Adaptation to climate change by rice farmers in central and northern Benin

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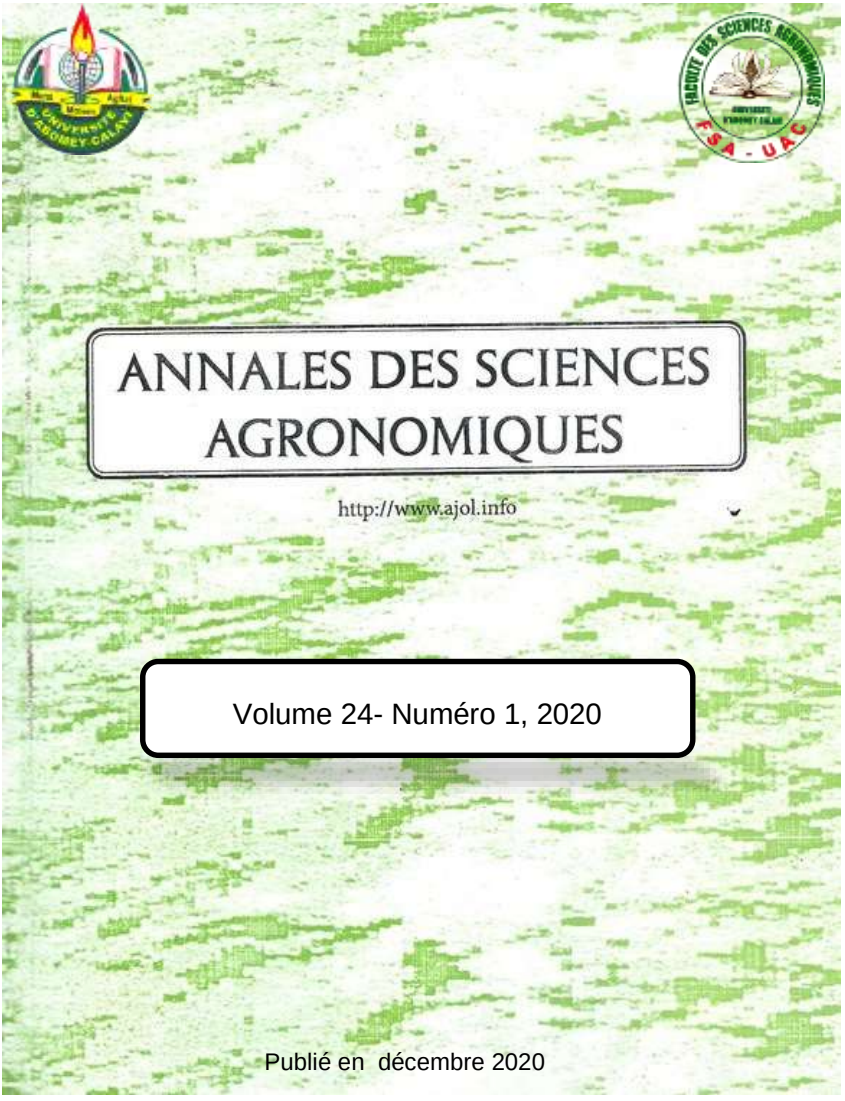
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ADAPTATION TO CLIMATE CHANGE BY RICE FARMERS IN CENTRAL AND NORTHERN BENIN

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ABSTRACT

This research investigated rice farmers' adaptation strategies to climate change in two rice production zones in Benin, Malanville in the extreme North zone and Glazoué in the Centre zone of the country, basing on a gender analysis and a multinomial logit regression model. A total of 294 rice farmers, including 144 in Glazoué and 150 in Malanville, have been sampled and interviewed. The findings showed that men were more prone to adopt a single adaptation strategy whereas women were keen on adopting double adaptation strategy. These strategies included irrigation, crop diversification, dyke construction, variety diversification, early planting and late planting. The main barriers were financial and information barriers and the low irrigation potential. Livestock ownership, receiving extension services, credit access, access to climate information and soil fertility degradation positively affected the likelihood of farmers' adaptation to climate change. Supportive policy measures should consider strengthening farmers with rice irrigation facilities, rice varieties resistant to water and heat stresses, digitizing climate information through local social networks, rural credit services, and in particular taking into account gender differences.

Keywords : gender, adaptation, climate change, rice farmers, Benin.

