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Determinant Factors of Rice Farmers' Selection of Adaptation Methods to Climate Change in Eastern Rwanda*

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동부 르완다 쌀 농업인의 기후변화에 대한 적응 방법 결정 요인

부테라 토니 · 김태균 · 최세현

The negative impact of climate change on the agricultural sector is rapidly increasing, and it is urgent to prepare policies at the government level to mitigate it. In the case of Rwanda's agricultural sector, which lacks the government's budget and farmers' capital, efficient and effective policy implementation is of paramount importance. To this end, rather than establishing related policies in the public sector from the top down, it is necessary to establish a bottom-up customized policy that is reflected in policy establishment by identifying the characteristics and behaviors of farmers who actually participate in adaptation activities. In this study, the effects of farmers' characteristics and farmers' perception status/adaptation status to climate change on the selection of adaptation methods for climate change were analyzed. 357 rice farmers randomly selected from Eastern Rwanda were surveyed to explore the information related to farmers' perception to climate change and adaptation methods as well as basic information of the farm. Research shows that the probability of selecting a variety of adaptation methods rather than not responding to climate change increases the younger the age, the higher the education level, and the easier access to climate information and credit. As a policy proposals, it is judged that public support such as strengthening agricultural technology support services, including more detailed guidance for elderly and

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low-educated farmers, and improving access to farm loan services by agricultural financial institutions is needed. In addition, it is necessary to adjust the planting time and cultivation method, provide timely information related to climate change, and provide crop variety improvement services to farmers.

Key words : *adaptation methods, climate change, eastern Rwanda, multinomial logit model, rice farmer*

Ⅰ. Introduction

Climate change refers to long-term changes in the Earth's climate and average daily weather patterns over long periods of time that occur as a result of natural unpredictability or human activities. And this climate change is already affecting many natural structures around the world (Easterling et al., 2000).

Efforts to cope with such climate change can be divided into an active method of mitigation that reduces carbon emission and a passive method of adapting to a given climate change. Mitigation deals with the root causes, while adaptation focus on lowering the risks caused by the consequences of climate change. Developed countries with good technology and abundant capital to reduce carbon emissions often adopt mitigation policies, whereas in developing countries with poor skills and capital, adaptation methods are often the only viable option.

Compared to other sectors, agriculture is very vulnerable to climate change, and various studies have shown that climate change, if there is no adaptation methods, continues to challenge agricultural economy and production (Lobell et al., 2008). Current research shows that Africa is at risk from the impacts of climate change due to various stresses and low adaptive capacity due to endemic diseases, fragile institutions, complex disasters and related conflicts. In many parts of Africa, rain-dependent agriculture is still considered a major source of food and income, and the effects of climate change are increasingly frequent and severe, exacerbating food production within the region (Kurukulasuriya et al., 2006).

Rwanda, located in East Africa, has faced rare asymmetries in climate change over the past 30 years, including extremes in temperature, variability and intensity in rainfall frequency. Rwanda is a country most vulnerable to climate change despite its low-carbon economy. Existing efforts to make the agricultural policy in Rwanda more 'climate smart' Rwanda commenced an ambitious, large-scale agricultural reform in 2007. However, a review of the key policy documents of relevance for the agricultural sector including the agricultural policy and Vision 2020, the overarching government policy framework reveal that most of them are unsighted

effects of climate change. The agricultural policy is structured around commercialization, regional crop specialization, and intensive cultivation techniques, none of which are very well-disposed to climate change adaptation. So, for an agrarian country like Rwanda, adaptation methods, if properly and consistently formulated and implemented, will help improve food security and the national economy.

The objective of this study is to analyze the factors that influence the selection of farmers' adaptation methods to climate change and to identify the barriers they face in adopting adaptation methods. In the case of Rwanda, where finances are poor, it is important to discover and implement more efficient and effective policies. To this end, a bottom-up policy that reflects the opinions of farmers, the policy beneficiaries, is required rather than establishing and uniformly implementing the central government's unilateral top-down policy. This bottom-up policy is a policy that takes into account farmers' preferences for various adaptation methods to climate change, adaptation methods currently in use, and barriers related to adaptation methods.

