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Drivers of initial adoption, continuous adoption and dis-adoption of selected rice varieties among rice farmers in Northern Ghana

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ABSTRACT

The government of Ghana has given significant attention to promoting adoption of rice varieties among farmers in Ghana. However, there are low adoption and high dis-adoption rates of rice varieties in Ghana. This study employed a Multivariate Probit model to estimate the drivers of initial adoption, continuous adoption and dis-adoption of rice varieties in Northern Ghana. The study used multistage sampling technique to collect primary data from 404 rice farmers in the study area. Rice farmers' adoption and dis-adoption decisions were significantly affected by age, gender, farm size, rice perception, extension services, market agents, and rainfall, among others. The interrelations among the rice varieties imply that farm-level policies that affect the adoption or dis-adoption of one rice variety can influence the adoption or dis-adoption of the other varieties. The policy implications are that failure to promote new varieties in the study area could result in massive dis-adoption of the existing varieties, low rice productivity, extreme poverty and hunger among farmers. The government of Ghana should therefore continue to promote improved rice varieties to ensure continuous adoption among farmers. Stakeholders in the rice sector should also intensify extension services to farmers, gender inclusive programmes, irrigation schemes and market opportunities to farmers.

Keywords: Continuous adoption; dis-adoption; rice varieties; pairwise correlations; Northern Ghana
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Introduction

Rice production attracted global attention due to its significant contribution to fighting food insecurity and malnutrition, especially among children. West Africa is well known to be rice production hub in the African continent. Nigeria alone supplies about 3 million metric of paddy to the rest of the world in West Africa (Ayedun & Adeniyi, 2019). Rice has become a commercial food crop in Ghana, making it the next to maize in terms of area of cultivation and productivity (MoFA, 2017 & APS, 2015). According to MoFA (2017), despite the fact that rice is next to maize in terms of production, the country has not been able to produce much to meet the local consumption. This, according

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to the publication, has necessitated the need for government to import high volumes of milled rice to meet the demand in the country (MoFA, 2017). The low productivity of rice in the country can be attributed to poor adoption of improved rice varieties and capital constraints facing farmers (Lamptey *et al*., 2022).

Achieving high rice productivity in Ghana has become the priority of government and other stakeholders. Rice farmers in Northern Ghana have therefore benefited from dissemination of high-yielding rice varieties coupled with other complementary agronomic technologies (Ragasa *et al.,* 2013; Langyintuo & Dogbe, 2005). However, adoption of improved rice production technologies has not yet met its expectation due to farmers over reliance on local rice varieties and traditional agronomic practices (Donkoh *et al.*, 2019). Meanwhile, adoption of rice production technologies is expected to enhance productivity and increase incomes, hence, reduction of poverty among resource-poor farmers (McNamara *et al.,* 2012; Asante *et al*., 2004).

The common improved or high-yielding rice varieties introduced to farmers for the past 10 years includes Mandee, AGRA, Afife, Tox, Jasmine, NERICA, among others. Many studies investigated the drivers and impacts of adoption of improved rice varieties. However, there is little information about drivers of initial adoption, continuous adoption and dis-adoption of these varieties, especially, Mandee, Jasmine, AGRA, and Afife to the best of the researchers' knowledge. This study therefore sought to examine the drivers of initial adoption, continuous adoption and dis-adoption of five selected rice varieties among farmers in Northern Ghana.

This study, which is premised on Roger (2003)'s Innovation Diffusion Theory (IDT), would be the first of its kind in Ghana to explore the dynamics of adoption and dis-adoption of improved rice varieties. The outcome of this study will offer policy directions to rice value chain actors to enhance continuous use of improved rice varieties among farmers, and will raise their living standards. A lot of studies have been done using different methodological approaches to examine the impact and factors influencing farmers decision to adopt rice improved technologies (Ragasa *et al.* 2013; Obayelu *et al*., 2016; Abdulai *et al*., 2018; Ayedun & Adeniyi, 2019; Zakaria *et al.*, 2020). Among these researchers, all failed to explore the dynamics of initial adoption, continuous adoption and dis-adoption of improved rice varieties using Multi-Variate Probit (MVP) model. To close this empirical and methodological gap, this study aimed at using MVP to examine the farmers' characterisation in decision to initially adopt, continue to adopt or dis-adopt five selected rice varieties in Northern Ghana. This is the first kind of study in Africa, particularly in Ghana, that uses four improved and one local rice varieties and examines drivers influencing farmers' decision to adopt and/or dis-adopt rice varieties.

Research Materials and Methods

Profile of the study area

The Northern Region is one of the 16 regions of Ghana, with Tamale as its regional capital. The region is bordered on the north by the North East Region, on the east by the Eastern Ghana-Togo international border, on the South by the Oti Region, and on the West by the Savannah Region. The region houses the Savannah Agricultural Research Institute (SARI), which is one of the 13 research institutes of the Council for Scientific and Industrial Research (CSIR), Ghana. Specifically, the study was carried out in Tolon, Kumbungu, Savelugu and Nanton Districts in the Northern region of Ghana. These four districts are among the top 10 districts for rice production in the country.

Source of data, sampling technique, and sample size

Primary information was solicited from rice farmers in the study area using semi-structured questionnaires. The multistage sampling method was used to select rice farmers in each rice-growing community in the study area. At the first stage, the Northern Region was purposively selected due to its significant contribution to national rice basket, accounting for 68,407.25 metric tonnes of paddy rice per annum, and 963,000 tonnes of paddy rice (665,000 tonnes of milled rice) in 2019 alone (MoFA, 2020). Tolon, Kumbungu, Savelugu and Nanton Districts were also purposively selected because they are the main districts in the Northern Region where improved rice varieties are disseminated, adopted and dis-adopted among the rice farmers (MoFA, 2020 & APS, 2015).

