the adoption of modern farming practices, and the same may be said specifically about rice farmers. When high-yielding, pest- and disease-resistant varieties are made available, affordable and accessible to smallholder farmers, some will adopt and be able to increase their productivities close to the potential values or even commercial level. Farmers can adopt modern rice cropping systems and farmer innovation rice cropping systems to help bridge the heterogeneity in the productivities of the selected crops. The discrepancies in rice yield may be as a result of differences in technologies (*IFPs*, *FISs* and *IATs*) used by farmers. It is against this backdrop that this study aimed at assessing the impacts of each technology adoption package on rice yield in Ghana.

METHODOLOGY

Study Area

Ghana, the study area of this research is located on the West African coastline and shares boundaries with Burkina Faso to the north, Cote d'Ivoire to the west, Togo to the east and Gulf of Guinea to the south. There are six agro-ecological zones namely Sudan Savannah Zone (SSZ), Guinea Savannah Zone (GSZ), Forest Savannah Transition Zone (FSTZ), Semi-Deciduous Rain Forest Zone (SDRFZ), High Deciduous Rain Forest Zone (HDRFZ) and Coastal Savannah Zone (CSZ). A stratified sampling technique was used to selected GSZ, FSTZ and CSZ. These three agro-ecological zones have environmental conditions which are suitable for rice production.

Sources, Type and Method of Data Collection

The study used primary and cross-sectional data of rice farmers for 2015/16 cropping season. The data was collected from October, 2015 to August, 2016. The data was collected using semi-structured questionnaire. The study also obtained secondary data climatic variables (rainfall and temperature) in the study area.

Sample Size

Using sample determination formula stated below, the number of rice farmers sampled for the study in GSZ, FSTZ and CSZ are 377, 359 and 171 respectively. This calculation was done based on 8% imprecision.

Sampling Procedure

The study used a multi-stage sampling technique. Stratified random sampling techniques were sued to select three agro-ecological zones thus GSZ, FSTZ and CSZ from SSZ, GSZ, FSTZ, SDRFZ, HDRFS and CSZ and districts with and without irrigation facilities. Simple random sampling techniques were used to selected the various districts under each of the strata. Also, rice-producing communities were stratified into communities with and without irrigation facilities. In each of the strata, two communities were selected using simple random sampling technique. The houses were selected using systematic sampling technique whereas rice farmers were randomly selected from each house.

Theoretical Framework

The general theoretical underpinning of agricultural innovation or technology adoption is the theory of consumer behaviour (behavioural theory). A farmer producing rice and other commodities has an option of being a net adopter of *FISs* or *IATs* or a combination of the two. This involves decision making following the assumption that the utility that a farmer derives from adopting *FISs* or *IATs* or a combination can be ordered (ordinalists approach to utility measurement). With this utility maximisation objective, a farmer chooses a combination of adoption options that will provide him or her with maximum utility. The *FISs* and *IATs* are bundles of innovations and technologies respectively. The net benefit or utility (*U*) from each or a combination can be compared (thus completeness assumption). The transitivity assumption states that given a range of innovations and technologies or a combination (y);

if $U(y_1) \geq U(y_2)$ and $U(y_2) \geq U(y_3)$, then $U(y_1) \geq U(y_3)$ [1]

Given two technologies, there are four possible combinations of net adoption options for each farmer. Let *I* and *T* represent *FISs* and *IATs* respectively. In this research, *FISs* and *IATs* are innovative strategies or technologies used by farmers to increase rice productivity. Following the work of Teklewold *et al.* (2013), Table 1 shows four possible permutations of classified adopters.

Table 1: Possible Combinations of Adoptions of FISs and IATs

Choice	*Classified Adopters*	*Binary combinations*	*FISs=I*		*IATs =T*	
			I_0	I_1	T_0	T_1
1	*Non-adopter*	I_0T_0	√	×	√	×
2	*Adopter of FISs only*	I_1T_0	×	√	√	×
3	*Adopter of IATs only*	I_0T_1	√	×	×	√
4	*Adopter of both FISs and IATs*	I_1T_1	×	√	×	√

Subscript *'1'* implies adoption whereas subscript *'0'* implies non-adoption
√ = choice and × = no choice

Farmers face nearly the same environmental conditions, prices and socio-economic circumstances and yet they may make different choices. For control experiment on the field, it is easier to determine the impact of alternative combinations of adoption options on rice yield. Due to the introduction of biases of self-selection when observational data is used (as it is the case in this study), it is inappropriate to simply compare rice yield of differently classified adopters of *FISs and IATs*. According to Teklewold *et al*. (2013), farmers endogenously self-select themselves into adopters and non-adopters and such decisions are likely to be influenced by unobservable factors such as managerial skills, motivation, productivity improvement expectations from adoption etc. which may be correlated with the outcomes of interest (in this study rice yield measured as output per area in ha).

Hence, selecting either adopters or non-adopters introduces sample selection bias. It occurs when adopters or non-adopters are not randomly selected resulting in the situation where the criteria for selection are correlated with the expected outcomes. Self-selection bias arises because farmers make voluntary decisions whether to adopt or not to adopt a particular technology. These decisions may be affected by farmers' inherent personal characteristics such as educational level and ownership of productive resources. This may lead to an endogenous selection bias. According to Maddala (1983), the remedy for the bias is the use of a selection correction model called endogenous switching regression model. Due to multiple adoption setting, this study used the multinomial endogenous switching regression treatment effect model (often called DM model) as used by Dubin and McFadden (1984). It has the strength of estimating the impact of alternative combinations of adoption options on rice yield and also solves the problem of self-selection bias (Mansur *et al*., 2008).

