

# **Determining Factors Influencing Farmers' Selection of Climate Change Adaptation Methods in Rural Gambia: Insights from West Africa.**

## **Abstract**

This study identifies different methods of adaptation used by farmers to adapt to climate change in the rural Gambia. The methods identified include use of agriculture technology, planting early and late varieties, practicing soil and water conservation, planting other crops varieties, fertilizer, and multiple crops under irrigation. Results from multinomial logistic regression as discrete choice model employed imply that household size, education of the respondents, gender, access to extension service, employment of household head category, access to credit has negative and insignificant impacts on adaptation options in the rural Gambia. The results further revealed that, total household income, drought as a proxy for climate change, and size of the farmland has positive and significant impacts on climate change adaptation options. Moreover, the analysis reveals that access to credit, migration response, drought, income and practicing livestock farming has positive relationship with no adaptation options.

**Keywords:** adaptation methods, rural Gambia, multinomial logistic, households' characteristics

## **Introduction**

The Determinants of Farmers' Choice of Adaptation Methods in West Africa: Evidence from the rural Gambia" aims to investigate the factors influencing farmers' decisions to adopt or not based on specific climate change adaptation methods in the rural Gambia, which is located in Western Africa. The research focuses on understanding the determinants that shape farmers' choices in adapting or not to the changing climate conditions in the region.

The study employs an econometric approach, specifically a multinomial logistic regression framework, to analyze the survey data and identify some of the factors influencing farmers' adaptation choices. The dependent variable in this model is the farmers' choice of specific adaptation methods, which could include practices such as multiple cropping, early and late planting, agriculture technology, irrigation, soil conservation, or others.

The independent variables used in the model are selected based on theoretical considerations and prior empirical research on climate change adaptation. These independent variables can include factors such as farm characteristics (e.g., farm size, access to credit, ownership status), socio-demographic variables (e.g., age, education level, employment, income, household size), access to

information and extension services, market conditions, and agro-ecological factors (e.g., rainfall patterns, variation in temperature).

The multinomial logistic regression model estimates the probabilities of farmers choosing different adaptation methods or not relative to a reference category or base category of non-adaptation, usually the non-adoption category. The model provides insights into the relative importance and significance of the independent variables in explaining farmers' choices of different adaptation methods e.g. income, gender. Did household with higher income enable to adapt to climate condition? Another example did male adapt more than female? Did drought cause them to adapt?

By analyzing the data and estimating the multinomial logistic regression model, the study aims to identify the key determinants that influence farmers' decisions to adopt specific adaptation methods. The results can inform policymakers, development practitioners, and researchers about the factors that shape farmers' adaptation choices and help design targeted interventions to promote effective and sustainable adaptation strategies in the rural Gambia and similar contexts in West Africa. Overall, the research contributes to the existing global literature on climate change adaptation by providing insights into the specific determinants of farmers' adaptation choices in the West African context, thereby enhancing our understanding of the factors influencing adaptation decision-making and facilitating evidence-based policy formulation and implementation.

**Research question:** What are the determining factors influencing farmers' selection of climate change adaptation methods in rural Gambia?

**Hypothesis:** Farmers' selection of climate change adaptation methods in rural Gambia is influenced by a combination of socio-economic factors, access to resources and information, perceived effectiveness of adaptation methods, and cultural norms and beliefs.

### **Brief review of Literature**

Adaptation to climate change in agriculture has been extensively studied, particularly in regions vulnerable to climate impacts like West Africa. Several studies have investigated the factors influencing farmers' decisions regarding adaptation methods. Here are some key themes and findings from the literature on climate change adaptation around the world.

Studies have found that variables such as age, education level, gender, household size, and farming experience influence farmers' adoption of climate change adaptation methods. , education and younger age tend to be positively associated with adoption.

Farm-related factors, including farm size, access to credit, land tenure, access to information, and previous exposure to climate shocks, play a significant role in farmers' decision-making. Larger farms and better access to resources tend to facilitate adaptation.

Farmers' perception of climate change risks and their understanding of adaptation strategies influence their adoption decisions. Studies have highlighted the importance of awareness programs and extension services in promoting adaptation.

Farmers' access to financial resources, technologies, inputs, markets, and infrastructure (such as irrigation facilities) affects their capacity to adopt and implement adaptation measures.

The influence of social networks and community organizations, as well as the role of government policies, support programs, and institutional arrangements, can shape farmers' decisions and their access to resources for adaptation.

