Original Article

Factor Influencing Adaptation Choices Employed by Farmers Against Climate Change to Improve Rice Yield in Bugarama Wetland in Rwanda

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ABSTRACT

The changing climate poses a great challenge to many wetlands productivity worldwide. Rice production in wetlands is a major source of livelihood in developing countries such as Rwanda. This study aimed at determining the factors influencing adaptation methods when farmers perceive the changing climate at Bugarama Wetland Rice Scheme in Rwanda. A descriptive research design was used by this study, whereby quantitative and qualitative data was collected. The analysis was based on data collected from 300 selected farmers using systematic random sampling method. We employed descriptive statistics to assess how farmers perceive the effects of climate change and descriptively measured the new adaptation methods used by farmers in Bugarama to increase their yields. The study adopted Heckman two-step model to determine factors that influence adaptation choices, this analysis procedurally required farmers' knowledge of perception that makes them respond to the effects of changes in climatic conditions by the use of new adaptation methods. The results deduced that level of education (p =0.019), extension access (p=0.001), market distance (p=0.002) and rice income (p < 0.001) had a probability of influencing farmers perceptions about climate change thus need to adapt. Based on the outcome model, results showed that extension access (p < 0.001), household size (p= 0.098), market distance (p= 0.047), rice income (p =0.032), farmers-to-farmers contact (p < 0.001) and effects of climate change on rice (p=0.038) had a greater probability of influencing farmers choice of adaptation method used to improve rice yields. To conclude, the study found that access to informational facilities and rice income, influenced farmers' perceptions while extension access, rice income, market distance, farmers-to-farmers contact and effects of climate change on rice yield strongly had a probability of determining farmers' choice of adaptation. This study recommends that the Rwandan

government and local administrators need to develop a strategy that would allow farmers to access information facilities about new technology so as to adapt to the effects of climate change thus improve their rice yields.

INTRODUCTION

Lowland and marshy areas are the most potential yields of agriculture. However, changing climate has destroyed the marshland fertility, consequently reducing crops yields. For example, some studies which had been done in developed nations generally showed great negative impacts on (-60, -70%) or a total failure of crop yields (Celia & Bancolita, 2014). However, it is reported that most of the countries in Africa are greatly experiencing the impacts of climate change on agricultural produce (Gupta *et al.,* 2019; Lamboll *et al.,* 2017; Mikova *et al.,* 2015; Moshi & Isinika, 2016). The validation of these studies posits that more studies are required in many different parts of Africa to specifically diagnose adaptation choices needed to improve agricultural yields. Empirically, climate change and its seasonal variability are of great significance to smallholder farmers, thus threatening their daily livelihoods (Belay *et al.,* 2017; Mashizha, 2019). Rwanda is one of the most identified vulnerable countries in terms of climatic changes. Moreover, rice farming has been playing a vital role in the socio-economic welfare of the

people due to Rwanda's rich alluvial soils that are suitable for rice farming (Garcia, 2015; Mikova *et al.,* 2015). This has caused farmers from Bugarama to have different perceptions on how to curb the effects of climate change while increasing their rice yield. The impacts of climate change have led to farmers and researchers to identify some coping mechanism that would maximize the yield of crops in agriculture. These adaptation options are employed by farmers depending on their socio-economic capacity. The new coping technology adopted always assumed to improve the farm produce in the midst of changing climate effects. However, the choice of adopted methods depends on farmers' level of knowledge about climate and the prevailing perception (Mashizha, 2019). There are many studies which have been done on factors determining the adaption options to be employed against climate change to improve yields (Ali & Erenstein, 2017; Amare & Simane, 2017; Asrat & Simane, 2018; Deressa *et al.,* 2009; Ferdushi *et al.*, 2019; Mabuku *et al.*, 2019; Ojo & Baiyegunhi, 2019) which mainly described determinants of the choices. This has limited the contribution of adaptation strategies and therefore there is an urgency to strengthen new measures that can be

employed by smallholder farmers of Bugarama. The understanding of factors influencing farmers decision is first perceived by the knowledge then farmers adapt depending on their socio-economic status (Asrat & Simane, 2018). The adoption of a particular choice is a vital insight into the productivity in the farm. In particular, Bugarama wetland has been affected by climatic conditions that have been changing (Shumbusho, 2009). This study aims at bridging the gap between factors influencing adaptation methods and choices that are made by the farmers in Bugarama rice production so as to improve their yields. This study has a significant contribution to the farmers of Bugarama because it can help them make better decisions when adapting mitigations against climate change. It can also help policymakers gain perspective on the adaptation methods for rice farming and generally add literature to the scientific discipline.