Multinomial Endogenous Switching Regression Model (MESR)

This study used a two-stage multinomial endogenous switching regression model. The first stage involves the use of a multinomial logit model to determine specific socio-economic factors that influence the decision of rice farmers in adopting the alternative combinations of *FISs* and *IATs* (I_0T_0, I_1T_0, I_0T_1, and I_1T_1). The second stage involves an ordinary least square estimation of the determinants of rice yield (outcome variable). In the second stage, the selectivity correction term called inverse mills ratio (IMR) from the selection model is incorporated into the outcome model using ordinary least squares (OLS) method. The impacts of each combination of *FISs* and *IATs* (I_0T_0, I_1T_0, I_0T_1, and I_1T_1) on rice yield (*RY*) are done by using post-estimation commands.

A farmer will choose *j*th combination of adoption option over that of *m* if the utility or benefit he/she will derive from choosing *j*th adoption option is greater than adopting *m*th package. Following the work of Noltze *et al*. (2012), the sample selection criterion models expressing the utility for adopting *j*th package (i.e. choosing any of these: I_0T_0, I_1T_0, I_0T_1 and I_1T_1) and not adopting any package (i.e. choosing I_0T_0) are respectively given as:

$$U_{ji}^{*k} = F_i^k \delta_j + \eta_{ci}^k \qquad [2a]$$

$$U_{mi}^{*k} = F_i^k \delta_m + \eta_{ci}^k \qquad [2b]$$

where F_i^k is a vector of exogenous variables explaining the choice decision of *i*th farmer in *k*th agro-ecological zone, δ_j and δ_m are vectors of parameters, η_{ci}^k is the error term for *i*th farmer in *k*th agro-ecological zone of the sample selection criterion model. According to McFadden (1973), η_c^k is assumed to be identically and independently Gumbel distributed; $N(0, \sigma_c^2)$ with the multinomial logit model indicating the probability that farmer i chooses *j*th package ((i.e. choosing any of these: I_0T_0, I_1T_0, I_0T_1 and I_1T_1) given as:

$$P\left(U^*_{j1i} - U^*_{mi} > 0 / F_i^k\right) = \frac{\exp\left(F_i^k \delta_j\right)}{\sum_{m=1}^{m=J} \exp\left(F_i^k \delta_m\right)} \quad [3]$$

The parameters were estimated using maximum likelihood method. Meanwhile, in order to solve the endogeneity and selection issues, an instrument which examines the access to agricultural information with advice was included in the model as explanatory variable.

The second stage of MESRM involves the regressing of rice yield (RY) on specific explanatory variables for adopters of any of the combinations (I_0T_0, I_1T_0, I_0T_1 and I_1T_1). For non-adopters of any of the combinations (I_0T_0), $j=0$ while for adopters of I_1T_0, I_0T_1 and I_1T_1, j represents *1, 2* and *3* respectively. The outcome equations for the various regimes are expressed as:

Regime 1: Non-adoption: package one (T_0T_0)

$$I = 0: RY_{0i}^k = \rho_0 G_i^k + \varepsilon_{0i}^k \quad [4a]$$

Regime 2: Adoption of package two (T_1T_0)

$$I = 1: RY_{1i}^k = \rho_1 G_i^k + \varepsilon_{1i}^k \quad [4b]$$

$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \vdots$$

Regime J: Adoption of package J

$$I = J: RY_{Ji}^k = \rho_1 G_J^k + \varepsilon_{Ji}^k \quad [4d]$$

Where RY_{Ji}^k represents the outcome variable measuring rice yield of the *i*th farmers adopting *j*th package. Also, G_i^k denotes a vector of exogenous variables that affect the outcome variable, *RY* and ρ_0 and ρ_J are vectors of parameters in the regimes *1* and *J* respectively. Also, ε_0^k and ε_J^k denote the error terms for regimes *1* and *J* respectively. The error terms ε_0^k and ε_J^k are respectively distributed as $N\left(0, \sigma_0^2\right)$ and $N\left(0, \sigma_J^2\right)$.

According to Maddala (1983), the error term of the sample selection equation, η_c^k is assumed to have a correlation with the error terms (ε_0^k and ε_J^k) of outcome equations. Also, the expectation of the error term in the selection criterion model (η_c^k) is nonzero and this violates an assumption of classical linear regression that the expectation of the error term must be zero. Henceforth, the use of OLS to estimate the parameters results in inconsistent estimates. It is also assumed that the error terms (ε_0^k, ε_J^k and η_c^k) have trivariate joint-normal distribution with zero mean vector and non-singular variance-covariance matrix.

One can use a two-stage procedure where the *IMRs* are incorporated into the outcome regime equations but this provides less efficient estimates. A full information maximum likelihood (*FIML*) method developed by Lokshin and Sajaia (2004) which estimates the selection and outcome equations simultaneously provides more efficient estimates. Therefore, this study used *FIML* multinomial endogenous switching regression method with the outcome equations specified as:

Regime 1: Non-adoption: package one (T_0T_0)

$$\text{If } I = 0: RY_{0i}^k = \rho_0 G_i^k + \sigma_{0c}\lambda_{0i} + \xi_{0i}^k \quad [5a]$$

Regime 1: Adoption of package two

$$\text{If } I = 1: RY_{1i}^k = \rho_1 G_i^k + \sigma_{1c}\lambda_{1i} + \xi_{1i}^k \quad [5b]$$

$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \vdots$$

Regime 1: Adoption of package J

$$\text{If } I = J: RY_{Ji}^k = \rho_J G_i^k + \sigma_{Jc}\lambda_{Ji} + \xi_{Ji}^k \quad [5d]$$

Where λ_0, …, λ_J evaluated at δF_i^k are known as *IMR*s and ξ_0^k, …, ξ_J^k are the error terms with zero expectations.

According to Akpalu and Normanyo (2012), if the covariances σ_{0c} and σ_{Jc} are statistically significant, then the decision not to adopt any of the packages and rice yield effects are correlated and the null hypothesis of absence of selectivity bias is rejected. This implies endogeneity i.e. endogenous switching is present and the reverse is true indicating exogenous switching. For applicability of *FIML* endogenous switching regression, the restriction criterion requires that there should be identification or valid instrumental variables. This means that at least one variable that affects selection decisions of farmers must not directly affect any of the rice yield. Also, endogenous switching regression modelling is applicable when the explanatory variables differ slightly between the two models and this is the case in this study.