## **Theoretic model**

### **Discrete choice models**

The use of discrete choice models<sup>1</sup> in climate change as adaptation strategies is recently being given full consideration (Deressa *et al.*, 2009, Hallegatte, 2009 and Masson *et al.*, 2014). Discrete choice model used Agricultural models on farmers' utility or profit maximizing behaviors of the farms (Norris and Batie 1987; Pryanishnikov and Katarina 2003, Berry, 1994, Ben-Akiva & Boccara, 1995 and McFadden & Train, 2000). The assumption here is new model of farming technology e.g. irrigation method is better than the traditional ways of farming and revenue derive from it increases economic wellbeing and livelihoods for the country and individual or households that adapt to climate change effects. The binary models such as Probit and logit models are the

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<sup>1</sup> Discrete models or outcome or qualitative response models or limited dependent variables are models for a dependent variable that indicates in which one of  $m$  mutually exclusive categories the outcome of interest falls. Usually, there is no natural ordering of the categories and the simplest case of binary outcomes, where there are two possible outcomes e.g. YES/NO or 1/0, Cameron and Trivedi 2005.

most commonly used empirical models for analysis of adaptation mechanism for agriculture. In this paper we shall employ two options agriculture and migration as a way of managing climate change migrants' or internal migration or external migration per se. Probit model is ... and logit model is Binary model either probit or logit models are employed when the number of discrete choices are two yes or no, food security or not, male or not, adopt or not, climate migrants or not, head of the households or not, vulnerable or not and so on (Hunter *et al.*, 2014, Maziya *et al.*, 2017 and Ngema *et al.*, 2018). The extensions of these models, most often referred to as multivariate models, are employed when the number of choices available are more than two. The most commonly mentioned multivariate choice models according to Deressa *et al.* (2008) in unordered choices are multinomial logit (MNL) and multinomial probit (MNP) models. These models have also been employed in climate changes adaptation research due to binary nature of adaptation. According to Nhemachena and Hassan (2007), multivariate probit model employed to analyse factors influencing the choice of climate change adaptation options in Southern Africa. They found out that access to credit, extension and awareness of climate change are some of the important determinants of farm-level adaptation in Southern Africa.

Kurukulasuriya *et al.* (2008), multinomial logit model employed to see if the choice of crop by farmers was climate sensitive and results confirmed that specialized crop cultivation especially mono-cropping per se is the agricultural practice most vulnerable to climate change in Africa and global warming especially in summer, poses the highest risk.

In Similar vein Seo and Mendelsohn (2006) and Seo *et al.* (2009), multinomial logit model was used to analyse how the choice of livestock species is climate sensitive. Additionally, Bryan *et al.* (2009), probit model was adopted to analyze the factors influencing the decision to adapt to climate change, using data from a survey of 1800 farm households in South Africa and Ethiopia.

### **Statistical Model**

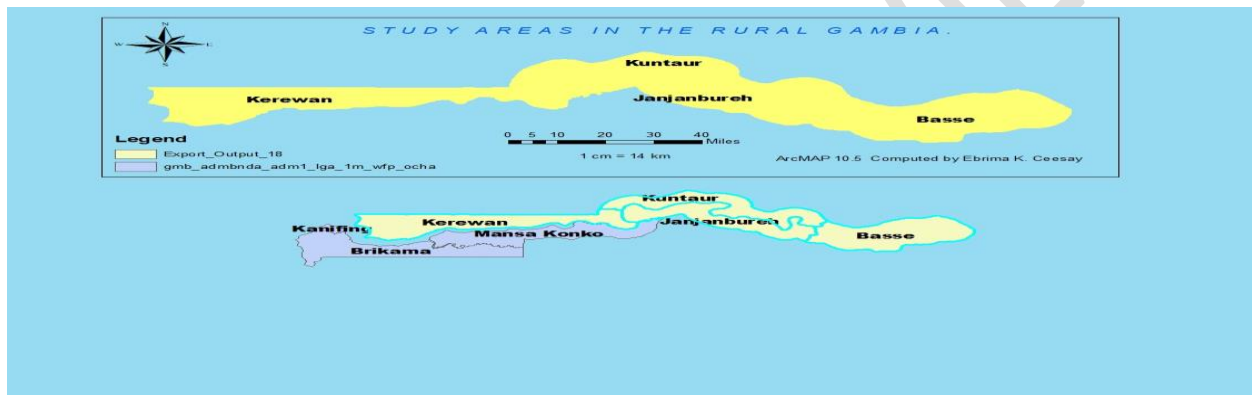
According to Schlenker and Lobell (2010) & Ceesay (2020), statistical models such as time series, cross-sectional or panel data study will be used to estimate the relationships between or among crop yields and climate changes variables such as temperature and precipitation. Statistical approaches can be time series e.g. VAR, OLS, ARDL, FDL, ARIMA, ECM, co-integration approaches  $-I(0)$ ,  $I(1)$  and so on and can be also panel data models such as fixed effect estimation,