Cluster sampling technique was used at the third stage to select four out of eight clusters in Tolon, Kumbungu, and Savelugu while two out of four clusters were also chosen in Nanton. The chosen clusters were known as the leading rice-growing communities (zones) in the study area. The chosen rice-growing communities comprised Nyankpala, Tingoli, Tolon and Woribogu in the Tolon District; and Botanga, Gbullung, Kpachi and Kumbungu in the Kumbungu District. The rest were Libga, Diare, Nabogu and Savelugu in the Savelugu Municipality, with Nyamadu and Nanton in the Nanton District. Proportional sampling was then used to choose the number of farmers per selected community. Finally, simple random sampling, based on the lottery method, was used to select farmers in each rice growing community for a total sample of 404 farmers.

The Smith (2019) sample size formula was employed to compute the sample size for the study. A 95% confidence level (0.5 margin of error) was chosen to determine the sample size for this study. The confidence level of 95% corresponded to a Z-score of 1.96. The sample calculation formula can be expressed as:

$$\text{Sample size (n)} = (\text{Z} - \text{score})^2 * \text{Std Dev.} * = \frac{(1 - \text{Std. Dev})}{(\text{margin of error})^2} \quad (1)$$

Based on the information provided, the sample size for the study was 385 rice farmers. The study however adjusted this sample size to 404 to cater for some design effects that might have arisen. Hence, 404 rice farmers were interviewed using 10 trained research assistants under the supervision of the researchers. The data were collected between December 2019 and February 2020, and covered information related to the 2009-2019 production seasons of the rice farmers.

Analytical framework –multi-variate probit model

The study employed Multivariate Probit (MVP) regression model to estimate the drivers of initial adoption, current adoption and dis-adoption of five main rice varieties in the study area. The MVP model is seen as a generalisation of the probit model used to estimate several correlated binary outcomes simultaneously (Greene, 2002). MVP model normally extends to more than two outcome variables just by adding equations. The study identified four improved (i.e. Mandee, Jasmine, AGRA and Afife) and one traditional (i.e. Salma-Saa) rice varieties that were dominant in the study area. It is possible that the farmers adopted a number of these varieties and also dis-adopted some of them for several socioeconomic factors. It is therefore not likely that the farmers would stick to a single variety and ignore or dis-adopt all the other varieties because of the inherent benefits and unique characteristics of each variety. All the four improved rice varieties included in the model are high-yielding. Therefore, to neglect the inter-relationships among these improved and unimproved rice varieties is to create bias estimates of factors influencing their adoption and dis-adoption (Wu & Babcock, 1998).

The MVP regression approach was thus employed to analyse jointly the factors affecting the probability of farmers' decision to adopt and/or dis-adopt the selected rice verities. The MVP helped to account for the interdependent relationships among rice varieties, relative to univariate models such as probit and logit (Ahmed, 2015; Belderbos *et al.,* 2004; Greene, 2008). A pentavariate probit model with five sets of binary dependent variables (i.e. Mandee, Jasmine, AGRA, Afife & Salma-Saa), was therefore formulated in tandem with Donkoh *et al*. (2019), Danso-Abbeam and Baiyegunhi (2017) and Mulwa *et al.* (2017), as indicated by Equation 2, which is:

$$Y^*_{ik} = \beta_k X_{ik} + \alpha_k + A_{ik} + \varepsilon_k \qquad (2)$$

(k = Mandee (M), Jasmine (J), AGRA (A1), Afife (A2), Salma-Saa (S). The binary dependent variable is specified by Equation 3;

$$Y_{ik} = 1 \text{ if } Y^*_{ik} > 0 \text{ or otherwise} \qquad (3)$$

Where Y^*_{ik} is a latent variable that captures the observed and unobserved preferences associated with the k^{th} improved rice variety, and Y^*_{ik} represents the binary dependent variables. X_{ik} represents the observed household and farm-specific characteristics, as well as institutional variables. A_{ik} represents plot characteristics to account for unobserved heterogeneity. β_k and α_k are parameters to be estimated. ε_k represents the multivariate normally distributed stochastic error term (Wooldridge, 2005). In our multivariate probit framework, the error terms jointly follow a multivariate normal distribution with zero conditional mean. The variance is normalised to unity, where $(\mu_{M,}\, \mu_{J,}\, \mu_{A1,}\, \mu_{A2,}\, \mu_S) \approx MVN\,(0, \Omega)$ and the symmetric variance covariance matrix Ω is specified by equation 4:

$$\begin{bmatrix} 1 & \rho^{MJ} & - & \rho^{MS} \\ \rho^{JM} & 1 & - & - \\ - & - & 1 & A1S \\ \rho^{A1M} & - & SA1 & 1 \end{bmatrix} \pm \qquad (4)$$

ρ is the pairwise correlation coefficient of the error terms with regard to any two of the estimated adoption equations in the model. The correlation between the stochastic components of different improved rice varieties adopted is represented by the off-diagonal elements such as ρ^{MJ} and ρ^{JM} in the variance-covariance matrix (Donkoh *et al.*, 2019). The correlation is based on the principle that adoption of a particular selected variety may depend on another (complementarity or positive correlation) or may be influenced by an available set of substitutes (negative correlation) (Khanna, 2001).

Description and measurement of variables and their a-priori expectations

The Table 1 illustrates the description of variables and the way all the measurement of all the variables. The expected effects of the variables on adoption/dis-adoption are also presented in the Table.