The MESR model can be used to compare observed and counterfactual of rice yield. The yardstick for comparison is the use of unbiased average treatment effects on the treated (*ATT*) for adopters and average treatment effect on the untreated (*ATU*) for non-adopters. It can be used to compare the expected rice yield of a farmer who adopted any of the packages (I_1T_0, I_0T_1 and I_1T_1) against a scenario that he/she does not adopt any package (I_0T_0). Conversely, it compares the expected rice yield of a non-adopter farmer of any of the packages (I_0T_0) to a situation had he/she does adopt any of the packages (I_1T_0, I_0T_1 and I_1T_1)

ATT measures the change (impact) in rice yield of the farmer due to adoption. It is the benefit that an adopter gets if he/she had not adopted and it is expressed as the differences between adopters with adoption and adopters without adoption.
ATT is expressed as:

$$ATT_i^k = E\left(RY_{1i}^k / I_i = 1\right) - E\left(PPI_{0i}^k / I_i = 1\right) = G_i^k\left(\rho_1 - \rho_0\right) + \lambda_{1i}\left(\sigma_{1c} - \sigma_{0c}\right) \quad [6a]$$

The difference between the expected yields of the counterfactuals and the observed is ATU and it is expressed as the differences between non-adopters with no adoption and non-adopters with adoption. *ATU* given as:

$$ATU_i^k = E\left(RY_{1i}^k / I_i = 1\right) - E\left(PPI_{0i}^k / I_i = 0\right) = H_i^k\left(\rho_1 - \rho_0\right) + \lambda_{0i}\left(\sigma_{1C} - \sigma_{0c}\right) \quad [6b]$$

RESULTS AND DISCUSSIONS

Summary Statistics of Continuous Variables

Table 2 shows the summary statistics of continuous variables used in MESRM. From the table, adopters of *IATs* had the highest average rice yield of 3.66Mt/ha followed by adopters of both *FISs* and *IATs* obtaining average rice yield of 3.10Mt/ha. The non-adopters obtained the lowest rice yield of 1.73Mt/ha. It is clear from Table 2 that adopters of *FISs* had the largest average farm size (2.8acres) whereas non-adopters had the smallest average farm size (2.4acres) albeit no wide variations in average farm size. Also, there are no wide variations in the average total labour employed among non-adopters and adopters of the various technology adoption typologies even though adopters of *FISs* employed the highest average mandays of labour of 47.1. As expected, the adopters of *IATs* applied the highest average quantity of fertilizer (295.7kg) as compared to their counterparts (51.0kg for non-adopters, 143.2kg for adopters of *FISs* and 242.6kg for adopters of both *FISs* and *IATs*). Adopters of FISs applied more pesticides than other technology typologically classified farmers. The farmers who invested the highest average amount of capital in rice production are adopters of *IATs*. This is due to the cost requirements of *IATs* as noted by Donkoh and Awuni (2011).

The mean age of adopters of *IATs* (44 years) is however higher than the mean age of adopters of *FISs* (42.6 years) whereas non-adopters have the highest mean household size of 8.9. The mean number of years of education of adopters is 7.9 years compared to 4.2 years of non-adopters. This observation reflects the fact that understanding and adopting *IATS* requires a high level of education or training to appreciate the science behind the technology. The non-adopters represent farmers with very little education and training and therefore are unable to appreciate modern technology. Thus, they stick to the familiar *IFPs* which they have been accustomed to over generations. Farmers in this category have the highest number of years of farming experience extending back into the past 43.7 years.

As shown in Table 2, farmers who had the highest mean number of agricultural extension officers visiting and advising them on rice production are joint adopters of *FISs* and *IATs*. Adopters of both *FISs* and *IATs* received the highest number of advice on rice cultivation from farmer based organization. In terms of distance, non-adopters stayed farthest away (averagely 12.1Km) from offices of agricultural extension officers, rice marketing centres (11.5Km) and Accra (514.3Km) than their adopting counterparts. Similarly, non-adopters stay in the area where mean annual rainfall and temperature are the highest.

Table 2: Summary Statistics of Continuous Variables

	Non-Adopters (n = 199)		**Adopters of *FISs* (n = 154)**		**Adopters of *IATs* (n = 365)**		**Adopters of both *FISs* and *IATs* (n = 189)**	
Variable	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Yield (Mt/Ha)	1.73	0.89	2.40	1.36	3.66	1.45	3.10	1.11
Production Inputs								
Farm size (acres)	2.4	1.43	2.8	1.75	2.6	1.34	2.7	1.52
Labour (mandays)	38.2	19.67	47.1	28.89	45.3	21.98	47.7	23.36
Fertilizer (Kg)	51.0	101.78	143.2	183.36	295.7	271.64	242.6	170.43
Seed (Kg)	94.3	116.73	97.7	87.37	72.2	57.21	73.9	54.55
Pesticides (litres)	3.0	3.51	4.5	5.52	3.8	4.45	4.3	4.30
Capital (Gh¢)	285.5	494.09	646.2	946.38	1081.2	1019.04	797.9	977.76
Farmer Characteristics								
Age (years)	43.7	10.37	42.6	10.62	44.0	10.11	41.4	9.48
Household size	8.9	4.09	8.2	4.41	6.7	3.33	7.7	3.62
Education years	4.2	4.50	5.3	4.91	7.9	5.11	7.3	5.17
Rice farming experience (years)	15.8	9.41	15.2	10.08	13.8	7.59	11.9	7.29
Institutional and Policy Variables								
Extension visits	0.9	1.59	2.0	2.24	3.2	2.13	3.4	2.23
No. of FBO advice	0.4	0.86	1.0	1.52	1.4	2.03	1.6	1.56
Infrastructure								
Distance from office of AEAs to community (Km)	12.1	12.85	7.9	10.30	4.5	6.38	7.9	8.89
Distance from community to rice marketing centre (Km)	11.5	12.70	9.3	10.36	3.9	8.93	7.2	8.97
Distance from Accra to rice farming community (Km)	514.3	23.0	441.4	21.0	298.0	20.50	494.6	27.22
Environmental Shocks								
Actual mean annual rainfall (mm)	1036.5	124.27	1035.6	153.32	1010.8	150.92	1024.2	127.98
Actual mean annual temperature (^0C)	27.8	1.46	27.3	1.81	26.5	1.58	27.5	1.56