random effect estimation, dynamic GMM, MLE etc. and it may also be panel VAR, panel Granger, and time series granger, panel impulse response function etc.

We take statistical approaches in this study due to the fact that they require less data than biophysical, simulation and social-economic modeling and we also applied Ricardian theory, because it was successful by studying adaptation response to climate change.

## Material and Method

**Fig 1. Study area**



## Analytical framework

The rural regions' consists of district, villages or settlement and that contain households and that households or individual decision to adaptation or not to adapt a new technology due to climate shocks and some other shocks happen in the households is considered under the framework of utility or profit maximization (Norris and Batie 1987;Pryanishnikov and Katarina 2003). It is always assumed that economic agents, including rain fed farmers or smallholder subsistence farmers, use different adaptation methods only when they perceived utility or income or net benefit from using such a method or adaptation option is significantly greater than with no adaptation method or other adaptation method. Although profit or utility is not directly observed but the actions of economic agents are observed through the choices they make(cite).

Suppose that  $Z_j$  and  $Z_k$  represent a household's utility for two choices, which are given by  $U_j$  and  $U_k$ , which are representing the utility for choice j and utility for choice k respectively. The linear random utility model could then be specified as follows:

$$\text{Eq1} \dots\dots\dots U_j = \beta'_j X_i + \epsilon_j \quad \text{and} \quad U_k = \beta'_k X_i + \epsilon_k$$

Where  $U_j$  and  $U_k$  are perceived utilities of adaptation methods j and k, respectively.  $x_i$  is the vector of explanatory variables that influence the perceived desirability of the different kind of adaptation practice,  $\beta_j$  and  $\beta_k$  are parameters to be estimated and  $\epsilon_j$  and  $\epsilon_k$  are the random utility error terms, which are assumed to be independent and identically distributed (Green, 2000).

In the case of climate change adaptation research, if the households decide to use options, it follows that the perceived utility or benefits or marginal benefits from choosing options j is greater than the utility of choosing options k i.e.  $j > k \forall j \neq k$  as given below;

$$\text{Eq2} \dots\dots\dots U_{ij} (\beta_j X_i + \epsilon_j) > ( U_{ik} (\beta_k X_i + \epsilon_k) ), \forall j \neq k$$

The probability that a household will use method j methods among the set of different climate change adaptation options could be depicted below.

$$\begin{aligned} P\left(Z = \frac{1}{X}\right) &= P(U_{ij} > U_{ik}) \\ P(\beta'_j X_i + \epsilon_j - \beta'_k X_i - \epsilon_k > 0/X) \\ P(\beta'_j X_i - \beta'_k X_i + \epsilon_j - \epsilon_k > 0/X) \\ P(X^* X_i + \epsilon^* > 0/X) &= F(\beta^* X_i) \dots\dots\dots \text{Eq3} \end{aligned}$$

Where P is the probability functions,  $U_{ij}$ ,  $U_{ik}$  and  $X_i$  are defined above,  $\epsilon_j - \epsilon_k$  is a random error terms as above,  $\beta_j^* = (\beta'_j - \beta'_k)$  is a vector of unknown parameters that can be interpreted as a net influence of the independent variables influencing adaptation,  $F(\beta^* X_i)$  is a cumulative distribution functions of  $\epsilon^*$  which is evaluated at  $\beta^* X_i$ . The exact distribution function of  $F$  depends on the distribution of the random disturbance term,  $\epsilon^*$ . Depending on the assumed

independent and identically distribution of which random disturbance term follows, several qualitative and categorical choice models can be estimated (Green 2000).

### Empirical Model

The multinomial logit (MNL) model is used to analyze categorical outcomes of the dependent variables. This method can be used to analyze different crop and livestock varieties as methods for climate change adaptation research to the negative impacts of climate change such as drought, flood, sea level rises. (Kurukulasuriya and Mendelsohn 2006b, Seo and Mendelsohn 2006). The main advantage of the MNL is that it allows the analysis of decisions across more than two categories and allowing the determination of choice probabilities for different categories (Madalla 1983; Wooldridge 2002). Furthermore, Koch (2007) emphasizes the practicality of this model by relating the ease of interpreting estimates from the MNL model.