TABLE 1

Variables description, measurement, and a-priori expectations

Variable	Description	Measurement	A-priori expectation
Adoption	If a farmer ever adopted improved rice variety and continue using.	Dummy: (1) Yes (0) No	N/A
Age	Age of a rice farmer.	Years	+/-
Gender	Sex of a rice farmer.	Dummy: (1) Male (0) Female	+/-
Education	Number of years a rice farmer attended formal school.	Years	+
Family labour	Total number of family labour used in rice production	Number	+/-
Electricity	A rice farmer household has access electricity	Dummy: (1) Yes (0) No	+/-
FBOs	A rice farmer belongs to rice farmers association	Dummy: (1) Yes (0) No	+
Mobile phone	A rice farmers has his/her own phone for communication	Dummy: (1) Yes (0) No	+
Output market	A rice farmer has access to output market in the community/nearby community	Dummy: (1) Yes (0) No	+
Input market	A rice farmer has access to input market in the community.	Dummy: (1) Yes (0) No	+
Credit	A rice farmer has access to production credit.	Dummy: (1) Yes (0)No	+
Extension service	A rice farmer has access to extension service in 2019/2020 cropping calendar	Dummy: (1) Yes (0)No	+
Farm area	Rice farm plot area of a farmer.	Acres	+/-
Rice policy	A rice farmer is aware of any government rice policy in Ghana	Dummy: (1) Yes (0)No	+
Field Demonstration	A rice farmer ever participated in rice production field demonstration	Dummy: (1) Yes (0) No	+
Road network	A community has good road network to marketing centres/towns	Dummy: (1) Yes (0) No	+
Mechanization	A farmer has access to tractor service and used it for ploughing rice field.	Dummy: (1) Yes (0)No	+
Rainfall perception	A rice farmer's perception of rainfall pattern.	Dummy: (1) decreased (0) increased	+
Combine harvester	A rice farmer has access and used combined harvester	Dummy: (1) Yes (0)No	+

Results and Discussion

Descriptive statistics of selected variables

The results of socio-demographic descriptions of the rice farmers are presented in Table 2. The study found that about 46% of the rice farmers had continued to adopt the selected rice varieties in the study area. This implied that majority of rice farmers (54%) had discontinued the adoption of improved rice varieties. This could lead to low rice production and productivity, which could worsen food insecurity and poverty situations among the rice farmers. In the field, the researchers discovered that the reasons for dis-adoption of the improved rice varieties included (1) poor access to farm inputs and output markets; (2) pests and diseases infestations; (3) lack of access to production credit; (4) differences in taste and aroma of rice varieties; and (4) high demand of labour for adopting rice varieties and its agronomic practices.

In addition, the average age of a rice farmer in the study area was approximately 40 years with a corresponding 3 years of formal education. This means the rice farmers were in their productive years, which could translate to continuous adoption/usage of the selected rice varieties. Meanwhile, formal education among rice farmers was still low, which could result in dis-adoption of rice production technologies. Martey *et al.* (2013) revealed that educated farmers were more prone to adoption because they had the tendency to cooperate favourably with other farmers. The family labour and farm size of the rice farmers were approximately 6 people and 0.65 ha respectively. The little higher use of family labour means that rice farmers can rely on family labour to reduce cost of production when adopting new rice varieties. The little rice farm size confirmed the fact that about 90% of smallholders in Ghana cultivated below 2 ha of farm land (Donkoh *et al.,* 2019; MoFA, 2016).

The study further revealed that about 90% of the respondents were males, meaning that rice production in the study area was dominated by men. The low percentage of female farmers in this study corroborated Martey *et al.* (2013), who asserted that females were normally occupied with domestic activities such that they did not have enough time to participate in Rice Development Projects (RDP) compared with their male counterparts. Rice farmers' awareness of government policy about rice production plays a critical role for technology adoption to enhance rice production and productivity.

TABLE 2

Descriptive statistics of variables

Variable	Mean	Std. Dev.
Adoption/ dis-adoption	0.46	0.50
Age	39.69	10.65
Gender	0.90	0.30
Education	0.29	0.46
Electricity	0.80	0.40
Family labour	5.63	8.80
FBOs	0.47	0.50
Mobile phone	0.25	0.43
Output market	0.86	0.34
Input market	0.85	0.36
Production credit	0.35	0.48
Extension service	0.80	0.40
Farm plot area	3.87	3.81
Government policy	0.87	0.34
Road Network	0.75	0.44
Mechanisation	0.78	0.41
Rainfall perception	0.92	0.28

Source: Survey data, 2020

The study demonstrated that about 87% of rice farmers were aware of government policy for the rice sector. This could influence farmers positively, especially the youth, to take to rice production as business instead of conventional farming. Also, about 86%, 85%, 80%, and 35% of rice farmers respectively had access to output market, input market, extension services and production credit respectively. These imply that rice farmers' access to agricultural extension services, farm inputs and output markets are high, but less access to production capital remains low.

About 92% of rice farmers perceived a decrease in the rainfall pattern for the past ten years, 75% had access to good roads, 47% belonged to FBOs, 25% owned mobile phones, and 78% practised mechanisation. However, 95% of the farmers failed to use combine harvester for rice harvesting because they did not have access to modern combine harvesters, and they could also not afford to use combine harvesters in rice production, corroborating Lamptey *et al.,* (2022) and APS (2015).

Initial Adoption, continuous adoption and dis-adoption rates of rice varieties

Twelve main rice varieties were selected for the study but five of them with unique adoption rates were used for the Multi-Variate probit analysis. The initial adoption, continuous adoption and dis-adoption rates of the rice varieties in the study area are presented in Table 3. The adopters are farmers who cultivated any of the rice varieties for a minimum of three years (Doss, 2006; Doss *et al.,* 2003). The adoption rates in this study are the proportions of the farmers in the Northern Region who adopted each of the rice varieties from 2009 to 2019. This is because the rate of adoption of an innovation is measured as the number of individuals who adopted the innovation for a period of time or the relative speed with which an innovation is adopted by members of a social system (Sahin, 2006; Rogers, 2005; Doss & Morris, 2001). The dis-adoption rate is therefore the relative speed with which an innovation is dis-adopted or the number of adopters who dis-adopt an innovation in a certain time frame (Sahin, 2006; Rogers, 2005).