Source: Author's analysis from field data and data obtained from Ghana Meteorological Agency (2017)

Summary Statistics of Discrete Variables

In Table 3, the technology adoption typology which had the highest percentage of males (71.4%) is adopters of both *FISs* and *IATs*. In this study, the proportion of female adopters is lower than the proportion of male adopters for each of the technologies. Most of the farmers who cultivate rice as a business are those adopting *FISs*. The majority of adopters of *IATs* (54.5%) had access to credit for rice cultivation and are also involved in contract farming (45.8%). On the other hand, the lowest percentage of farmers having access to credit and engaging in contract farming are farmers who stick to their traditional IFPs without adopting any technology. This is because *IFPs* are not highly expensive. Also, farm credit lending institutions and companies or individuals providing farmers with credit or engaging farmers in contract farming are not ready to work with *IFPs'* users. Comparatively, it can be observed in Table 3 that a greater percentage of joint adopters of *FISs* and *IATs* (75.13%) belongs to FBOs. They are the majority who as well receive input subsidy from government and NGOs. Additionally, technology adoption typology of farmers who perceived lodging of rice and low annual amount of rainfall are those who did not adopt any technology.

Table 3: Summary Statistics of Discrete Variables

Variables		**Non-Adopters (n = 199)**		**Adopters of *FISs* (n = 154)**		**Adopters of *IATs* (n = 365)**		**Adopters of both *FISs* and *IATs* (n = 189)**	
		Freq	**%**	**Freq**	**%**	**Freq**	**%**	**Freq**	**%**
Farmer Characteristics									
Sex:	*Female*	62	31.16	51	33.12	124	33.97	54	28.57
	Male	137	68.84	103	66.88	241	66.03	135	71.43
Business purpose	*No*	42	21.11	34	22.08	73	20.00	37	19.58
of farming rice:	*Yes*	157	78.89	120	77.92	292	80.00	152	80.42
Institutional and Policy Variables									
Credit access:	*No*	174	87.44	121	78.57	199	54.52	110	58.20
	Yes	25	12.56	33	21.43	166	45.48	79	41.80
Contract farming:	*No*	187	93.97	121	78.57	167	45.75	121	64.02
	Yes	12	6.03	33	21.43	198	54.25	68	35.98
Membership of	*No*	135	67.84	80	51.95	111	30.41	47	24.87
FBOs	*Yes*	64	32.16	74	48.05	254	69.59	142	75.13
Input subsidy:	*No*	184	92.46	127	82.47	291	79.73	127	67.20
	Yes	15	7.54	27	17.53	74	20.27	62	32.80
Environmental Shock Factors									
Lodging of rice:	*No*	77	38.69	87	56.49	286	78.36	156	82.54
	Yes	122	61.31	67	43.51	79	21.64	33	17.46
Low rains:	*No*	63	31.66	80	51.95	252	69.04	128	67.72
	Yes	136	68.34	74	48.05	113	30.96	61	32.28
Agro-Ecological Zone Dummies									
Guinea Savannah	*No*:	86	43.22	95	61.69	263	72.05	86	45.50
Zone	*Yes*	113	56.78	59	38.31	102	27.95	103	54.50
Forest Savannah	*No*	125	62.81	86	55.84	206	56.44	131	69.31
Transition Zone	*Yes*	74	37.19	68	44.16	159	43.56	58	30.69

Source: Author's analysis from field data (2017)

Impacts of Technology Adoption Package on Rice Yield

The impacts of technology adoption package on rice yield was analysed using MESR. The study used full information maximum likelihood approach for the estimation and the results are presented in tables 4 and 5. For proper identification, Lokshin and Sajaia (2004) indicated that the selection equation should contain all the variables in the regime equations except that the selection equation should have at least one instrument. From the MESRM results as shown in table 4, the model used fits well for the data since the *Wald test* is statistically significant at 1% for each of the technology adoption packages. The significance of the *Wald Chi-Square* test implies that the null hypothesis that all regression coefficients are jointly equal to zero is rejected in favour of the alternate hypothesis.

Factors Explaining Adoption of FISs and IATs

The results of the multinomial endogenous switching regression explaining the technology adoption packages (I_1T_0, I_0T_1 *and* I_1T_1) are presented in Table 4. From the table, the base category with which the technology adoption packages were compared is non-adoption (I_0T_0). The selection equation explains the factors determining technology adoption package. As noted by Donkor *et al.* (2016), the coefficients of the adoption equation are normal probit coefficients which can be interpreted as probabilities. The adoption of *FISs* is positively determined by the number of advice farmers receive from FBOs, rice farming experience and distance from farming communities to input markets. Conversely, farmers who have well-co-ordinated and synergised the adoption of *IATs* have low probability of adopting *FISs* only. This implies that farmers who sequentially adopted all the technology units of *IATs'* package (from planting to harvesting) have low probability of adopting *FISs.* The cost that comes with co-ordinated adoption of *IATs* is high and hence farmers might not be ready to incur addition additional cost by adopting *FISs* which even gives lower yield.

This study has revealed that probability of adoption of *IATs* increases with number of extension visits, credit access, contract farming and closeness of the farmers to input markets as well as Accra. The results also show that farmers located in areas with high amount of rainfall, high amount of temperature and farmers who are closer to rice markets have low incentive of adopting *IATs*. Farmers located in CSZ have higher probability of adopting *IATs* than their counterparts living in other agro-ecological zones. Also, farmers who have higher probability of jointly adopting *FISs* and *IATs* are the older farmers and farmers who have access to input subsidy. They are ready to blend their innovations with improved technologies introduced by AEAs.