ADAPTATION AU CHANGEMENT CLIMATIQUE PAR LES RIZICULTEURS DU CENTRE ET DU NORD DU BÉNIN

RÉSUMÉ

Cette recherche a examiné les stratégies d'adaptation des riziculteurs au changement climatique dans deux zones de production, Malanville dans l'extrême zone du nord et Glazoué dans la zone centre du Bénin en se basant sur une analyse de genre et un modèle de régression logit multinomial. Un total de 294 producteurs de riz, dont 144 à Glazoué et 150 à Malanville ont été sélectionnés et interviewés. Les résultats ont montré que les hommes étaient plus enclins à adopter une stratégie unique alors que les femmes étaient plus enclines à adopter deux stratégies combinées. Ces stratégies sont l'irrigation, la diversification des cultures, la construction de digues, la diversification des variétés, la plantation précoce et la plantation tardive. Les principaux obstacles étaient les insuffisances d'information et de moyens financiers et le faible potentiel d'irrigation. La possession du bétail, l'accès aux services de vulgarisation, l'accès au crédit, l'accès aux informations climatiques et la dégradation de la fertilité des sols ont eu une incidence positive sur la probabilité d'adaptation des agriculteurs au changement climatique. Les mesures de politiques de soutien devraient envisager le renforcement des producteurs en installations d'irrigation, en variétés de riz résistantes aux stress hydriques et thermiques, la numérisation des informations climatiques via les réseaux sociaux locaux, les services de crédit rural, et en particulier tenir compte des différences de genre.

Mots clés : genre, adaptation, changement climatique, riziculteurs, Bénin.

INTRODUCTION

Since the 1970s in West Africa, there has been an increase in the average temperature and increasing variability in precipitation (IPCC, 2013 ; Sylla *et al.*, 2016). In a special issue, Speranza & Scholz (2013) argue that adapting to

climate change is a challenge for Africa due to living conditions, widespread poverty, food insecurity and varying adaptive capacities. Moreover, climate change and variability will affect water availability (Speranza & Scholz, 2013). In Benin, for more than 50 years, the agricultural sector has suffered from the harmful effects of climate change, which are manifested by a change in temperature and precipitation (Agbossou *et al.*, 2012 ; Yabi & Afouda, 2012). Between 1960 and 2008, Gnanglè *et al.* (2011) noted in Benin a significant increase of more than 1°C in the average temperature, an average decrease of 5.5 mm / year in precipitation and a decrease in the average number of rainy days. Under these conditions, knowledge of climate change and adaptation practices would make it possible to better target the improvement of adaptation practices and support for adaptation.

Economic theories suggest that adaptation is efficient if its benefits exceed its costs (Mendelsohn, 2012). He emphasized that adaptation depends on the current local climate and its evolution. Adaptation is seen as a change in behaviour or practices that the farmer makes to reduce the damage or to increase the gains of climate change. Previous studies on adaptation to climate change in Benin have focused on yield losses of maize, cotton, yam, cowpea, Barbara groundnut, pineapple and cashew due to climate change (Agbossou *et al.*, 2012 ; Arodokoun *et al.*, 2012 ; Bello *et al.*, 2017 ; Yegbemey *et al.*, 2017). There is therefore a lack of knowledge on the adaptation strategies of rice farmers in a context of climate change to be able to develop the appropriate policy measures.

Rice ranks second for its contribution to total agricultural growth and is one of the main food crops identified for economic growth in West Africa (CORAF/WECARD, 2011). In Benin, rice occupies a strategic place because of its growing importance in national consumption (MAEP, 2005). Rice has conquered its position in households and in collective catering, due to the ease and speed of its preparation and cooking (Adégbola & Sodjinou, 2003). In terms of production volume, rice has emerged as the third cereal crop (9%) following maize (77 %) and sorghum (11%) in Benin (MAEP, 2014). Rice can be grown on five of the country's seven agricultural development poles (Zannou *et al.*, 2018). The total quantity of rice consumed each year is increasing with an estimated annual consumption of 25 kg per capita (Gandonou *et al.*, 2010). The rice sector is a priority in terms of investment and development because not only of the need to meet food and nutritional security objectives and to improve the balance of payments, but also to enable the country to cope with the continuous increase in domestic demand for rice (Lawin, 2006). Despite the economic, food and social importance of rice production in Benin, it suffers as much as other crops from the effects of climate change. On the assumption that the demand for rice will increase with, among other things, galloping urbanization and population growth, the needs are far from being met despite the enormous rice-growing potentials available to Benin (Verlinden & Soulé, 2003).