Previous studies related to this study can be divided into studies related to the effects of climate change on agriculture and studies related to farmers' adaptation to climate change. The former includes a study by Moriondo et al. (2011) that evaluated the impact of climate change through crop yield simulation and a study by Ojija et al. (2017) on the impact of climate change on agriculture in Tanzania. The latter includes a study by Reidsma et al. (2010) on the importance of a farm-level response in the adaptation of European agriculture to climate change, and Enete et al. (2015) on the choice of climate change adaptation methods for Nigerian food crop farmers. There is also a study by Weli et al. (2017) on the adaptation of root crop farming system to climate change in Ikwerre Local Government Area of Rivers State in Nigeria.

This study is meaningful in that it analyzed factors affecting the selection of climate change adaptation methods at the rice farm level. In particular, it can be said that there are few studies that empirically analyze how to adapt to climate change by conducting a survey targeting farmers in developing countries such as Rwanda.

The order of writing this paper is as follows. Following the introduction of Chapter 1, Chapter 2 explains the empirical analysis model and data. Chapter 3 presents the results of survey and model estimation. Finally, Chapter 4 is the conclusion part, which includes a summary of the study, policy proposals, and limitations of the study.

Ⅱ. Model and Data

1. Model

McFadden's (1974) multinomial logit model was used to analyze the relationship between farmers' adaptation methods to cope with climate change and the characteristics of farmers influencing the select of adaptation methods. The reason for using this model is that the dependent variables of the model are the five adaptation methods that farmers are implementing in response to climate change. These adaptation methods consist of no adaptation, adjustment of planting dates and cultivation methods, use of improved varieties, changing level of inputs, and investments in irrigation.

This model is based on the random utility model and is based on the indirect utility function. The indirect utility function obtained by farmer i from alternative j of the joint selection set S_i can be expressed as

$$U_{ij} = V_{ij}(Z_{ij}) + e_{ij} \tag{1}$$

where V_{ij} is the observable deterministic part and e_{ij} is the unobservable probabilistic part. V_{ij} is a function of the characteristics (Z_{ij}) of the individual farmers. Farmer i selects alternative j if $U_{ij} > U_{ik}(\forall k \neq j)$ is satisfied for all but the jth alternative in the joint selection set S_i. In this case, the probability that farmer i selects alternative j is given by

$$\begin{aligned} P_i(j|S_i) &= \Pr[V_{ij} + e_{ij} > V_{ik} + e_{ik}] \\ &= \Pr[V_{ij} - V_{ik} > e_{ik} - e_{ij}] \text{ for } \forall k \neq j \end{aligned} \tag{2}$$

It is assumed that the error terms in equation (2) are independent and follow the same distribution of type I extreme values (McFadden, 1974). In this case, the probability that farmer i selects alternative j can be expressed as in equation (3).

$$P_i(j|S_i) = \frac{\exp(\mu V_{ij})}{\sum_{k \in S_i} \exp(\mu V_{ik})} \tag{3}$$

Here, μ cannot be separately estimated by a scale parameter that has an inverse relationship

with the variance of the error term, and is generally assumed to be equal to 1, which means a constant error variance. Then the parameters of equation (3) are estimated using the maximum likelihood process that maximizes the log-likelihood function.

2. Data

The data used in this study were targeted at 357 farmers who are currently affiliated with a cooperative and are engaged in rice farming. The cooperatives to which they belong are located in Nyagatare, Gatsibo and Bugesera in three of the seven districts of the Eastern Province. The Eastern Province is one among five provinces of Rwanda.