Determinants of Rice Yield in the Regime Equations

Table 5 presents the second-stage of the FIML estimates of MESRMs for each of the technology packages (I_1T_0, I_0T_1 *and* I_1T_1). As noted by Tambo (2013), the *rho* is the correlation coefficients between the error terms of the selection and outcome equations and it indicates the presence or absence of selection bias. From the results shown in Table 4, the *rho* for non-adopters of *IATs* is statistically significant, suggesting that self-selection is present, meaning both observed and unobserved factors influence the adoption decisions and the yield outcomes. Also, it implied that selectivity bias was present and that if it was not corrected, the coefficients would not have shown the true effects of the explanatory variables on rice yield.

The *Wald Chi-Square* (likelihood ratio) test of independent equations is statistically significant for *FISs* and *IATs* indicating evidence of joint dependence between the technology adoption selection and the rice yield outcome equations for both adopters and non-adopters. This suggests that the selection and outcome equations cannot be estimated separately, confirming the findings of Donkor *et al.* (2016). The insignificance of the Wald Chi-Square (likelihood ratio) test of independent equations for I_1T_1 package implies that there is no joint dependence between the selection and the outcome equations for adopters of both *FISs* and *IATs*.

There are differences between factors determining rice yield for adopters and non-adopters of the three technology packages (I_1T_0, I_0T_1 *and* I_1T_1). From Table 5, for adopters of *FISs*, quantity of fertilizer applied, capital, purpose of rice farming, contract farming, perception about lodging of rice and GSZ dummy variable significantly influence rice yield, holding other factors constant. Rice yield for adopters of *FISs* will increase when the quantity of fertilizer applied increases, but the reverse is true for amount of capital invested in rice production. Contract farming also increases rice yield of adopters of *FISs*. From the results, rice yield of adopters of *FISs* is lower for farmers who cultivate rice as a business venture, farmers who experienced lodging of rice and farmers who are located in the GSZ. The effects of all these factors are consistent with the *a priori* expectations, except amount of capital. The reason could be that farmers who cultivate rice as a business are not innovative enough but rather rely on externally developed technologies like *IATs*. Unlike their counterparts who are subsistent farmers, their farm sizes are so large that they cannot implement their own innovation effectively.

The factors which have positive significant impacts on rice yield for non-adopters of *FISs* are fertilizer, business purpose of rice farming, credit access, contract farming and FBO membership holding other factors constant. On the contrary, an increase in the amount of labour employed, quantity of rice seed planted, farmers' age, household size, annual amount of rainfall and temperature results in a significant decline in rice yield for non-adopters of *FISs*. Non-adopters of *FISs* who experienced lodging of rice, low rainfall amount, are not located in GSZ, have access to credit, do contract farming, are members of FBOs as well as apply recommended quantity of fertilizer have higher rice yield than their counterparts. The directions of the effects of these factors confirmed the *a priori* expectation.

From Table 5, rice yield of adopters of *IATs* is positively affected by quantity of fertilizer applied, business purpose of rice cultivation, credit access, contract farming and FBO membership. For adopters of *IATs*, quantity of rice seed planted, household size, lodging of rice, perceived low amount of rainfall and the actual total annual rainfall amount decrease rice yield. In all, the *a priori* expectation is met except total annual amount of rainfall. The results for the non-adopters of *IATs* have the same significant factors influencing rice yield except household size and amount of annual rainfall, which are not significant. The direction of the effects of the significant factors for both adopters and non-adopters of *IATs* is the same.

For adopters of both *FISs* and *IATs*, the factors which significantly and positively affect rice yield are capital and contract farming, as opposed to quantity of rice seed, input subsidy, perception of experiencing low rainfall amount and GSZ dummy which have significant and negative effects on rice yield. Among these significant variables, it was only access to input subsidy that did not conform to the *a priori* expectation. On the other hand, quantity of fertilizer, business purpose of rice farming, credit access and contract farming have positive significant impact on rice yield of non-adopters of joint adoption of *FISs* and *IATs*. Also, from the last column of Table 4, labour, seed, lodging of rice, perceived low rainfall amount, actual average annual rainfall in the area and actual average annual temperature in the area have negative significant effects on rice yield for farmers who do not jointly adopted *FISs* and *IATs*. The direction of effects of the above significant factors affirms the *a priori* expectations, except actual average annual rainfall amount within the farming area.

Table 4 Full Information Maximum Likelihood Estimation of Determinants of Adoption