Women are active in rice production in Benin. Both men and women are affected by the effects of climate change, but to varying degrees (OIT, 2008). It is increasingly recognized that women are more vulnerable than men, because they represent the majority of the world's poor and are more dependent on threatened natural resources. Moreover, women have less access than men to resources, such as land, credit, agricultural inputs, technology, training and extension services that would strengthen their capacities to adapt to climate change (Aguillar, 2008).

The question that can be asked is what are the characteristics of farmers that could affect the likelihood of adaptation and to what extent? Policies cannot be properly defined without a good knowledge of the adaptation strategies used by rice farmers and of the factors that determine these strategies. This research focused on the determinants of climate change adaptation strategies used in rice production areas, one of the flagship crops of Benin.

RESEARCH METHODOLOGY

This research was carried out in two agro-ecological rice production zones in Benin: Malanville in the extreme North zone and Glazoué in the Centre zone of the country (Figure 1). These agro-ecological zones are the most exposed to climate change. In each agro-ecological zone, villages were selected with the help of agents from the Communal Agricultural Development Sector according to their rice production capacities. The selected villages in Glazoué are Adourékoman, Attogbo, Gomè, Houala, Kpakpaza, Kpakpa-Zounmè, Ouèdèmè, Sokponta, Sowé and Yawa, and in Malanville are Malanville-center, Bodjécali, Garou-Tédji, Garou Xenon, Toumbouctou, Molla, and Madécali-Center. The choice of rice farmers within each village was made randomly from the list of rice farmers having at least forty years old. Indeed, the research relates the facts observed on the climatic normal and the adaptations of the last thirty years. The farmer age criterion is a predefined criterion to ensure that the perceptions of climate change are effectively those experienced by the respondents. To be able to do this exercise, the farmer should be at least forty years old. A total of 294 rice farmers including 144 in Glazoué and 150 in Malanville have been selected. Women represent 38% of this sample. The data collected using questionnaires focused on the socio-economic profiles, the characteristics of their farms, their perceptions and adaptations to climate change and the barriers to adaptation. The rice farmers surveyed were on average 48 years old (Table 1), with an average of 17 years of experience in rice production. About 77% of rice farmers have access to climate information. The farmer adopted either a single strategy or a double strategy. Farmers used a combination of two different strategies, what is called “double strategy”, and one strategy, what is called “single strategy” in this paper.