Rice farmers were selected because rice is among the major and priority food crops in Rwanda and so very important crop for that matter, which has been affected by climate change. (Wassmann et al., 2009). The Eastern Province of Rwanda borders Tanzania, Uganda and Burundi with a total area of 9,813 km^2, a population of 2,600,812 people, and a population density of 275 km^2. The province is Rwanda's largest rice producer, accounting for 40% of the country's production. Rice farmers in all paddy wetlands are incorporated into cooperatives according to the size of the wetlands in the eastern provinces. Rice is grown mainly by poor small scale farmers who grow the crop through farmer cooperative schemes set up by the government. About 62,000 farmers operating under 55 cooperatives cultivate on 12,000 ha, with an average of 2 ha per household. Farmer cooperatives not only provide farmers with easy access to inputs and markets, but also serve as an institutional framework for governments and development partners to support farmers to increase productivity.

The survey was conducted through individual face-to-face interviews using a well-prepared questionnaire for a month in February 2020. The questionnaire includes information on the demographic and farm characteristics of respondents and adaptation to climate change. Climate change-related information includes farmers' perceptions, experiences and concerns about climate change, how to adapt to climate change, barriers to adaptation, agricultural extension services and access to water resources.

Ⅲ. Results

1. Key Results of the Survey

1) Basic Information of the Respondents

Table 1 presents the basic information of responding farmers. The proportion of men was 70% and the proportion of women was 30%. In Rwanda, the roles of women and men in agriculture are not divided. However, climate change will have a greater impact on women, especially during periods of extreme drought and floods, because it is difficult for women to heavy duties. As a result, farms with women head are vulnerable to flooding and drought under these irregular conditions. Previous research has shown that in most rural households, women have fewer educational opportunities than men, which may limit their ability to understand and follow the adaptation methods implemented.

By age of respondents, under 30 years old (7.6%), 31~40 years old (28.3%), 41~50 years old (30.0%), 51~60 years old (22.1%), 61 or older (12.1%) was surveyed. In general, younger farm households in their 30s and 40s have higher labor force and educational background than older farm households, and are advantageous in terms of access to climate information and extension services. In addition, in terms of securing credit, it is judged that the climate change adaptation methods can be implemented more easily, as it has advantages over older farmers.

As for the number of household members farming, single or two-person households accounted for the most at 85.1%. 3 persons were surveyed as 10.0%, and 4 persons or more were 4.3%. As for the level of education, primary education accounted for the most at 67.2%, followed by secondary and higher education at 19.6% and illiteracy at 13.2%. In terms of land size, less than 4 hectares (52.7%), 5~9 hectares (37.2%), and more than 10 hectares (10.1%) were surveyed.

Table 1. Basic information of the respondents

Independent variable	Description	Frequency	Percentage (%)
Gender	Female	107	30.0
	Male	250	70.0
Age	Under 30	27	7.6
	31~40	101	28.3
	41~50	107	30.0
	51~60	79	22.1
	Over 61 Years	43	12.1

Independent variable	Description	Frequency	Percentage (%)
Number of household members farming	1	160	44.8
	2	144	40.3
	3	38	10.6
	More than 4	15	4.3
Land size (ha)	1~4	188	52.7
	5~9	133	37.2
	More than 10	36	10.1
Education level	Illiteracy	47	13.2
	Primary	240	67.2
	Secondary	68	19.0
	University graduate	2	0.6
Total		357	100

2) Information Related to Climate Change Adaptation

Table 2 shows information related to climate change adaptation by farmers. While 74.5% of the total respondents were aware of the temperature change, 25.5% said they did not. Similar results were observed for precipitation.

For use of irrigation and extension services, 63.9% of respondents reported that they had access to irrigation facilities. However, this does not mean that there is enough water on the farm. 36.1% did not have access to an irrigation system, so their agriculture relies on rain-dependent irrigation. 30.8% of respondents said they had never received agricultural extension services, and 69.2% said they had received services.