	FISs **(*I_1T_0*)**		***IATs*** **(*I_0T_1*)**		***FISs*** **and** ***IATs*** **(*I_1T_1*)**	
Variables	**Coef.**	**Robust SE**	**Coef.**	**Robust SE**	**Coef.**	**Robust SE**
Conventional inputs						
Labour	0.1510	0.1048	-0.4549*	0.2425	0.1438	0.2317
Fertlizer	-0.0646	0.0897	0.2022*	0.1063	-0.0486	0.1773
Seed	-0.0061	0.0373	-0.0912	0.0987	-0.1172	0.1254
Pesticides	0.0575	0.0465	-0.0208	0.0634	0.0200	0.0443
Capital	0.0166	0.0623	0.1853	0.0789**	-0.0275	0.0714
Farmer Characteristics						
Age	-0.0204***	0.0053	-0.0043	0.0070	0.0196**	0.0081
Sex	0.0468	0.1129	-0.1433	0.1086	0.1271	0.1336
HHS	0.0209	0.0154	0.0068	0.0143	-0.0061	0.0141
BusFm	-0.0810	0.1170	0.1376	0.1212	-0.2436*	0.1367
Eduyrs	-0.0020	0.0062	0.0069	0.0094	0.0075	0.0134
FmExp	0.0162***	0.0037	-0.0003	0.0065	-0.0188	0.0074
Institutional and Policy Variables						
CredAcc	-0.1436	0.1286	-0.0997	0.1191	-0.2459	0.1820
ContFarm	-0.0903	0.1580	0.1822	0.1403	-0.1725	0.1988
FBO	0.0207	0.1079	-0.0257	0.1231	-0.0604	0.1236
InpSub	0.0122	0.1308	-0.0536	0.1208	0.2510	0.2039
ExtVisits	-0.0533***	0.0187	0.0879**	0.0345	0.1461	0.0980
FBO_Adv	0.0514***	0.0198	0.0130	0.0281	-0.0019	0.0312
DistAEAs	-0.0052	0.0058	-0.0070	0.0070	-0.0094	0.0072
DistInpMkt	0.0176***	0.0059	-0.0265*	0.0128	0.0009	0.0134
DistAccraCom	0.0003	0.0004	-0.0002	0.0008	0.0016	0.0022
Environmental Factors						
LodgRice	0.1222	0.1027	-0.2159	0.1400	-0.0612	0.1888
LowRain	-0.1141	0.1048	-0.0021	0.0999	0.0483	0.1474
RainAmt	-0.0002	0.0009	-0.0022**	0.0009	0.0013	0.0030
Temp	0.0983	0.0807	-0.2349***	0.0871	0.0991	0.2440
Agro-Ecological Zone Dummies						
GSZ	-1.2362***	0.3994	1.0358**	0.5261	-0.8006	0.7810
FSTZ	-0.4046	0.4458	1.1295***	0.4188	-0.5983	0.6245
Rice Production Technologies						
IFPs_PC_Index	-0.0631**	0.0269	0.1571*	0.0806	0.0762	0.0610
FISs_PC_Index			-0.0956	0.0831	0.4188	0.3202
IATs_PC_Index	-0.1415***	0.0367				
Constant	-2.4767	2.5493	7.8466***	2.6907	-5.6418	8.0650

***, **, * represent 1%, 5%, and 10% significance level, respectively. Also, SE represent standard error.

Source: Author's analysis from field data and data (2017)

Table 5: Full Information Maximum Likelihood Estimation of Determinants of Rice Yield

	***FISs* (I_1T_0)**		***IATs* (I_0T_1)**		***FISs* and *IATs* (I_1T_1)**	
Variables	**Adopters**	**Non-adopters**	**Adopters**	**Non-adopters**	**Adopters**	**Non-adopters**
Conventional Inputs						
Labour	0.1664	-0.1876*	0.1081	-0.2125	-0.3150	-0.2194**
	(0.1697)	(0.0989)	(0.1508)	(0.1377)	(0.2484)	(0.1036)
Fertilizer	0.2805*	0.3216***	0.1795**	0.3489***	0.2346	0.3326***
	(0.1687)	(0.0599)	(0.0698)	(0.1041)	(0.1689)	(0.0644)
Seed	-0.0841	-0.1247**	-0.1317*	-0.0966*	-0.4666***	-0.0914**
	(0.0554)	(0.0507)	(0.0765)	(0.0569)	(0.1595)	(0.0428)
Pesticides	-0.0553	0.0599*	0.0895	-0.0194	-0.0402	0.0315
	(0.0734)	(0.0307)	(0.0715)	(0.0445)	(0.0570)	(0.0299)
Capital	-0.2666**	0.0160	-0.0764	-0.0037	0.1670**	-0.0115
	(0.1143)	(0.0419)	(0.0562)	(0.0764)	(0.0666)	(0.0449)
Farmer Characteristics						
	-0.0104	-0.0073**	-0.0062	-0.0028	-0.0124	-0.0054
Age	(0.0082)	(0.0036)	(0.0053)	(0.0040)	(0.0095)	(0.0037)
	0.0093	0.0188	0.0578	0.0856	-0.0136	-0.0309
Sex	(0.1671)	(0.0743)	(0.1019)	(0.0937)	(0.1637)	(0.0945)
	0.0178	-0.0145*	-0.0351***	-0.0020	0.0038	-0.0089
HHS	(0.0262)	(0.0082)	(0.0129)	(0.0101)	(0.0193)	(0.0087)
BusFm	-0.3195*	0.1582**	0.2508*	-0.0978	0.2440	0.1767**
	(0.1768)	(0.0776)	(0.1290)	(0.0918)	(0.1962)	(0.0844)
Institutional and Policy Variables						
	-0.2554	0.2570***	0.3772***	0.1698*	-0.0174	0.2716**
CredAcc	(0.2280)	(0.0730)	(0.0998)	(0.1006)	(0.1802)	(0.1141)
	0.8390***	0.5668***	0.3176**	0.6246***	0.7599***	0.7028***
ContFarm	(0.2748)	(0.0963)	(0.1320)	(0.2054)	(0.1714)	(0.1328)
FBO	0.0090	0.1461**	0.0191*	0.1637*	0.2542	0.0340
	(0.1548)	(0.0664)	(0.0971)	(0.0855)	(0.1743)	(0.0928)
	-0.1618	-0.0592	0.0039	-0.1329	-0.3443*	-0.2002
InpSub	(0.1839)	(0.0810)	(0.1266)	(0.1036)	(0.1855)	(0.1444)
Environmental Factors						
	-0.7459***	-0.5854***	-0.4003***	-0.5605***	-0.3462	-0.5624***
LodgRice	(0.1474)	(0.0693)	(0.1224)	(0.0894)	(0.2694)	(0.0784)
	-0.1429	-0.4283***	-0.4572***	-0.2404***	-0.2634*	-0.2957***
LowRain	(0.1443)	(0.0654)	(0.0966)	(0.0789)	(0.1494)	(0.0783)
RainAmt	-0.0013	-0.0027***	-0.0031***	-0.0004	-0.0023	-0.0035***
	(0.0012)	(0.0005)	(0.0007)	(0.0009)	(0.0025)	(0.0006)
	0.0084	-0.1296***	-0.0677	0.0600	-0.1561	-0.2228***
Temp	(0.1237)	(0.0491)	(0.0778)	(0.0829)	(0.1822)	(0.0691)
Agro-Ecological Zone Dummies						
	-1.2950*	-0.9606***	-1.0165**	-1.0811***	-1.1956**	-0.4606
GSZ	(0.6598)	(0.2605)	(0.3997)	(0.3353)	(0.5643)	(0.3516)
	-0.0128	-0.1197	-0.2563	-0.4341	-0.1174	0.4630
FSTZ	(0.6788)	(0.2699)	(0.4064)	(0.4466)	(0.8291)	(0.3886)
	3.1239	10.0883***	9.3808***	1.9415	11.6251	12.4836***
Constant	(3.6435)	(1.5417)	(2.4002)	(2.9677)	(7.8391)	(2.0875)
Rho	0.9941	0.2900	-0.5143	-0.8563**	-0.7418	-0.9028
Wald chi^2 (19)	127.76***		571.63***		205.58***	
Wald chi^2 (1) test of indep. eqns.	9.87***		7.06***		1.07	