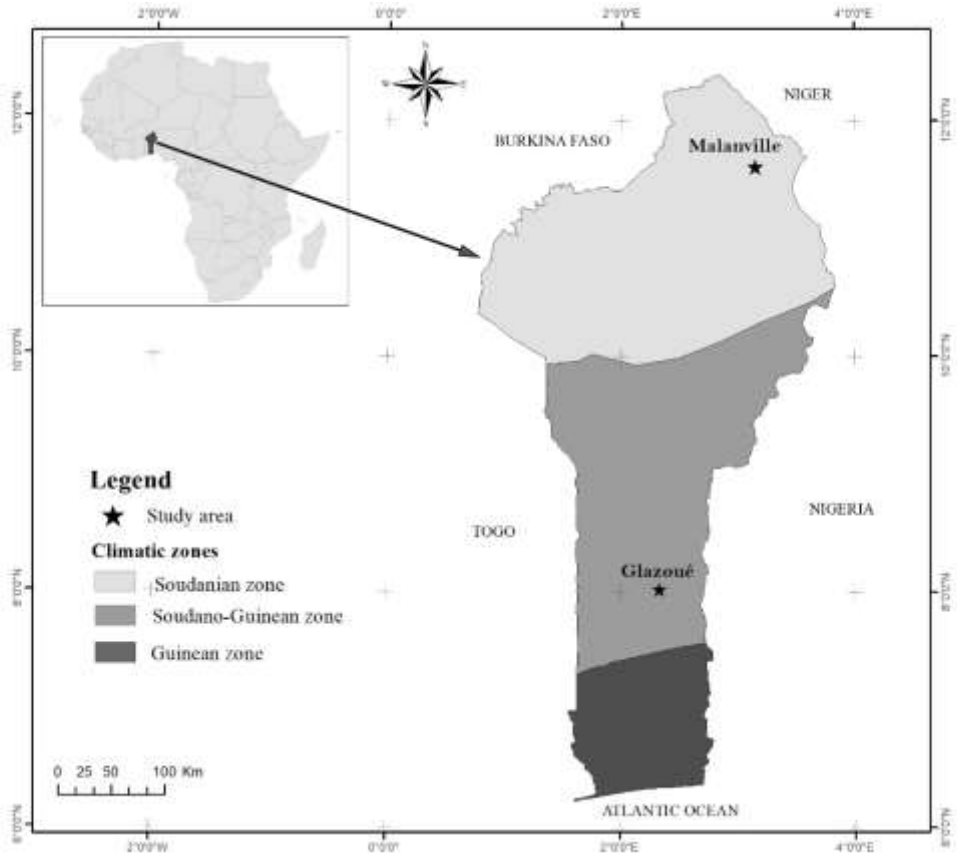

Figure 1. Location of surveyed regions

Table 1. Descriptive statistics of the variables in multinomial logit model

Variables	Definition	Mean	Std. Dev.	Signs
sex	Dummy, the sex of the farmer: 1 if man, 0 otherwise	0.62	0.49	+
hhsize	The size of the household	8.77	4.82	+
Age	Age of the rice farmer (in years)	48.25	8.41	+
livestock	Dummy, 1 if the farmer owns a livestock, 0 otherwise	0.49	0.50	+
credit	Dummy, 1 if the farmer gets access to credit, 0 otherwise.	0.64	0.48	+
infoclimat	Dummy, 1 if the farmer gets access to climate information, 0 otherwise	0.77	0.42	+
soilfertil	Soil fertility: 1=very fertile, 2=fertile; 3=Poor, 4=Degraded	1.73	0.74	+/-
nexp	Number of years of experience in rice cropping	16.92	7.07	+
memgroup	Dummy, 1 if the farmer is a member of farmer group, 0 otherwise.	0.80	0.40	+
consvulga	Dummy, 1 if the farmer is in contact with extension agent, 0 otherwise.	0.96	0.19	+
suptot	Total areas cropped (ha)	1.50	1.17	+

A gender difference analysis based on the chi-square test was performed to compare adaptation strategies adopted by men and women. Multinomial logistic regression was also performed to determine the factors that affect the likelihood of farmers' adaption to climate change.

As postulated by economic theories, the choice of an adaptation strategy will depend on the satisfaction or the utility that the farmer derives from this strategy or not. The farmer will choose the strategy that will give him the most satisfaction. Such an alternative will have the highest probability of being chosen. The multinomial logit model will be appropriate to estimate this probability. Let P_{ij} denotes the probability that a farmer i chooses the alternative j :

$$P_{ij} = \frac{\exp(\alpha_j + \beta_j X_i)}{\sum_{j=0}^{2} \exp(\alpha_j + \beta_j X_i)} \qquad (1)$$

The set of alternatives defined in this research is : j = 0 : no adaptation strategy, j = 1 : single adaptation strategy, and j = 2 : double adaptation strategy. The alternative j = 0 will be considered as the reference to which the other alternatives are compared. X_i is a vector of socioeconomic and environmental variables for the rice farmer i ; α_j is the constant for the alternative j ; β_j is a vector of the regression coefficients of the explanatory variables for the alternative j. Various hypothesized signs of the coefficients of the explanatory variables are shown in Table 1. The signs (+) and (-) represent respectively the hypothesized positive and negative effects of the explanatory variables on the dependent variable. The estimate was made using maximum likelihood. The Likelihood Ratio (LR) test is the test of the overall significance of the model. The LR test follows a chi-square distribution. For the reference alternative, $\alpha_0 = 0$ and $\beta_0 = 0$.

The respective probabilities for each alternative (0, 1 or 2) are :

$$P_{i0} = \frac{1}{1 + \exp(\alpha_1 + \beta_1 X_i) + \exp(\alpha_2 + \beta_2 X_i)} \qquad (2)$$

$$P_{i1} = \frac{\exp(\alpha_1 + \beta_1 X_i)}{1 + \exp(\alpha_1 + \beta_1 X_i) + \exp(\alpha_2 + \beta_2 X_i)} \quad (3)$$

$$P_{i2} = \frac{\exp(\alpha_2 + \beta_2 X_i)}{1 + \exp(\alpha_1 + \beta_1 X_i) + \exp(\alpha_2 + \beta_2 X_i)} \quad (4)$$