Table 2. Information related to climate change adaptation

Independent variable	Description	Frequency	Percentage (%)
Perception on temperature	Not perceived	91	25.5
	Perceived	266	74.5
Perception on precipitation	Not perceived	93	26.1
	Perceived	264	73.9
Access to irrigation	Never accessed	129	36.1
	Accessed	228	63.9

Independent variable	Description	Frequency	Percentage (%)
Access to extension services	Never accessed	110	30.8
	Accessed	247	69.2
Availability of credit	Unavailable	149	41.7
	Available	208	58.3
Source of information on climate	Local authorities	299	83.8
	Others	58	16.2
Adaptation methods	Planting dates/Cultivation methods	145	40.6
	Improved crop varieties	131	36.7
	Changing level of inputs	49	13.7
	Investment in irrigation	10	2.8
	No adaptation	22	6.2
Barriers to adaptation	Lack of credit	143	40.0
	Lack of info. on adaptation methods	127	35.6
	Shortage of farm laborers	73	20.4
	Shortage of farmland	7	2.0
	Shortage of farm inputs	7	2.0
Total		357	100

When it comes to access to credit, 41.7% of respondents do not have the credit they need to invest in one of farmers' adaptation methods such as improving agriculture and production. For information on climate, 83.8% of respondents said they were getting climate change information from local authorities, and 16.2% were getting information from other sources such as public media or private company.

In the case of adaptation practices perceived as most important by farmers, adjustment of planting dates/cultivation methods (40.6%), utilization of improved crop varieties (36.7%), changing levels of inputs (13.7%), and investment in irrigation (2.8%) appeared in order. Investing in irrigation is one of the most important adaptation methods, but very few farmers in the survey selected irrigation because they believe that investment in irrigation is the responsibility of local governments. It was found that 6.2% of farmers did not practice any adaptations at all.

When it comes to barriers of selecting an adaptation methods for climate change, lack of credit and/or capital was ranked as the most important barrier at 40.0%. Access to timely

weather information was second with 35.6%, and labor shortage was third with 20.4%. Lack of agricultural land or farm inputs was not considered as a major barrier.

2. Estimation Results of the Multinomial Logit Model

Table 3 shows the estimation results of the multinomial logit model. As a result of the likelihood ratio test, the model of this study showed good explanatory power. In this study, the estimation result was interpreted using only the sign of the estimated value without obtaining a specific probability value. The reason is that when each independent variable influences the selection of an adaptation methods for climate change, it is important to know whether the probability of being selected compared to the reference method (no adaptation) is high or low. On the other hand, knowing exactly what percentage is higher or lower is less important.

The statistical significance of the estimates can be judged by the P-value. For all dependent variables, age, climate information and access to credit were estimated to be significant at the statistical significance level of 5%. The number of household members farming and the level of education were all significant at 10% except for the dependent variables of investment in irrigation. Perception to temperature was significant at 10% only in the dependent variables of adjustment of planting dates and cultivation method. In the case of land size, there was no consistency in coefficient sign and significance level.

Also to keep in mind, that if the estimated coefficient is positive (negative), the interpretation is as follows. When the independent variable increases, other things being constant, the probability of selecting the dependent variable becomes higher (lower) than the probability of selecting the reference variable, which is no adaptation.

It was illustrated that age affected climate change adaptation selection. Young farmers were seen to select adaptation methods more readily than older farmers since their education level is higher and have better access to climate information, access to extension services and are also eligible to secure credit. As expected, it was estimated that farmers with better information on climate change from local agencies used more diverse adaptation methods than those who did not. Number of household members farming was negatively significant to adapting to changing levels of inputs and a climate adaptation method. It is speculated that the smaller the farmhouse's workforce, the greater the need to choose various adaptation methods as an alternative to increasing productivity.

Perception to temperature was a significant factor that affected climate adaptation selection. Household with perceiving change of temperature were ready to select adaptation methods,

especially adjusting the planting dates and cultivation methods. The changes in temperature will affect production and productivity hence increase in the probability of selecting adaptation options. Availability of credit was positively significant to the selection of the adaptation methods. Availing loans and credit schemes to farmers is key and will help them to adapt to climate change adaptation more readily. Farmers who have access to credit are more likely to adopt the climate change adaptation measures than select no adaptation. Variables such as gender, perception of precipitation, access to irrigation water and access to extension services were estimated to have low statistical significance.