RESEARCH METHODOLOGY

Area of Study

Bugarama rice scheme is located at 2°41′50″S 29°00′30″E of Rusizi Districts in Rwanda. It is about 307 km Southwest from Kigali, the capital city of Rwanda. Bugarama covers 24km^2 with a population density of 1244/km^2. This zone is identified as highland at 1200m above sea level. Soils are transitional and characterized by an intermediary between upland and lowland which are marshy, alluvial connected to the lowland due to material deposits. However, the colloidal concentration at the upland is due to better drainage. The main soil type at Bugarama is generally alluvial soils, characterized by fluvisols with sandy loam texture.

Figure 1: *Area covered by Bugarama wetland, Rwanda*
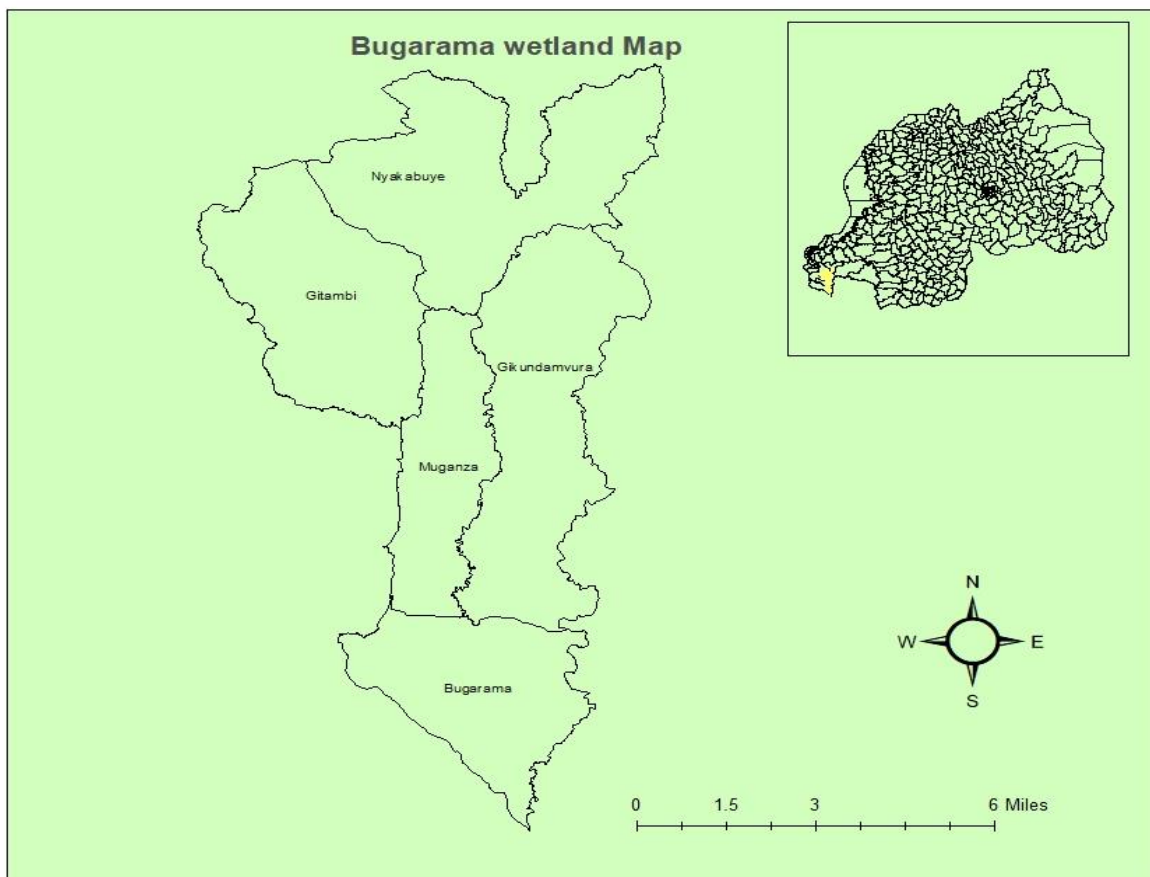
Data Collection and Sampling Procedures