The marginal effect is the effect of a change in X, all else held constant, on the probability that a rice farmer chooses the alternative j=0, 1, or 2. It is the partial derivative of P_{ij} with respect to the kth explanatory variable (Greene 2003 ; Adkins & Hill, 2008).

$$\frac{\partial P_{ij}}{\partial X_{ik}} = P_{ij}\left[\beta_j - \Sigma_{j=1}^{2} \beta_j * P_{ij}\right] \quad (5)$$

Multicollinearity among the explanatory variables was checked using the Variance Inflation Factor (VIF) whose values ranged from 1.08 to 1.68 with an average of 1.30. Stata 13.0 was used to analyse the data.

RESULTS

Gender analysis of adaptation strategies

All rice farmers perceived a change in climatic parameters (precipitation, temperature and wind intensity) over the past 30 years. Overall, 65.64% of rice farmers used climate change adaptation strategies such as irrigation, crop diversification, construction of dykes, early planting and variety diversification. Among the rice farmers who developed adaptation strategies, some used a single strategy and others a double strategy (i.e. a combination of two strategies) (Table 2).

The overall significance test (Pearson χ^2 = 6.90 ; p = 0.032) was significant.

Moreover, the χ^2 test revealed that the proportion of men (36.61 %) adopting a single strategy was significantly higher than that of women (20.72 %), whereas the proportion of women adopting double strategy (44.14 %) was significantly higher than the proportion of men (29.51 %) (Table 2).

Table 2. Adaptation options to manage climate change risk

Adaptation options	Men		Women		Together		Pearson χ^2
	Freq.	%	Freq.	%	Freq.	%	
No adaptation	62	33.88	39	35.14	101	34.35	0.048
Single adaptation strategies	67	36.61	23	20.72	90	30.61	8.217***
Double adaptation strategies	54	29.51	49	44.14	103	35.03	6.503**
Total	183	100	111	100	294	100	

Significance level : ***: (1 %), **: (5 %), *: (10 %)

The most used adaptation strategies were irrigation (38.61 %), crop diversification (26.74 %), construction of dykes (13.86 %) and early planting (12.21 %). Overall, there is a significant difference between men and women in the extent to which strategies were adopted. The overall significance test for proportion is highly significant (Pearson χ^2= 48.82, p < 0.001). The comparative analysis between men and women for each strategy showed a clear difference for irrigation, crop diversification and dyke construction (Table 3).

Table 3. Diversity of adaptation strategies to climate change by gender

Main adaptation strategies	Men		Women		Together		Pearson χ^2
	Freq.	%	Freq.	%	Freq.	%	
Irrigation	95	53.76	22	17.46	117	38.61	29.70***
Crop diversification	31	17,51	50	39.68	81	26.74	27.34***
Construction of dykes	13	7.34	29	23.02	42	13.86	20.42***
Early planting	27	15.25	10	7.94	37	12.21	2.07
Variety diversification	9	5.08	11	8.73	20	6.60	2.72
Late planting	2	1.13	4	3.17	6	1.98	2.18
Total	177	100	126	100	303	100	

Significance level : ***: (1 %), **: (5 %), *: (10 %)

The main barriers to adaptation faced by rice farmers in production areas were the lack of financial means (88 %), the lack of information on adaptation strategies (48 %), and the low irrigation potential (11.88 %) (Figure 2).