The adoption rates in the study area, over the past decade, were below 80% with the four most currently adopted improved rice varieties being AGRA (77.33%), SAKAI (50%) Jasmine (40.64%) and Afife (23.17%). GR-18 had the lowest current adoption rate of 5.77% followed by NERICA (5.88%) and Faro (11.10%), corroborating Lamptey (2022). AGRA and Jasmine had high initial and continuous adoption rates because they were the main varieties promoted in the study area during the period under review, corroborating MoFA, (2017), and Ragasa et al. (2013). The current adoption rate of Salma-Saa (67.37%) was higher than that of Kpokpula (6%), with their corresponding dis-adoption rates being 32.63% and 96% respectively.

TABLE 3

Initial adoption, continuous adoption and dis-adoption rates of rice varieties

Rice varieties*	Initial Adoption		Cont. Adoption		Dis-adoption	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
AGRA	150	37.13	116	77.33	34	22.67
SAKAI	2	0.50	1	50.00	1	50.00
Jasmine	166	41.09	67	40.64	99	59.64
Afife	82	20.30	19	23.17	63	76.83
NERICA	68	16.83	2	5.88	64	94.12
Digang	57	14.11	7	12.28	50	87.72
Mandee	55	13.61	10	18.18	45	81.82
GR-18	52	12.87	3	5.77	49	94.23
Tox	50	12.38	6	12.82	44	87.18
Faro 15-20	27	6.68	3	11.10	24	80.90
Local varieties *						
Salma-Saa	95	23.51	64	67.37	31	32.63
Kpokpula	50	12.38	3	6.00	47	96.00

Source: Survey data, 2020 *Multiple responses

The results from Table 3 further showed that the most dis-adopted improved rice varieties were GR-18 (94.23%), NERICA (94.18), Digang (87.72%), Tox (87.18%), Mandee (81.82%) and Faro (80.90%). The dis-adoption rate of Kpokpula was higher than all the other rice varieties, indicating the farmers' preference for adopting the improved varieties over the unimproved varieties modelled.

The Relationships among five selected rice varieties – pairwise correlations

AGRA, Jasmine, Mandee, Afife and Salma-Saa were selected for the multivariate regressions. SAKAI and other varieties were dropped from the MVP model because their initial adoption rates were too low (skewed) and could not fit well into the model. Besides, the five main rice varieties were selected for this econometric model to enhance precision and clarity of analysis. Table 4 presents the results of the correlation matrix from the multivariate regressions.

The results indicate that the joint probability of success for adopting all the rice varieties was 0.0003% and the joint probability of failure for dis-adoption was 0.395%. From the linear predictions, the probability of a rice farmer adopting Mandee, Jasmine, AGRA, Afife and Salma-Saa are 100%, 11.10%, -46.70%, 40.30% and 65.30% respectively. All the pairwise coefficients were positively correlated, indicating complementarity among the selected rice varieties. The relationship among all the complementary varieties were significant except for Jasmine and Mandee, AGRA and Mandee, Salma-Saa and AGRA, and Salma-Saa and Afife. The highest positive correlation was between Afife and Jasmine (42%), while the lowest was between Jasmine and Mandee (4.90%). As farmers adopt the complete package of the main rice varieties, they may be able to maximise their impact for improved output.

TABLE 4

Correlation matrix of five rice varieties used for the MVP model

Variable	Mandee	Jasmine	AGRA	Afife	Salma-Saa
Mandee	1				
Jasmine	0.049 (0.100)	1			
AGRA	0.049 (0.108)	0.387*** (0.077)	1		
Afife	0.171* (0.082)	0.420*** (0.082)	0.340*** (0.090)	1	
Salma-Saa	0.253*** (0.099)	-0.172* (0.091)	-0.106 (0.093)	-0.094 (0.100)	1
Linear prediction of the equations	1.000***	0.111**	-0.467***	0.403***	0.653***
Joint probability of success			0.00025		
Joint probability of failure			0.39496		
Wald $chi^2(75)$			260.94		
Prob > chi^2			0.0000		
Log likelihood			-933.8894		
Likelihood ratio test of $Rho_{kj} = 0$; Chi^2 (10) = 65.514; Prob > Chi^2 = 0.000					

Source: Survey data, 2020; *Significant at 10%; ** Significant at 5%; ***Significant at 1%

Drivers of initial adoption

A number of factors can influence rice farmers' decision to adopt one particular rice variety or the other (Birthal *et al.,* 2015). This section identifies the variables which determine the initial adoption of five selected rice varieties by farmers using multivariate probit. The model contained five dependent variables (rice varieties). 15 explanatory variables, of which 10 were dummy and five continuous, were included in the model.

Results in Table 5 show that the explanatory variables affecting initial adoption decisions differ substantially across the varieties. Gender had significant but negative effect on the initial adoption of Mandee, AGRA and Afife, but was redundant in explaining farmers' initial adoption decision of Jasmine and Salma-Saa. It means female farmers in the study area tend to adopt Mandee, AGRA and Afife more than their male counterparts. This is opposed to Mulwa *et al*. (2017), and Ragasa *et al.* (2013), who found the sex variable to be positive and significant in influencing the adoption of improved agricultural technologies. Donkoh *et al.* (2019), also found that the sex of a farmer positively and significantly influenced only nursery, spacing and line planting, but redundant in explaining the adoption of the other technologies. The finding in this study is plausible, since females contribute about 60-80% of the labour force in rice farming (FAO, 2011).