The research employed survey method to collect data from households by the use of structured questionnaires. We purposively selected Bugarama marshland among other rice production schemes in Rwanda due to climatic vulnerability and high reduction in water level in the marshland (Shumbusho, 2009). This research employed Yamane's (1967) method to approximate the sample size of the study from the rice farmers population.

$$n = \frac{N}{1 + Ne^2}$$

The method of sampling was considered appropriate because the study systematically randomized the selection of respondents from different villages within Bugarama wetland. Notably, this study employed stratification to categorize farmers with respect to their location. The selected respondents per strata depended on the number of farmers within the villages in the stratas and the scale of rice production. 300 farmers' households were sampled.

Data Analysis

The data obtained from farmers' households was descriptively analyzed and then ran through the Heckman two-step sample selection method for STATA-14.0, SPSS-20.0 and Microsoft Excel software 2016. The descriptive statistics described the adaptation methods used by farmers to increase rice yields in the midst of changing climate and its effect. We decided to use Heckman two-step selection method to analyze the researched data. This procedurally determined the choices adopted by farmers to maximize their yield by the use of emergent technology (Heckman, 1979). The steps require more than one model to realize two regressions that appropriately correct selection bias during the process of decision-making on the preferred choice. Heckman's models are based on the farmer's utility, behaviours and knowledge to adopt new technology that maximizes the yields. It is assumed that farmers perceive the utilization of new technology to be better than the old methods for profit maximization (Asrat & Simane, 2018).

The Heckman method considers options of perception. Either farmers perceived climate change or do not for the selection model. The outcome model explored whether the farmers adopted a method of adaptation relying on the condition in stage one. During the two processes, it was likely that the respondents to the perception of climatic change did not necessarily respond to adaptation method choice. This would then cause sample bias (Asrat & Simane, 2018). This selection bias is likely to be corrected by the two-step procedural maximum likelihood that underlay the association between the variables as shown in the equation below:

$$y_j = x_j \beta + u_{1j} \qquad (1)$$

Therefore, the only observed binary outcome was given by probit model as:

$$y_j^{probit} = (y > 0) \qquad (2)$$

Lastly, the dependent variable is observed only if j is in the selection as:

$$y_j^{probit} = Z_j \delta + u_{2j} > 0 \qquad (3)$$

$$u_{1j} \sim N(0,1)$$

$$u_{2j} \sim N(0,1)$$

$$corr(u_1, u_2 \sim N(0,1) = \rho$$

Where; y_j^{probit} is the perception when there is climate change or not, Z is a coefficient vector that was hypothesized; δ is the variable estimates; u_1, u_2 are terms of error. According to Asrat and Simane (2018) when ($\rho \neq 0$), the standard probit give biased results. Therefore, outcome and the selection models are correlated and consistently yield by coefficient estimates for all variable. Equation (3) is the stage one of Heckman's two-step model and Equation (1) is for outcome model that determines the choice of adaptations strategy by farmers from the knowledge of perception on climate change.

We used perception as the dependent variable for selection and adaptation for the outcome equation

model. The variables are dummy variables that are in correlation with the Heckman assumption (Asrat & Simane, 2018; Heckman, 1979). The independent variables that explained Bugarama farmers' perceptions and adaptation choices included characteristics of households, environmental issues and new technology options as selected by hypothesized association of variables.