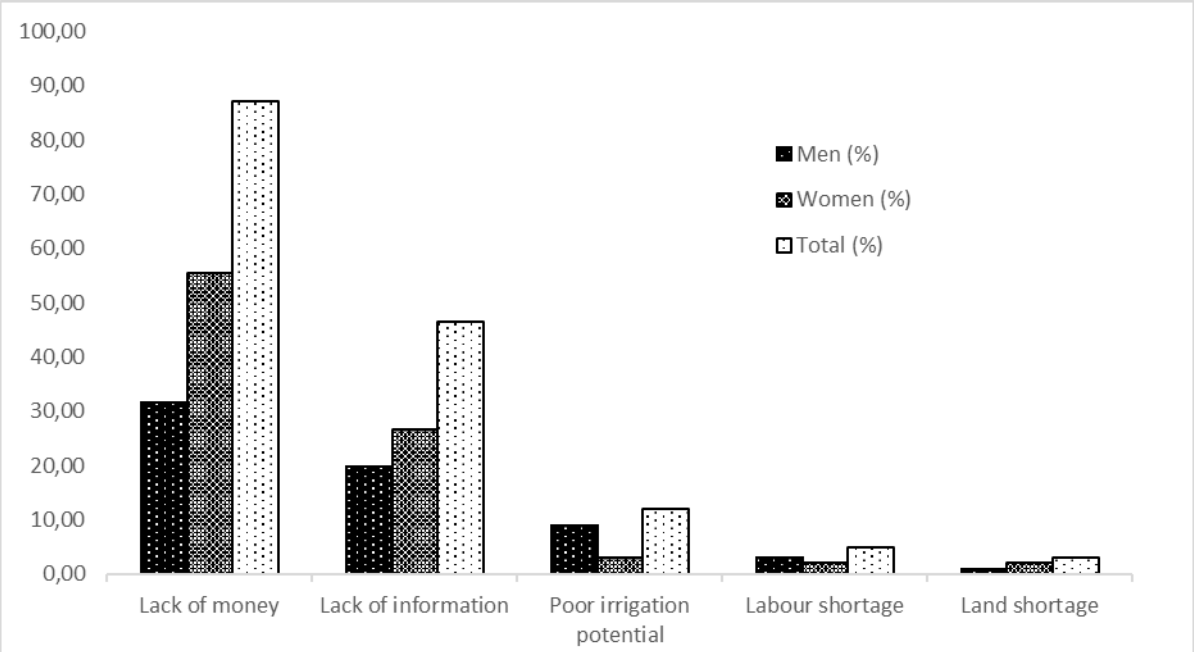

Figure 2. Barriers to adaptation to climate change

DETERMINANTS OF ADAPTATION STRATEGIES TO CLIMATE CHANGE

The LR test indicated that the multinomial logit regression model was highly significant (χ^2=137.46, $p < 0.0001$). The probability that a rice farmer chose a double strategy was higher than the probability that he chose a single strategy (Table 4). The results showed that access to credit, access to climate information, the number of years of experience in rice growing, the soil fertility level and livestock ownership positively and significantly influenced the probability of rice farmers' adaptation to climate change (Table 5). The same factors (except livestock ownership) appeared to be highly significant for both those who adopted a single strategy and those who adopted a double strategy. Belonging to a farmer group is only significant for farmers who adopted a double strategy.

Table 4. Description of the alternatives and related probabilities

Alternatives	Description of the strategies	Probability
j=0	No adaptation strategy	$P_{i0} = 0.301$
j=1	Single adaptation strategy - Irrigation - Crop diversification - Construction of dykes - Early planting - Variety diversification - Late planting	$P_{i1} = 0.273$
j=2	Double adaptation strategies - Crop diversification and dykes - Irrigation and early planting - Variety diversification and crop diversification - Variety diversification and dykes - Irrigation and crop diversification - Crop diversification and early planting - Variety diversification and irrigation - Late planting and crop diversification - Late planting and Irrigation	$P_{i2} = 0.426$

Table 5. Determinants of adaptation strategies to climate change

Variables	Single strategy		Double strategy	
	Coeff.	Std. Err.	Coeff.	Std. Err.
credit	2.179***	0.416	1.758***	0.346
nexper	0.085***	0.030	0.074***	0.028
nfertil	1.080***	0.314	0.604**	0.292
livestock	1.799***	0.466	0.254	0.424
infoclimat	0.963**	0.465	0.944**	0.423
hhsize	-0.010	0.045	0.014	0.043
age	-0.035	0.025	-0.006	0.021
memgroup	0.514	0.467	0.686*	0.424
consvulga	1.153	1.271	-0.725	0.847
suptot	0.200	0.190	0.223	0.174
constant	-6.448***	1.947	-3.940***	1.495
Base category	No adaptation			
Number of obs.	294			
LR chi-square	139.27***			
Log likelihood	-252.849			
Pseudo-R^2	0.216			

Significance level : *** : (1 %), **: (5 %), *: (10 %)

In terms of marginal effects, livestock ownership, access to credit, receiving extension services, and a unitary increase in the degree of soil fertility degradation positively affected the likelihood to choose a single strategy by 0.323, 0.218, 0.213 and 0.144 respectively. Access to credit and climate information had a respective positive effect of 0.199 and 0.129 on the likelihood of doubling the adaption strategy (Table 6).