Table 3. Estimation results of the multinomial logit model

	Adjustment of planting dates and cultivation method		Use of improved crop varieties		Investing in Irrigation		Changing levels of inputs	
	Coef.	P-value	Coef.	P-value	Coef.	P-value	Coef.	P-value
Age	-.072	.001**	.086	.009**	-1.586	.008**	-.181	.003**
Gender+	-.362	.508	-.415	.442	-1.416	.239	-.039	.947
No. of household members farming	-.447	.067*	-.465	.056*	.687	.465	-.734	.019**
Land size	-.007	.001**	-.004	.524	.011	.003**	-.003	.714
Education level	.807	.117	.870	.086*	.829	.351	.983	.080*
Perception to temperature+	1.302	.002**	.323	.545	1.073	.282	.735	.221
Perception to precipitation+	.986	.162	1.041	.133	1.279	.199	1.047	.160
Access to irrigation water+	-.124	.818	-.050	.926	-.936	.968	-.131	.825
Access to extension services+	.455	.416	-.435	.431	-1.401	.125	-.273	.657
Climate information+	.359	.001**	-.618	.003**	1.426	.003**	.888	.003**
Availability of credit+	2.555	.001**	1.778	.024**	3.060	.004**	1.390	.010**
N	357							
Base category	No adaptation							
Log-likelihood	-774.267							
LR χ^2	120.435							

Notes: 1. * and ** mean 10%, 5% significant levels, respectively.
2. + are dummy variables.

Ⅳ. Conclusion

Studies have shown that global average temperature has risen 0.74℃ over the past century, and climate change model projections in Rwanda indicate that the trend of rising temperatures and decreasing precipitation will continue. This means that stakeholders in agriculture must rapidly implement appropriate and applicable adaptation practices to mitigate the imminent impacts of climate change.

In order to establish and implement adaptation policies to respond to climate change, it is important to first understand the risks associated with climate change and various climate change response methods. In particular, in the case of Rwanda's agricultural sector, which lacks the government's budget and farmers' capital, efficient and effective policy implementation is of paramount importance. To this end, rather than establishing related policies in the public sector from the top down, it is necessary to establish a bottom-up customized policy that is reflected in policy establishment by identifying the preferences of farmers who actually participate in adaptation activities. These well-tailored methods allow rice farmers to better adapt to climate change while improving productivity.

In this study, the effects of farmers' characteristics and farmers' perception/adaptation status to climate change on the selection of adaptation methods for climate change were analyzed. Results show that the probability of selecting a variety of response methods rather than no responding to climate change increases with age, and with enhanced access to climate information and credit. In general, older farmers are more passive in adapting response methods, so publicity to engage older farmers should be strengthened. Additionally, access to flexible lending and credit facilities and lower farm input costs will improve farmers' ability to adapt to climate change.

It was found that the higher the education level, the higher the probability of adapting various response methods. It can be said that the improvement of education level is an area that requires investment in the long term. However, it is necessary to help farmers with low education levels understand the adaptation methods more easily by improving the guidance method.

Prioritizing access to timely weather information will be a key factor in helping farmers select adaptation options. In order to collect and disseminate accurate weather information in a timely manner, training of agricultural workers and Rwanda Meteorological Agency is necessary. Development of improved crop varieties are essential as a method to respond to climate change. Of course, this should be done mainly by the public sector within the budget allowed.

As mentioned earlier, farmers did not respond that this is an adaptation method they are implementing, given that investment in irrigation is the responsibility of local governments.

However, since proper management and maintenance of existing irrigation facilities is a very important adaptation method to cope with climate change, continuous investment at the government level is required. Development of improved crop varieties are essential as a method to respond to climate change. Extension services for the dissemination of developed varieties should also be conducted mainly under the management of the public sector.

This study is meaningful in that it made policy proposals for the future government policy formation by analyzing the factors affecting rice farmers' selection of adaptation methods to climate change. In particular, it can be said that there are few studies that empirically analyze how to adapt to climate change by conducting a survey targeting farmers in developing countries such as Rwanda in Africa. However, due to time and budget constraints, this study was conducted only in 3 districts of the Eastern Province, which is one of the five provinces in Rwanda. Further research targeting a wider area is left as a future task.

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