***, **, * represent 1%, 5%, and 10% significance level, respectively. Values in parentheses are standard errors *Source: Analysis from field data (2017)*

Rice Yield Treatment Effects

From the full information maximum likelihood estimates of the MESRM, the *mispredict* command in Stata was used to predict observed and the counterfactual rice yields of farmers' technology adoption package decision. The use of MESRM to predict the observed and the counterfactual rice yields is grounded on the observation of Maddala (1983) and Di Falco and Veronesi (2013) that a simple comparison between the observed mean yield values of rice between adopters and non-adopters is misleading and does not tell the true impact of adoption. The predicted rice yields for the observed and the counterfactuals were used to estimate average treatment effect for the treated (ATT) and average treatment effects for the untreated (ATU). The t-*test* was used to test whether or not there is significant difference between the observed and counterfactual mean rice yields and the results presented in Table 6. Note that ATT is the difference between the mean values of actual rice yield obtained by adopters of a given technology package and the mean rice yield that they would have obtained if they had decided not to adopt the said technology package. On the other hand, ATU is the mean difference between the actual rice yield of non-adopters and the yield they would have obtained if they had adopted the technology package.

From Table 6, ATT and ATU for all the technology adoption package are significant. All the directions of the impacts of technology adoption packages on rice yield confirmed the *a priori* expectations and economic theory except ATU for non-adopters of *FISs*. There is general positive impact of adoption of any of the three technology packages on rice yield with the exception of counterfactual adoption decision of non-adopters of *FISs*. The ATT and ATU for *FISs* are 0.4404Mt/ha and -2.2157Mt/ha respectively. This implies that adopters of *FISs* will be better off if they continue to adopt the technology holding other factors constant. What it means is that if adopters of *FISs* decided to be non-adopters they are going to lose rice yield of 0.4404Mt/ha. This suggests that there is a justification for adopters of *FISs* to maintain and even improve upon the adoption of *FISs*.

On the other hand, if non-adopters of *FISs* decide to adopt *FISs*, their rice yields will decrease from 3.0069Mt/ha to 0.912Mt/ha. This finding is against the *a priori* expectation.

Also, the estimated ATT and ATU values for adoption and non-adoption of *IATs* are 1.5330Mt/ha and -1.1929Mt/ha respectively suggesting that there is benefit in adopting *IATs*. If an adopter of *IATs* decides not to adopt, his or her rice yield is expected to decrease by 1.5330Mt/ha. Conversely, if non-adopters of *IATs* decided to adopt, their rice yield will increase by 1.1929Mt/ha. Row planting is one of the *IATs*. The positive impact of *IATs* on rice yield is a confirmation of the empirical studies conducted by Donkor *et al*. (2016), who found that row planting improves rice productivity. A study by Wiredu *et al.* (2010) observed that the adoption of New Rice for Africa (NERICA) and National Agricultural Research Stations (NARS) rice varieties which are *IATs* increases rice yield by 0.024Mt/Ha in Ghana. Furthermore, the findings by Kijima *et al*. (2008) that improved crop variety increases rice yield are confirmed in this study, since improved rice yield is associated with the adoption. A similar finding was made by Awotide *et al*. (2012).

From the t-test results in Table 6, adopters of both *IATs* and *FISs* would have significantly reduced rice yield from 5.7672Mt/ha to 0.9852Mt/ha if they had not jointly adopted both technologies. This implies if the adopters of both *FISs* and *IATs* had decided not to adopt, they would have lost rice yield of 4.7820Mt/ha. This quantity is colossal enough to motivate farmers to continue joint adoption of *FISs* and *IATs*. In the same vein, non-adopters of both *FISs* and *IATs* will obtain rice yield of 1.1389Mt/ha (ATT) more if they decided to adopt both technologies.

Table 6: Treatment Effects of Impact of Technology Adoption on Rice Yield

Technology Adoption Package	Sample	Adoption Decision Adopting	Not Adopting	Treatment Effects	% Change in TE	Transitional Heterogeneity (ATT - ATU)
I_1T_0	Adopters *FISs*	1.2754 (0.0507)	0.8349 (0.0153)	ATT = 0.4404*** (0.0471)	52.75	2.2157
	Non-Adopters of FISs	0.7912 (0.0308)	3.0069 (0.0405)	ATU = -2.2157*** (0.0208)	73.69	
I_0T_1	Adopters *IATs*	3.3862 (0.0432)	1.8532 (0.0530)	ATT = 1.5330*** (0.0866)	82.72	0.3401
	Non-Adopters of *IATs*	3.5246 (0.0355)	2.3317 (0.0290)	ATU = 1.1929*** (0.0161)	51.16	
I_1T_1	Adopters of *FISs* and *IATs*	5.7672 (0.1111)	0.9852 (0.0288)	ATT = 4.7820*** (0.1239)	485.38	3.6431
	Non-Adopters of *FISs* and *IATs*	3.7871 (0.0439)	2.6482 (0.0401)	ATU = 1.1389*** (0.0137)	43.01	

I_1T_0 =154, I_0T_1 = 365, I_1T_1=189, I_0T_0=199,

***, **, * represent 1%, 5%, and 10% significance level, respectively. Values in parentheses are standard errors

Source: Analysis from field data (2017)

CONCLUSIONS AND RECOMMENDATIONS

The econometric estimation of the impact of technology adoption packages on rice yield was done using multinomial endogenous switching regression models. This model was used to account for the possible occurrence of selection bias and disentangle the potential hidden self-selection biases affecting farmers' decisions to adopt any of the technology packages. The base category to which all adoption of *FISs*, adoption of *IATs* and joint adoption of *FISs* and *IATs* were compared with is non-adoption.