Table 6. Marginal effects of adaptation strategies to climate change

Variables	Single strategy		Double strategy		No adaptation	
	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
credit	0.218***	0.054	0.199***	0.064	-0.417***	0.065
nexper	0.008*	0.005	0.008*	0.005	-0.017***	0.005
nfertil	0.144***	0.048	0.022	0.055	-0.166***	0.056
livestock	0.323***	0.070	-0.147**	0.080	-0.176**	0.076
infoclimat	0.087	0.068	0.129*	0.081	-0.215**	0.090
hhsize	-0.004	0.007	0.005	0.008	-0.0009	0.008
age	-0.006	0.004	0.003	0.004	0.004	0.004
memgroup	0.028	0.076	0.109	0.083	-0.138*	0.090
consvulga	0.213***	0.083	-0.272*	0.165	0.060	0.151
suptot	0.014	0.028	0.031	0.031	-0.045	0.035

DISCUSSION

This research aims to contribute to the understanding of the factors that favour the process of adaptation of rice farmers to climate change in the North and Center of Benin. It reveals that around 34.35% of rice farmers have not developed any adaptation options to climate change due to various barriers among which the lack of financial means and climate information. As revealed by Bryan *et al.* (2009), although a large number of farmers perceived changes in climate factors, they did not make any adjustments to their farming practices, due to barriers to adaptation. In Ghana, Antwi-Agyei *et al.* (2014) have highlighted the interactions between the barriers that hinder household adaptation to climate change. The lack of appropriate information on climate variability and changes and their impacts are related to the infrastructural and financial barriers which prevent the use of adequate meteorological equipment. There is a close relationship between institutional barriers and the lack of communication of climate information to farmers in an appropriate and timely manner due to poor coordination among organizations involved in adapting to climate change. There are interactions between financial barriers, infrastructural and sociocultural barriers.

The proportion of women adopting a double strategy (44.14 %) is significantly higher than the proportion of men (29.51 %). This result shows that women are more prone to diversify their adaptation strategy to climate change than men. The negative impact of livestock ownership and contact with extension services for those adopting double strategy could be explained by the fact that women are keen to adopt a double strategy and very often in African societies, women are not like men in contact with extension services and have not livestock like men. By analysing the gender issues of perceptions and knowledge related to climate change in Uganda, Kisauzi *et al.* (2012) found significant gender gaps in access to climate information and suggested that climate adaptation interventions should consider gender-based variations to ensure equitable adaptation to climate change.

In maize farming systems in Benin, crop diversification and adjustment of the crop calendar have been noted by Yegbemey *et al.* (2017) as the main strategies to fight climate change. In other regions of Africa (Ethiopia and

South Africa, Malawi, Mozambique, South Africa, Zambia and Zimbabwe), the options for adapting to climate change and variability are generally the same, but with varying magnitudes depending on the prevailing socioeconomic and environmental conditions (Bryan *et al.*, 2009; Vincent *et al.*, 2013).

This research shows that the socio-economic characteristics of rice farmers such as access to credit, number of years of experience in rice growing, livestock ownership, access to climate information and membership in a farmer organization are determining factors adaptation to climate change. In the same line, Chirambo (2016) found that microfinance institutions in Africa can be sustainable mechanisms for funding climate change initiatives while promoting rural development and financial inclusion.

Thornton & Herrero (2014) have listed the level of importance of a number of adaptation options, including changing crop varieties, changing crops, changing livestock breed, grazing management, efficiency use of water. These adaptation options have the most impact on food security, potential impact on resilience, the potential to promote diversification and the potential for risk managing.

CONCLUSION

This research reveals that rice farmers have perceived a change in climatic parameters over the past 30 years and shows gender differences among those who develop suitable strategies. The most commonly used adaptation strategies were irrigation, crop diversification, construction of dykes, early planting and variety diversification. Some farmers adopt a single strategy whereas others adopt a double one. The main barriers for those who have not adopted any strategy are financial and information barriers. Access to credit and climate information, extension services, livestock ownership, and the number of years of experience in rice growing positively affected the likelihood of adopting adaptation strategies.

Supportive policy measures should consider rice irrigation facilities, rural credit services, a climate risk information and warning system, in particular with regards to gender differences. Climate change policies should consider strengthening innovations in crop varieties that can support adaptation to erratic rainfalls and temperature stresses, and the digitization of climate information through local social networks.

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