To describe the multinomial logistic (MNL) model, let  $Z$  denote a random variable taking on the values  $\{1, 2, 3, 4, \dots, J\}$  for any  $J$ , a positive integer, and let  $\mathbf{x}$  denote a set of conditioning independent variables. In this case,  $Z$  denotes adaptation options or methods, or categories or choice and  $\mathbf{x}$  contains household characteristics such as size of the households, Age of the household's head, Gender, education status of the respondent, income levels, and so on. The question is how changes in the elements of  $\mathbf{x}$  affect the response probabilities  $Z$  i.e.  $P(Z = j / \mathbf{x})$ ,  $j = 1, 2, 3, 4, \dots, J$ . Since the probabilities must sum to one i.e.  $P'(x) + P(x) = 1$ . Then,  $P(Z = j / \mathbf{x})$  is determined once we know the probabilities for  $j = 2, 3, 4, 5, \dots, J$ .

Let  $\mathbf{x}$  be a  $1 \times K$  vector with first element as one. The multinomial MNL model has response probabilities model as follows;

$$P(Z = j / \mathbf{x}) = \frac{\exp(\beta_j \mathbf{x})}{1 + \sum_{h=1}^J \exp(\beta_h \mathbf{x})}, j = 1, 2, 3, \dots, J \quad \text{Eq 4}$$

where  $\beta$  is  $K \times 1$  matrix,  $j = 1, 2, 3, 4, \dots, J$ .

For this study, the model of adaptation options or response probabilities are:



availability. The explanatory variables considered in this study consist of climate variables, migrations variables and socioeconomic factors. Resource limitations coupled with household characteristics and poor infrastructure limit the ability of most farmers to take up adaptation measures in response to changes in climate (Kandlinkar & Risbey, 2000).

## Results and Discussions

### The determinants of farmers' actual adaptation decisions

Our motivation of choosing six categories of adaptation measures in figure and table as main strategic for adaptation research in the rural Gambia as imitated in core farming systems in Africa according to FAO (Food and Agriculture Organization) classification (Dixon et al., 2001) and as indicated in the empirical research in the following papers Maddison (2006) and Nhemachena and Hassan (2007). From below table 1, we can see that majority of the rural farmers do plant other crops varieties as a form of adaptation (about 42%). Thus, it is clear from table 1; that multiple cropping under irrigation is the second dominant system of adaptation in the rural Gambia (about 37.75%). From farmers perception, about 9.25% uses fertilizer as a form of adaptation strategies. Moreover, Soil and water conservation is the least common adaptation method in the rural Gambia (about 0.25%).

**Table 1: Actual adaptation measures used by farmers**

Variables	Percent
No Adaptation	5.75
Agriculture technology	3.50
Practicing water and soil conservation	0.25
Fertilizer	9.25
Early varieties	1.50
Plants other varieties	42.00
Multiple crops under irrigation	37.75
Number of respondents	400

Own evaluation using 2021 household survey data

The data for this study was generated from households surveyed in 2021. Table 2 below shows the descriptive statistics for the continuous variables used in this section. The household income per capital per month has the highest mean and it is also associated with the highest standard deviation. The mean age is 47 years for the respondents, whereas mean number of peoples in the households

in the rural Gambia according to the survey is approximately 21. Size of the farms measure in hectares has a mean of 42 hectares and standard deviation of 51.13. The maximum income is 489 approximately in dollars, after conversation from our local currency. The maximum age is 105 and the minimum age is 23.

**Table 2: Description of the continuous independent variables**

Explanatory variable	Obs	Mean	SD	Min	Max
Size of the households	382	20.78534	17.25967	2	212
Age of the household's head	383	47.20888	12.14262	23	105
Size of the farmland's hectares	338	42.19379	51.13349	0	500
Total household income in dollar	400	159.6041	83.69826	0	488.7586

### Own Evaluation

In the below table3 , most households have at least one migrant (about 69.79%). Due to adaptation research, the identification of climate change shocks indicated that majority of households in the rural Gambia (73.28%) are affected by drought in one way or the others. Majority of the respondents are male 66.76% and female 33.33% respectively. Most of the respondents does not have access to credit (about 90.40%), while majority of the respondent said they do not have access to agriculture extension service (90.56%).