RESULTS AND DISCUSSION

Farmers' adaptation methods at Bugarama wetland

The adaptation methods that were surveyed from the field were described and ranked descriptively by percentages. The descriptive statistics from the results showed that all farmers perceived and adapted to climate change in different ways. Most of the farmers adopted the integration of crops and livestock (12.0%) to supplement rice yields during adverse climatic conditions. The most adopted methods of adaption to increase yield are supplementary irrigation (10.8%), use of shallows for water irrigation (11.1%), water conservation through mulching (5.8%), planting of improved rice crop (9.2%) and the intensification of pest control (11.6%) due to emergence of diseases in crops. Moreover, farmers adapted to climate change in various ways at Bugarama that includes seeking for early warning information (4.9%), shifting planting dates (5.9%), diversifying to other businesses during loss (3.9%), avoiding flood-prone areas (6.9%), insuring farms against risk (0.8%) and receiving compensation (0.5%) from cooperatives. Most of the adaptation methods adopted by the farmers from Bugarama rice production were also identified in other studies (Ansari *et al*., 2018; Hamza & Iyela, 2012; Mase *et al*., 2017; Mase *et al.,* 2017; Moshi & Isinika, 2016; Omondi *et al*., 2014; Phinzi *et al.*, 2019; Teklewold *et al.*, 2019). The methods are as shown in *Figure 2*.

Figure 2 *Methods used by Bugarama rice farmers*
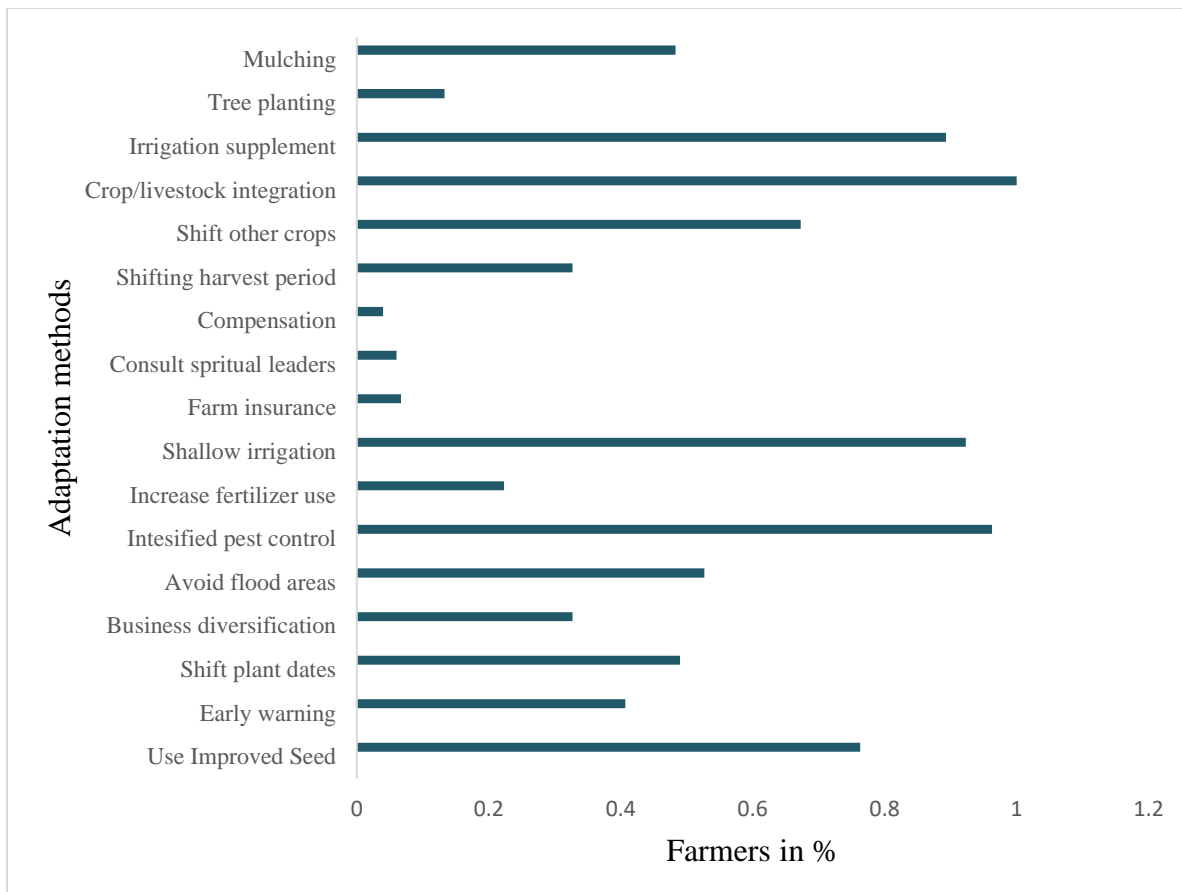
Factors influencing adaptation methods