Household headship was significant and had positive effect on all the varieties except Salma-Saa. It means farmers who were household heads had a higher probability of adopting Mandee, Jasmine, AGRA and Afife more than their other counterparts. Similarly, household size was significant and had positive effect on Mandee and Salma-Saa but negative effect on Jasmine and AGRA, except Afife. It means farmers with larger household sizes had a higher tendency of adopting Mandee and

Salma-Saa while those with smaller household sizes were more inclined towards adopting Jasmine and AGRA. This should be expected, because Mandee is an older improved variety while Salma-Saa is an unimproved variety, both of which had adapted to the climatic and growth conditions of their localities where most of the farmers are peasants with large household sizes and cannot meet the input requirements of newly improved varieties like AGRA and Jasmine (Rogers, 2005).

FBOs was significant and had effects on all the rice varieties with positive signs on Jasmine and AGRA but negative signs on Mandee, Afife and Salma-Saa. This implies that farmers who belonged to FBOs were inclined towards the adoption of Jasmine and AGRA whereas their other counterparts had a higher probability of adopting Mandee, Afife and Salma-Saa. This is so because, newly improved rice varieties are normally introduced to farmers in groups but the group normally disintegrate during the adoption periods (Lamptey, 2018). This should be expected because Mandee, Afife and Salma-Saa were older in the communities than AGRA and Jasmine (AGRA-SSTP, 2016; Ragasa *et al.,* 2013). Donkoh *et al.* (2019), and Mulwa *et al.* (2017), also found a negative relationship between membership of FBO and the adoption of improved technologies. Aryal *et al*. (2018), likewise found that FBO membership increased farmers' level of using stress tolerant rice varieties positively and significantly.

Credit had significant but negative relationship with the initial adoption of Mandee, Jasmine and Afife, but failed to explain the farmers' adoption decision on AGRA and Salma-Saa. This implies that farmers who did not have access to credit were more likely to adopt Mandee, Jasmine and Afife than farmers who had access to credit. The famers indicated during interviews that borrowing money to farm rice was counter-productive, due the negative effects of climate change on rice production in recent times. This corroborates Doss (2006) and Doss *et al.,* (2003) that farmers will borrow only if it is profitable or less risky to do so. Similarly, Mateos & Dadzie (2014) found that access to credit prevented abandonment of the maize crop among farm households.

Extension services had significant and positive effect only on Mandee and Salma-Saa but was redundant in explaining the initial adoption decision of AGRA, Jasmine and Afife, which implies that farmers who had access to extension services were more probable of adopting Mandee and Salma-Saa but not any of the other varieties. This is plausible, since rice varieties are better promoted from farmer-to-farmer than the combined efforts of researchers and extension agents, due to the ineffectiveness of the agricultural extension service delivery in Ghana (Lamptey, 2018). This is consistent with Donkoh *et al.* (2019), who also found that access to research service significantly and positively influenced the adoption of only one out of seven agricultural technologies promoted in the study area. It means the farmers depend more on their fellow farmers for technical information on agricultural innovations than on extension agents and researchers. However, due to the huge ratio of one extension officer to about 3000 farmers in Ghana (GSS, 2014), the extension agents collaborate with researchers and other stake holders in agriculture to facilitate the adoption of technologies, through contact farmers (Lamptey, 2022; Etwire *et al*., 2019).

Distance to market had significant but negative relationship with all the varieties but could not explain that of Mandee, which implied that the farmers were more likely to adopt Jasmine, AGRA, Afife and Salma-Saa, except Mandee, if the distances to both the input and output markets were shorter. Irrigation was not significant for Mandee but was significant with positive relationship for AGRA, Jasmine, Afife and Salma-Saa, meaning farmers who practiced irrigation were more likely to adopt those four varieties than those who depended on rainfall. The farmers may have considered Mandee to have been acclimatized to the locality and would do well under rain-fed agriculture, even in the absence of irrigation.

Farm size was not significant for three of the varieties but was significant with positive relationship for AGRA and negative relationship for Jasmine. It means farmers with larger farm sizes had a lower probability of adopting Jasmine while those with smaller farm sizes were more likely to adopt AGRA than Jasmine. This is plausible, because this study revealed that increase in farm size increased the cost of production but did not result in increased output. So, the farmers preferred to cultivate smaller acres (averagely, 0.65 ha per farmer), which they could adequately manage. This finding is consistent with the study of Kassie *et al.* (2015), who suggested that the scarcity of land could induce agricultural intensification through the adoption of improved technologies.

Rainfall was significant with a positive relationship with all the rice varieties except Mandee, whose adoption decision could not be explained by rainfall. This implied that all the rice varieties needed more water (rainfall) to grow well than Mandee, meaning, the adoption of Mandee did not depend on maximum rainfall, as climate risk factor. Aryal *et al.* (2018) also found that decreasing rainfall pattern significantly and positively associated with the adoption of water-stress tolerant rice varieties. Finally, fertiliser was found to be significant and had a positive relation with the initial adoption of all the rice varieties, except that of Salma-Saa. This implied that the adoption of improved rice varieties was heavily dependent on the use of fertilisers, for maximum rice growth and output.

Table 5

The drivers of initial adoption (MVP)

	Mandee		**Jasmine**		**AGRA**		**Afife**		**Salma-Saa**	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Age	0.006	0.009	-0.003	0.007	-0.003	0.007	-0.003	0.008	0.008	0.008
Gender	-0.927[c]	0.282	-0.207	0.251	-0.827[c]	0.263	-0.484[a]	0.278	0.275	0.285
Headship	0.432[a]	0.261	0.535[c]	0.201	0.463[b]	0.206	1.026[c]	0.263	-0.019	0.218
Education	0.044	0.199	0.050	0.154	0.236	0.158	0.131	0.170	-0.145	0.169
Household size	0.035[c]	0.014	-0.030[b]	0.013	-0.026[b]	0.013	-0.023	0.016	0.028[b]	0.012
FBOs	-0.544[c]	0.193	0.686[c]	0.146	0.617[c]	0.148	-0.306[a]	0.165	-0.364[b]	0.155
Credit	-0.540[c]	0.212	-0.289[a]	0.152	-0.147	0.154	-0.434[b]	0.173	0.088	0.161
Extension	0.432[a]	0.230	-0.001	0.179	0.213	0.189	-0.086	0.196	0.724[c]	0.212