**Table 3: Description of the dummy independent variables**

Explanatory variable	Frequency	Percent
Gender: 1/0	256	66.67
	128	33.33
education status: 1/0	300	77.32
	88	22.68
agriculture extension services: 1/0	37	9.44
	355	90.56
Employment status: 1/0	269	68.80
	122	31.20
access to credit: 1/0	38	9.60
	358	90.40
Migration response HH_G: 1/0	201	69.79
	87	30.21
Drought: 1/0	288	73.28

	105	26.72
Practicing livestock farming: 1/0	243	71.89
	95	28.11

**Own evaluation:0/1 is dummy variables 1 for male and 0 otherwise and so on.**

### Correlation analysis

The correlation matrix is used to determine the relationship between two variables (see Table 4 below). The Pearson correlation coefficient is used to represent this relationship which ranges from -1.00 to +1.00. The results of the test of correlation show the relationship between the size of the household and the size of the farmland in the rural Gambia is negative (a correlation coefficient of -0.0107). Thus, if the number of peoples in the household increase by 1 person, the farm size decreases by by 0.0107%. This may be attributed to inheritances from household's total farm size. In the African context, large family sizes are important determinants of larger income. This is evidences in the rural Gambia where households size increases with household income (correlation coefficient is 0.3067). Additionally, 1 new born added to family, rises income by 0.3067%. The result also indicated that the households that has more male are more likely to have large household size. As education rises, the likely of getting married early reduces and that in turn have negative effects of household size in the rural Gambia (correlation coefficient is -0.0293). Access to agriculture extension service and access to credit has positive correlation (correlation coefficients is 0.6720). Those that are male are more likely to migrate in rural Gambia, the study noted. Thus, that are employed are more likely to migrate than those that are educated. Those migrated were more likely to have higher income, the study found (correlation coefficient is 0.2453). See details in the table below.

**Table 4: Correlation analysis of continuous and dummy explanatory variables included in the analysis**

	size of~s	Sizeof~s	Total~ar	Gender	educat~e	Employ~a	Drought	access~t	agri~ces	Migrat~G
Size of the h~s	1.0000									
Size of the farm	-0.0107	1.0000								
Totalhous~ar	0.3067	0.1540	1.0000							
Gender	0.0620	0.1027	0.1181	1.0000						
educations~e	-0.0293	-0.0802	-0.0721	-0.2089	1.0000					
Employment~a	-0.0325	0.1550	0.0165	-0.0336	0.0193	1.0000				

Drought	-0.1658	0.0753	-0.3875	0.1331	0.0083	0.0440	1.0000			
accesstocr~t	-0.0432	0.0612	0.0289	-0.0221	-0.0744	-0.0415	0.0772	1.0000		
agricult~ces	-0.0716	0.1002	-0.0258	-0.0315	0.0351	0.0091	0.0701	0.6720	1.0000	
Migrationr~G	0.1104	0.1987	0.2453	0.1643	-0.0178	0.1010	-0.0025	-0.0295	-0.1217	1.0000

Own Evaluation

To test for the independent of the irrelevant alternative (IIA), we apply Hausman test and Small-Hsiao tests. For independent variables, we use likelihood ratios, and Wald test. For the multicollinearity test (see table 6 below), change in rainfall, heavier rainfall, flood and change in temperature were dropped. All these variables were dropped due multicollinearity test, in which the tolerance factor and inflation factor are greater than 5 and less than 0.20 respectively. They were insignificant as well. From dropped those variables, the multinomial logit was run and to test for IIA, the model was run and tested for the validity by using the above tests. Both tests failed to reject the null hypothesis of independence of the climate change adaptation options in the rural Gambia, suggesting that the multinomial logit (MNL) model is more appropriate for the analytical model for climate change adaptation practices of smallholder subsistence farmers. For Hausman tests of IIA assumption, the chi-square value ranged from 0.000-0.000. For Small-Hsiao tests of IIA assumption, Ho: Odds (Outcome-J vs Outcome-K) are independent of other alternatives (see the details explanation on the methodology). Due to few categories selected, could not estimate Small-Hsiao test. The likelihood ratio statistics (the Prob. Chi-square ranged from 0.354-0.000) and wald test statistics (Prob. Chi-square ranged from 0.169-0.000) as indicated by the probability of the chi-square are highly significant (P-value < 0.0000), signifying the model has a strong explanatory power.