Table 1 shows the descriptive statistic of explanatory variables that are used to define the determinants of adaptation methods adopted by the rice farmers of Bugarama. 77.7% of farmers in Bugarama perceived climate change as affecting their rice yields thus 76.7% of the farmers responded that they apply adaptation methods to increase the rice yield in the midst of climate change effects. As the Heckman model procedure, we decided to underline factors that influence farmers' perception about climate as age, gender, level of education, extension access and training, effects of climate change on rice yield and frequent of catastrophes like droughts and floods. We determined factors that affect adaptation methods employed by farmers such as Household characteristics and farm income that includes off-farm income, information access, cooperative influence, farmers experience, employment status, rice income and other factors (Berhanu & Beyene, 2015; Ferdushi *et al.*, 2019). A summary of the influencing factors has been recorded in *Table 1* and *Table 2*.

Table 1: *Descriptive statistics of Heckman model variables*

Variable	Mean	Std. Dev.	Min	Max
Perception	.253	.701	0	1
Adapted	.233	.424	0	1
Age	41.2	9.24	23	71
Gender	.626	.485	0	1
Marital status	.323	.469	0	1
Level of Education	2.33	.823	1	4
Household size	4.03	1.804	1	8
Credit access	.623	.485	0	1
Extension access	.873	.333	0	1
Info from other farmers	.953	.211	0	1
Access to market	.967	.179	1	5
Market Distance	3.10	.842	1	5
Rice income	237.2	141.8	5.38	660.64
Farm size	1.599	1.017	.2	5.0
Climate awareness	3.79	.852	1	5
Climate effects	3.52	.955	1	5
Invasion by Pest	1.53	.5	1	2
Farmers' experience	8.86	7.05	1	35
Water level	3.11	1.06	1	5

Table 2: Results of the Heckman probit selection model for Bugarama Rice production

Variable	Regression				Marginal effects			
	Perception (Selection)		Adapted (Outcome)		Perception (Selection)		Adapted (Outcome)	
	Coefficient	P value	Coefficient	P value	dy/dx	P value	dy/dx	P value
Age	-0.002	0.677	0.009	0.327	-0.037	0.15	0.002	0.524
Gender	0.088	0.382	-0.145	0.448	0.003	0.946	-0.046	0.385
Level of education	-0.072	0.196	0.069	0.54	-0.073**	0.019	0.021	0.486
Extension access	0.144	0.443	-1.226***	0.000	0.151***	0.001	-0.472***	0.000
Level of water	-0.03	0.231	0.109	0.237	-0.037	0.113	0.03	0.229
Marital status	-0.123	0.347	-0.126	0.535	-0.035	0.466	-0.033	0.532
Household size	0.029	0.926	0.075	0.162	0.019	0.135	0.023*	0.098
Farm size	0.005	0.251	-0.113	0.247	-0.01	0.673	-0.031	0.242
Market Distance	0.122	0.074	-0.301**	0.036	0.105***	0.002	-0.078**	0.047
Credit access	0.192*	0.017	-0.094	0.65	0.022	0.678	0.035	0.54
Access to market	-0.248	0.665	-0.280	0.518	-0.098	0.513	-0.08	0.567
Rice income	0.0005	0.288	0.003***	0.000	0.155***	0.000	0.782**	0.032
Aware of climate			-0.01	0.928			0.017	0.581
Effect of climate			0.212**	0.043			0.058**	0.038