Rice perception	-0.209	0.187	-0.157	0.143	-0.081	0.147	0.176	0.162	0.015	0.159
Distance-market	-0.003	0.002	-0.007[c]	0.002	-0.008[c]	0.002	-0.006[c]	0.002	-0.004[b]	0.002
Market agents	0.146	0.191	-0.238	0.149	-0.181	0.155	-0.261	0.176	0.171	0.159
Irrigation	-0.682[a]	0.368	0.612[c]	0.219	0.515[b]	0.221	0.368	0.245	-0.630[b]	0.259
Farm size	-0.041	0.045	-0.065[b]	0.033	0.126[c]	0.023	0.025	0.028	-0.039	0.031
Rainfall	-0.076	0.330	0.916[c]	0.278	0.598[b]	0.262	0.788[b]	0.345	0.622[b]	0.322
Fertilizer	0.005[b]	0.002	0.004[b]	0.002	0.004[a]	0.002	0.005[b]	0.002	-0.002	0.005
_cons	-0.960[a]	0.565	-0.688	0.475	-0.438	0.480	-1.252[a]	0.560	-2.384[c]	0.535

Model diagnosis: Number of obs. = 404; Wald chi2(75) = 260.94; Prob > chi2 = 0.0000; Log likelihood = -933.8894

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: chi2(10) = 65.514 Prob > chi2 = 0.0000

Source: Survey data, 2020; [a] Significant at 10%; [b] Significant at 5%; [c] Significant at 1%

Drivers of continuous adoption

Results in Table 6 showed that FBO Membership was the only variable which significantly affected the adoption decisions of all the five rice varieties in this model. The rest of the explanatory variables were significant with various levels of influence on the adoption decisions of the varieties. Age was significant with a positive effect on Mandee and negative effects on Jasmine and AGRA but could not explain farmers' continuous adoption decisions of Afife and Salma-Saa. It means age was more effective in explaining farmers' real adoption decision of Mandee but less effective in explaining farmers' adoption decisions of Jasmine and AGRA. The effect of this result is that older farmers had a higher probability of adopting Mandee than Jasmine and AGRA.

This should be expected, because Mandee is an older improved rice variety, the cultivation of which does not require much labour and cost compared with newly improved varieties like AGRA and Jasmine that may even require additional agronomic practices besides cost and labour intensiveness. Similarly, Danso-Abbeam & Baiyegunhi (2017), found a positive and significant relationship between the age of a farmer and the adoption of agricultural technology. Denkyirah *et al.* (2016), also found a negative effect of age on adoption of pesticides. Gender was not significant for three of the varieties (Mandee, Jasmine and Salma-Saa) but was significant with negative relationship for AGRA and Afife. This means that female farmers were more likely to adopt AGRA and Afife compared to their counterpart male rice farmers. This finding is inconsistent with Donkoh *et al*. (2019), Mulwa *et al.* (2017), and Ragasa *et al.* (2013), who found the sex variable to be positive and significant in influencing the adoption of improved agricultural technologies in the study area.

Household headship of the farmer was also significant and positively related to the actual adoption of AGRA and Afife, but did not explain the current adoption decision of

Mandee, Jasmine and Salma-Saa. The impact of this result is that, farmers who were household heads had a higher probability of adopting AGRA and Afife than their non-household head counterparts. FBOs had significant and positive associations with the actual adoption decisions of Jasmine and AGRA but negatively influenced the current adoption of Mandee, Afife and Salma-Saa. It means farmers who belonged to FBOs had a higher probability of adopting AGRA and Jasmine whereas those who did not belong to FBOs were more likely to adopt Mandee, Afife and Salma-Saa. It presupposes that the FBOs that were formed during the dissemination of AGRA and Jasmine were still in existence, since the AGRA and Jasmine were the latest improved rice varieties to be disseminated in the study area (MoFA, 2020). The FBOs that were formed during the dissemination of Mandee, Afife and Salma-Saa might have fizzled out because those varieties were promoted early on (APS, 2015; Ragasa *et al.* 2013). Mulwa *et al.* (2017), also found a negative relationship between membership of FBO and the adoption of improved technologies.

Access to extension was significant and positively related to farmers' continuous decision to adopt Mandee, Afife and Salma-Saa but was redundant in explaining the adoption of AGRA and Jasmine. This finding met the a priori expectation of the study, since agricultural extension is meant to influence technology uptake by farmers, corroborating Akpan *et al.* (2013) and Amao (2013). Rice perception was significant and positively influenced only the continuous adoption of Afife, implying that farmers who perceived improved rice varieties to be better than unimproved varieties in terms of high yields were more likely to cultivate Afife.

Distance to market was significant and negatively affected the continuous adoption of all the rice varieties except Afife, whose adoption decision could not be explained by that variable. It means longer distance to markets had the probability of limiting the real adoption of Mandee, Jasmine, AGRA and Salma-Saa. Market agents significantly and positively influenced the continuous adoption of Afife, implying that farmers were cultivating more of Afife due to high demand for the produce by market agents and traders. Also, Afife was strongly promoted in the study area by market women from the Volta Region of Ghana where the crop was initially disseminated (Lamptey *et al*, 2022).

As expected, irrigation was significant and positively influenced the current adoption of AGRA, and negatively related to Mandee and Salma-Saa but insignificant in explaining the adoption of Jasmine and Afife. It means irrigation farmers had a higher probability of adopting more of AGRA and less of Mandee and Salma-Saa, possibly due to the fact that Mandee and Salma-Saa do well under rain-fed agriculture than AGRA (MoFA, 2020).