The results from this study made us understand that *FISs* and *IATs* have heterogeneous impact on rice yield. If non-adopters of *FISs* decide to adopt them, their rice yield will decrease by 2.2157Mt/ha. Conversely, if non-adopters of *IATs* decide to adopt *IATs*, their rice yield will increase by 1.1929Mt/ha. Also, joint adoption of *FISs* and *IATs* are better off in terms of rice yield as compared to the non-adoption option of both technologies.

Farmers will be motivated to adopt *IATs* when they have access to extension advice, credit, engaged in contract farming, have easy access to improved inputs. Adhoc adoption of *FISs* by non-adopters reduces rice yield. Wholesome recommendation of *FISs* to all farmers is not justifiable. The superior technology that can increase rice yield of farmers is *IATs*. Contract farming concept, provision of improved rice seeds, intensification of agricultural extension services should be vigorously pursued to the latter. Farmers should always modify any *FISs* that they adopt to suit their situations. *IATs* should be highly promoted among farmers in the whole country. Though *IATs* have the highest impact on rice yield, *FISs* should be researched into, modified and made available for farmers' adoption.

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APPENDIX

Appendix 1: Examples of FISs and IATs

Farmer Innovation Systems	Improved Agricultural Technologies
• Selection of seed from healthy and good rice plant • Spray weeds on the field with plant extracts (pepper, neem, hot water or others • Spray field with soap and oil • Use of wood ash to speed up germination • Transplanting seedlings without a definite distance or space between plants • Broadcasting in rows with approximate spacing • Dibbling with approximate spacing • Rice straw as mulch/synthetic mulch • Rain harvesting • Application of self-prepared organic manure (compost) or farm yard manure • Water control bunds • Incorporating rice straws into soil during ploughing • Colouring of rice seed with charcoal to prevent birds and rodents from recognizing and picking the seeds • Use of magnetic ribbon or strips of tape cassette to scare birds when wind blows. • Use of bell or shaking of containers with pebbles • Storing paddy rice in airtight rubber or metal containers placed in ordinary room • Storing rice with wood ash or paddy husk ash mixed with cinnamon leaves • Storing paddy rice with neem extract or dried chopped leaves of wild tobacco • Mixing red pepper with paddy rice for pests' prevention	• Rouging: removing unintended rice variety plant from the field • Certified seeds • Using tractor to plough the field • Zero ploughing/tillage • Removing of tree stumps • Soaking seeds in water before planting • Planting of seed directly on the field in rows • Transplanting of seedlings in rows • Using mechanical trans planter • Dibbling (hill planting) method with correct spacing (at least 20cm x 20cm) • Use of planter with correct spacing (at least 20cm x 20cm) • Drilling with correct spacing (at least 20cm x 20cm) • Formal irrigation • Controlling weeds with chemical herbicides • Chemical fertilizer application • Green manuring • Application of pesticides • Use of combined harvester and thresher • Use of stationary thresher • Pedal or treadle thresher (threshing drum, foot crank) • Storing paddy rice in airtight rubber or metal containers placed in warehouse or silo • Storage of paddy rice in bags placed in warehouse or silo

• Use of granules of salt to prevent pests	

Appendix 2: Definition and Measurements of Explanatory in MESRMs

Explanatory Variables	Definitions and Measurements
Conventional inputs	
L	Quantity of labour (mandays)
F	Quantity of fertilizer (Kg)
S	Quantity of rice seed (Kg)
Pc	Quantity of pesticides (lit)
K	Ghana Cedis (GH¢)
Fs	Farm size (acres)
Farmer Characteristics	
Age	Age (years)
Sex	Sex (1 if male, 0 otherwise)
HHS	Household size (numbers)
Eduyrs	Number of years in formal education (years)
FarmExp	Rice farming experience (years)
BusFm	Business purpose of farm rice (1 if yes, 0 otherwise)
Institutional and Policy Variables	
ExtVisits	Number of extension contacts with advice on rice farming (number)
CredAcc	Credit access ((1 if access, 0 otherwise)
ContFarm	Contract farming (1 if yes, 0 otherwise)
FBO	Farmer-based organisation membership (1 if member, 0 otherwise)
FBO_Adv	FBO advice on rice production (numbers)
InpSub	Inputs' subsidy (1 if access, 0 otherwise)
DistAEAs	Distance from office of AEAs to community (Km)
DistInpMkt	Distance from community to market centres of rice (Km)
DistAccraCom	Distance from Accra to Community (Km)
Environmental Factors or Shocks	
LodgRice	Lodging of rice (1 if rice lodged, 0 otherwise)
LowRain	Affected by low rainfall amount (1 if experienced low rainfall amount, 0 otherwise)
RainAmt	Actual mean annual rainfall amount within the district (mm)
Temp	Actual mean annual temperature within the district (^{0}C)
Agro-Ecological Zone Dummies	
GSZ	Guinea savannah zone (1 if a farmer is located in guinea savannah zone, 0 otherwise)
FSTZ	Forest savannah transition zone (1 if a farmer is located in forest savannah transition zone, 0 otherwise)
Rice Production Technologies	
IATs_PC_Index	Principal component index of *IATs* (indices)
FISs_PC_Index	Principal component index of *FISs* (indices)
FISs_PC_Index	Principal component index of *IFPs* (indices)