Variable	Regression				Marginal effects			
	Perception (Selection)		Adapted (Outcome)		Perception (Selection)		Adapted (Outcome)	
	Coefficient	P value	Coefficient	P value	dy/dx	P value	dy/dx	P value
Invasion pest			-0.083	0.305			-0.019	0.37
Farmers' experience			-0.0003	0.984			0.0005	0.886
Other farmers' info.			5.996***	0.001			0.233***	0.000
lambda	-0.102	0.590						
Constant	0.189		-0.472					
	(0.437)		(1.170)					

Note: ***p<0.01 **p<0.05 *p<0.1 for significant levels

The results from the outcome regression model in *Table 2* showed that the effects of climate change on rice farming was positively correlated to the farmers 'choice of adaptation method against climate change to improve their yields at (p < 0.05) which would increase the use of new strategies by 5.8% in Bugarama wetland rice production. There was a negative and weak correlation between farmers' awareness and choice of adaptation. However, this correlation was not statistically significant (p > 0.05). These findings are in contrast with sentiments expressed by Adego *et al.,* (2019) and Omondi *et al.,* (2014) who claimed that the knowledge and awareness of climate change had a positive and significant influence on the choice of adaptation by farmers. There was a negative relationship between pest invasion and farmers' choice of adaptation, this would influence the choice of adaptation by 1.9% which was not significant. The same results were also supported by Onyeneke (2019) that the farmers' choice of adaptation was influenced by pest invasion which is a critical determinant of controlling pest and disease epidemics.

The age of a farmer at Bugarama had a weak and negative influence on farmer's perception about climate change, (p > 0.05), which was not significant. Similarly, with regards to the influence of age on adaptation choice, (p > 0.05), it was found that age was not statistically influencing adaptation though there was a probability of 0.2% influence on farmers' choice of adaptation. Mabuku *et al.,* (2019) reported that experience in farming influences the adaptation option though was not significant. The same results were posited by this study where farmers' experiences would increase the probability of adaptation choice by 0.05% only. Thus, this revealed that regardless of the age or experience farmers would perceive climate change

and make choices on adaptation options at Bugarama wetland.

The results showed that there was a positive association between gender and the perceptions though there was no statistical significance. Gender (male or female) did not necessarily affect the farmer's perception nor the choice of adaptation method against climate change effects. However, these findings were contrary to those found in other studies (Amare & Simane, 2017; Mabuku *et al.*, 2019; Moroda *et al.,* 2018). The same results as the gender of this study were reported by the marital status which showed that whether married or single would not make a farmer perceive climate change or adapt against its effects.

As from other studies around the world, farm income makes farmers perceive climate change and decide on adaptation method to curb climate change effects on their farm (Alemayehu & Bewket, 2017; Moroda *et al.,* 2018; Ojo & Baiyegunhi, 2019). Rice income was highly positive and statistically significant to make Bugarama farmers decide on the adaptation choices (p < 0.001). Moreover, rice income would increase farmers' perception by 15.5% and adapt to climate change by 78.2%. Therefore, there was a high probability that farmers adapt to climate change effects to utilize the best methods to improve yields and make more income as reported by Mikémina, (2013). Notably, there was neither a significant relationship between farm size and perception nor adaptation method chosen by Bugarama farmers. However, this result was contrary to those posted by Belay *et al.,* (2017) and Enete, (2013) who reported that firm size had a statistically significant influence on the adaptation methods employed by farmers.

With regards to the farmers' level of education, it can be seen that there was a negative relationship to

perceptions about climate change, though not significant (p >0.05). However, there was a probability of 7.3% to increase in the farmers' perception of climate change. On the other hand, there was no significant association between the level of education and the adaptation strategies chosen by farmers of Bugarama wetland to mitigate climate change effects. These findings showed that the level of education did not affect the choice of adaptation options against climate change. Therefore, in Bugarama rice scheme, all farmers had the same opportunities to adapt. (Deressa *et al*., 2009; Onyekuru & Marchant, 2016) also reported that farmers' level of education was statistically associated with the farmer's adaptation which was in contrast to this study.