Though farm size could not explain the real adoption decisions of Mandee and Afife, it significantly and positively influenced the continuous adoption of AGRA but negatively affected Jasmine and Salma-Saa. This suggests that farmers with bigger farm sizes had lower probabilities of adopting Jasmine and Salma-Saa, but a higher probability of adopting AGRA. Donkoh *et al.* (2019), also observed that farm size was significant and had a negative relationship with the adoption of six out of seven agricultural technologies.

Rainfall was not significant for two of the varieties (Mandee and Afife) but was significant with positive relationship for

Jasmine, AGRA and Salma-Saa. This implies that increase in the rainfall pattern would result in a higher probability of farmers adopting Jasmine, AGRA and Salma-Saa. Fertiliser was positive and significantly related to only AGRA and Jasmine but insignificant in explaining the continuous adoption of the other varieties. It means that the availability or access to fertilisers would encourage the adoption of AGRA and Jasmine. In other words, the adoption of AGRA and Jasmine is highly dependent on fertiliser usage. The constant explanatory variable significantly but negatively explained the real adoption decision of farmers regarding Mandee, Afife and Salma-Saa. It implied that few farmers would have still adopted those three varieties, in the absence of all the other explanatory variables.

TABLE 6

Drivers of continuous adoption (MVP)

	Mandee		**Jasmine**		**AGRA**		**Afife**		**Salma-Saa**	
	Coef.	Std. Err.	Coef.	Std. Err	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Age	0.022[c]	0.009	-0.015[a]	0.009	-0.013[a]	0.008	-0.009	0.009	0.013	0.009
Gender	0.005	0.326	-0.195	0.289	-0.592[b]	0.267	-0.534[a]	0.285	0.483	0.395
Headship	-0.267	0.244	0.022	0.238	0.376[a]	0.233	0.460[a]	0.267	0.071	0.267
Education	0.061	0.191	-0.266	0.200	0.040	0.171	0.112	0.189	-0.051	0.197
Household Size	0.009	0.014	-0.012	0.016	-0.021	0.014	0.004	0.015	0.038[c]	0.014
FBOs	-0.402[c]	0.190	0.630[c]	0.184	0.924[c]	0.165	-0.327[a]	0.185	-0.454[b]	0.181
Credit	0.263	0.188	-0.306	0.195	-0.062	0.168	-0.057	0.189	0.241	0.185
Extension	0.482[b]	0.232	0.103	0.218	0.140	0.212	0.588[b]	0.259	0.513[b]	0.236
R-perception	-0.106	0.187	-0.049	0.176	-0.196	0.159	-0.408[b]	0.191	-0.136	0.184
Dist.-market	-0.004[a]	0.002	-0.008[c]	0.003	-0.007[c]	0.002	-0.003	0.002	-0.006[c]	0.002
Market agents	0.213	0.182	-0.277	0.193	-0.269	0.173	0.446[b]	0.183	-0.118	0.189
Irrigation	-0.695[b]	0.330	-0.347	0.345	0.531[b]	0.224	-0.320	0.279	-0.839[b]	0.407
Farm size	-0.049	0.045	-0.306[c]	0.077	0.142[c]	0.024	0.021	0.027	-0.141[c]	0.052
Rainfall	-0.304	0.286	1.033[b]	0.493	0.598[b]	0.308	0.122	0.353	0.709[a]	0.424
Fertilizer	-0.001	0.005	0.007[c]	0.002	0.005[b]	0.002	-0.011	0.014	-0.013	0.012
_cons	-1.749[c]	0.572	-0.647	0.678	-0.692	0.523	-1.057[a]	0.580	-2.902[c]	0.670

Model diagnosis: Number of obs. = 404; Wald chi2(75) = 222.98; Prob > chi2 = 0.0000; Log likelihood = -738.463

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: chi2(10) = 18.9866 Prob > chi2 = 0.0404

Source: Survey data, 2020;[a] Significant at 10%; [b] Significant at 5%; [c] Significant at 1%

Drivers of dis-adoption

As in the case of initial and continuous adoption decisions, FBO Membership was the only statistically significantly variable that influenced the dis-adoption decisions of all the five rice varieties in this model. The rest of the explanatory variables were significant and had different relationships with the dis-adoption decisions of all the varieties, similar to the initial and continuous adoption behaviours of the farmers. For example, age was significant and had a positive relationship with dis-adoption of Jasmine and AGRA but had a negative effect on dis-adoption of Mandee, yet redundant in explaining the dis-adoption of Afife and Salma-Saa.

Table 71

The drivers of dis-adoption (MVP)

	Mandee		**Jasmine**		**AGRA**		**Afife**		**Salma-Saa**	
	Coef.	Std. Err.	coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Age	-0.022[c]	0.009	0.0154[a]	0.009	0.013[a]	0.008	0.009	0.009	-0.013	0.009
Gender	-0.005	0.326	0.195	0.289	0.592[b]	0.267	0.534[a]	0.285	-0.483	0.395
Headship	0.267	0.244	-0.022	0.238	-0.376[a]	0.233	-0.460[a]	0.267	-0.071	0.267
Education	-0.061	0.191	0.266	0.200	-0.040	0.171	-0.112	0.189	0.051	0.197
HH 6size	-0.009	0.014	0.012	0.016	0.021	0.014	-0.004	0.015	-0.038[C]	0.014
FBOs	0.402[b]	0.190	-0.630[c]	0.184	-0.924[c]	0.165	0.327[a]	0.185	0.454[b]	0.181
Credit	-0.263	0.188	0.306	0.195	0.062	0.168	0.057	0.189	-0.241	0.185
Extension	-0.482[b]	0.232	-0.103	0.218	-0.140	0.212	-0.588[b]	0.259	-0.513[b]	0.236
Rice perception	0.106	0.187	0.049	0.176	0.196	0.159	0.408[b]	0.191	0.136	0.184
Distance-market	0.004[a]	0.002	0.008[b]	0.003	0.007[c]	0.002	0.003	0.002	0.006[C]	0.002
Market agents	-0.213	0.182	0.277	0.193	0.269	0.173	-0.446[b]	0.183	0.118	0.189
Irrigation	0.695[b]	0.330	0.347	0.345	-0.531[b]	0.224	0.320	0.279	0.839[b]	0.407
Farm size	0.049	0.045	0.306[c]	0.077	-0.142[c]	0.024	-0.021	0.027	0.141[c]	0.052
Rainfall	0.304	0.286	-1.033[b]	0.493	-0.598[b]	0.308	-0.122	0.353	-0.709[a]	0.424
Fertilizer	0.001	0.005	-0.007[c]	0.002	-0.005[b]	0.002	0.0114	0.014	0.013	0.012
_cons	1.749[c]	0.572	0.647	0.678	0.692	0.523	1.057[a]	0.580	2.902[c]	0.670