The number of individuals in the household was not statistically significant at (p < 0.05). However, the results showed that the household size would increase the probability of adaptation by 2.3%. Therefore, results showed that some farmers would adopt the best adaptation options to improve income for their households. The findings were similar to those reported by Ali and Erenstein, (2017), who stated that family size had a statistically significant influence on the adaption of measures to combat the constraints caused by environmental degradation and climate change effects.

According to this study, credit access influence perception about climate change at (p < 0.1), it was correlating to adaptation methods applied by Bugarama farmers. This was in line with studies such as (Deressa *et al.,* 2009; Shongwe *et al.,* 2014) who implied that access to loan and credit necessarily influence the adaptation option by farmer even though Bugarama farmers mainly depend on cooperative assistance and guidance to improve their productivity as reported Barayandema *et al.*, (2017).

This study found that extension access at Bugarama was key to rice farmers. Credit access influenced farmers' perception though was not significance at (p < 0.05) and access to credit had a probability of influencing perception by 15.1% at p < 0.01. It also noticed that there was a negative and significant influence of credit access to adaptation option at p < 0.01. Moreover, this had a probability of 47.2%

to make choice on new adaptation strategies. Thereby, access to farm inputs such as seeds, fertilizers, machinery and training services increase the probability of adapting. Bugarama farmers were subsidized by cooperatives to access extension services. The same results were reported by (Mulwa *et al.*, 2017; Shongwe *et al.*, 2014) who reported that due to the subsidies by cooperatives, extension services were found to have a statistically significant influence on the farmer's decision to adapt to climate change methods. Similar sentiments were also expressed by Ali and Erenstein (2017) who reported that when farmers have access to extension, they tend to adopt alternative methods.

Access to market was neither significantly influencing farmers' perception nor the choice of adaptation since all Bugarama farmers had ready market in the cooperatives (Barayandema *et al.,* 2017). However, market distance had a probability of 10.5% influence to farmers' perceptions. Moreover, farmers' choice of adaptation was negatively and statistically determined by market distance at (p < 0.05) and had a probability of 7.8% to decrease the choice of adaptation methods However, there have been mixed results on the market distance as reported by Adego *et al.* (2019), Khanal *et al.* (2018) and Moshi and Isinika (2016).

Farmers to farmers contact was statistically significant and influenced the farmers' adaptation choices at (p< 0.001) which showed a positive association, and this had a probability of increasing farmers' decision making by 23.3% on new adaptation method against climate change. Alemayehu and Bewket (2017) and Khatri-Chhetri *et al.* (2017) posited that, it is easier to access information from other farmers was for the new adaptation methods. Lastly, this study reports that, the wetland water level did not influence perception about climate change or making a choice on the adaptation methods against climate change.

CONCLUSION

The choice of adaptation to climate change requires two steps to make a concrete choice so as to respond to the changing climate. These are perception followed by decision-making. This study decided to use Heckman two-step sample selection model to

determine factors that influence the choice of adaptation options. It was found that farmers perceive the changing climate and make a decision to survive by implementing adaptation strategies.

The study concluded that, farmers of Bugarama significantly perceive climate change due to its effects on the rice production, rice income and extension access from cooperatives. These were factors that were found to have a significant probability of influence on farmers' decision for adaptation strategies.

Sensitively, the government of Rwanda needs to formulate enabling policies that allow access to facilities such as fertilizers and pest controls. There should be adequate infrastructural development that pursue the reduction of input costs by Bugarama rice farmers and also provides informational services through cooperative agents. The government should also provide subsidies to farm inputs like fertilizers. Finally, our study in Bugarama wetland may be suitable for other areas in Rwanda and other parts of the world which are vulnerable to climate change effects.

RECOMMENDATION AND POLICY IMPLICATION

Rwanda Ministry of Agriculture needs to come up with participatory programs that take care of the farmers' access to information facilities on new adaptive technologies in order to develop a practical farmer-centered intervention strategy with the aim of positive perceptions towards rice farming in the country.

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