Model diagnosis

Number of obs. = 404; Wald chi2(75) = 222.98; Prob > chi2 = 0.0000

Log likelihood = -738.463

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: chi2(10) = 18.9866 Prob > chi2 = 0.0404

Source: Survey data, 2020; *Significant at 10%; ** Significant at 5%; ***Significant at 1%

This implied that older farmers had a higher probability of dis-adopting Jasmine and AGRA and a lower tendency of dis-adopting Mandee. That was probable, since the older farmers appeared to be conservatives, who did not easily take the risk of adopting the technologies (Rogers, 2005), especially Jasmine and AGRA. They may have been used to adopting an older rice variety such as Mandee more than Jasmine and AGRA. Doss (2006) as well as Doss *et al.* (2003), posited that it was difficult to determine which factors were behind farmers' decisions not to use new technologies. However, we found that the factors that influenced current adoption also affected dis-adoption, as shown in Table 7. The production constant in this dis-adoption model shows that some farmers would still dis-adopt Mandee, Afife and Salma-Saa, the other explanatory variables notwithstanding.

Conclusion and Recommendation

Rice is considered the second most important cereal crop in Ghana because it is widely cultivated across the country. It is the number two crop in terms of area planted. It serves as a major food and cash crop, and one of the most common staple crops contributing significantly to consumer diets. In spite of the aforementioned importance of rice in Ghana, the industry is characterised by low productivity resulting from low use of improved rice seeds and inputs. Adoption rates of the selected rice varieties in the study area have been very low with alarming rates of dis-adoption.

The main objective of this study was therefore to investigate the drivers of initial adoption, continuous adoption and dis-adoption of selected rice varieties among smallholder farmers in Northern Ghana by estimating a multivariate probit model. The multivariate correlation coefficients revealed complementarities (positive relationships) among all the rice varieties farmers adopted initially, continuously, and those they dis-adopted, implying that the adoption and dis-adoption of a given rice variety depended largely on the adoption and dis-adoption of the other varieties as indicated by the pairwise correlations.

The interrelations among these rice varieties suggest that farm-level policies that affect the adoption or dis-adoption of one rice variety can condition the adoption or dis-adoption of the other varieties. The estimation results indicate that the drivers of farmers' initial adoption, continuous adoption and dis-adoption decisions differ between varieties. Among the socioeconomic variables, only gender, farm size and household headship of the farmer played significant roles, partly with differing signs across the varieties.

Among the institutional factors, FBO membership, extension services, access to credit, access to irrigation and access to fertilizer were significant in affecting farmers' initial adoption decisions, with differing signs across the rice varieties. Among the locational and environmental factors, only distance to market and rainfall were significant in affecting farmers' initial adoption decisions, with differing signs across the rice varieties. Farmers' age, gender, farm size, rice perception and household headship were the socioeconomic variables that significantly affected the current adoption decisions of farmers, partly with differing signs across the varieties.

Among the institutional factors, FBO membership, extension services, access to irrigation, market agents and access to fertiliser were significant in affecting farmers' continuous adoption decisions with differing signs across the rice varieties. Among the locational and environmental factors, only distance to market and rainfall were significant in affecting farmers' continuous adoption decisions with differing signs across the rice varieties. The farmers' dis-adoption decisions were significantly affected by the following socioeconomic variables: age, gender, farm size, rice perception and household headship, partly with differing signs across the varieties. Among the institutional factors, FBO membership, extension services, access to irrigation, market agents and access to fertilizer were significant in influencing farmers' dis-adoption decisions with differing signs across the rice varieties.

Among the locational and environmental factors, only distance to market and rainfall were significant with differing signs across the rice varieties. Thus, the factors that affected the continuous adoption decisions of farmers also affected their dis-adoption decisions. The policy implications are that continuous promotion of improved rice varieties in the study area would increase adoption rates and reduce dis-adoption rates of the existing varieties, increase rice productivity, and reduce extreme poverty and hunger among farmers. Also, continuous adoption of improved rice varieties in the absence of good road networks, credit facilities, market opportunities, irrigation facilities, extension services and favourable climatic conditions, would trigger dis-adoption.

The study concludes that adoption and dis-adoption are not mutually exclusive variables since dis-adopters of one improved rice variety are also adopters of another variety. For continuous adoption of improved rice varieties and sustainability of agricultural innovations in the study area, the government and all stakeholders in the rice value chain must ensure that improved rice varieties disseminated are given a minimum of 10 years to diffuse completely before new varieties are introduced in the same area. The government must also formulate policies to ensure that any agents introducing any rice varieties to farmers in Ghana must necessarily collaborate with MoFA and comply with national principles regarding agricultural technology dissemination. Since distance to market and rainfall significantly affected farmers initial adoption, continuous adoption and dis-adoption decisions, it would be very prudent for the government of Ghana to establish markets and irrigation facilities in all rice farming communities, to increase and sustain adoption but reduce dis-adoption.

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