**Table 5: Tested for The Validity of the Independence of The Irrelevant Alternatives (IIA) Assumptions**

Name of the test	Chi-square	Prob. Chi-square
Hausman	0.000-0.000	1.000-1.000
likelihood ratio	25.898-53.826	0.354-0.000
Wald	13.215-36.717	0.169-0.000

Own Evaluation

**Table 6: Variance inflation factor (VIF) test for multicollinearity among variables included in the analysis**

Variable	VIF	1/VIF
agricult~ces	1.92	0.521439
accesstocr~t	1.89	0.527848
Totalhous~ar	1.33	0.750536
Drought	1.27	0.789785
Migrationr~G	1.15	0.866294

Gender	1.13	0.887461
Sizeofthef~s	1.12	0.894240
educations~e	1.08	0.929497
Employment~a	1.04	0.960227
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Mean VIF	1.33	

. Source: Own Evaluation Using Survey data (2021)

## Model results and discussion

### The Determinants of Farmers' Choice of Adaptation Methods

The multinomial logit model (MNL) estimation for this study was undertaken by normalizing one category with highest number of observations as a started category, which is normally referred to as the “base category.” In this analysis, the last category i.e. (no adaptation) is the base outcome or base category or reference stage. As specified previous, the coefficient of the parameter estimates of the MNL model provide only the way of the consequence of the independent variables on the dependent (response) variable. One critical change is that the sign of the estimated model coefficients does not determine the direction of the association between an independent variable and the probability of choosing an exact categorical alternative (Bowen & Wiersema, 2004). As an alternative, to be able to draw valid conclusions about relationships, scholars must rely on other interpretational strategies such as marginal effect(dy/dx) and predicted probabilities. For instance, the marginal effects from the multinomial logit analytical method, which measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable (Nhemachena, C., and R. Hassan. 2007, and Hassan R. and Nhemachena, C., and. 2008), are reported and discussed below. In all cases the estimated coefficients and marginal effects should be compared with the base outcome or category i.e. no adaptation. Furthermore, the multinomial logit model has seven categories from “All adaptations”: no adaptation, agriculture technology, early varieties, plant other varieties, fertilizer, soil and water conservation, and multiple cropping under irrigation. We also have some household characteristic, climate change characteristics and farm level characteristics for adaptation research. We selected all these variables as they are key important method for adaptation research in Africa ((Asfaw and Admassie 2004, Kurukulasuriya and Mendelsohn 2006, Nhemachena, C., and R. Hassan. 2007, and Deressa 2007, ). Table7 presents multinomial logit model with the marginal effects, std. errors, z-statistics, and the levels of statistical significance i.e. the p-value and confidence interval.

**Table 7: Parameter estimates of the Marginal effects from the multinomial logit climate change adaptation model in the rural Gambia**

	dy/dx	Delta- method Std. Err.	z	P> z	[95% Conf. Interval]
Size of the households					
_predict					
AT	-.00033	.0008668	-0.38	0.703	-.0020288 .0013688
PSWC	-.0019153	.001509	-1.27	0.204	-.0048728 .0010423
EVLV	-1.70e-09	2.26e-06	-0.00	0.999	-4.42e-06 4.42e-06
F	-.0015966	.0012502	-1.28	0.202	-.0040469 .0008536
POCV	.0003957	.0009907	0.40	0.690	-.001546 .0023374
MCUI	.0060841	.0020886	2.91	0.004***	.0019905 .0101777
NA	-.0026379	.0024108	-1.09	0.274	-.007363 .0020872

Ageofthehouseholdshhead							
	_predict						
	AT	-.0000648	.0012849	-0.05	0.960	-.0025832	.0024536
	PSWC	.0010453	.0012405	0.84	0.399	-.001386	.0034767
	EVLV	2.37e-09	2.56e-06	0.00	0.999	-5.01e-06	5.01e-06
	F	.0003182	.0007409	0.43	0.668	-.001134	.0017704
	POCV	.0014384	.0014133	1.02	0.309	-.0013316	.0042084
	MCUI	-.0029283	.002588	-1.13	0.258	-.0080007	.0021442
	NA	.0001911	.0027156	0.07	0.944	-.0051315	.0055136
Gender							
	_predict						
	AT	-.0337412	.0351426	-0.96	0.337	-.1026194	.0351371
	PSWC	-.0523077	.033208	-1.58	0.115	-.1173942	.0127789
	EVLV	-2.15e-08	.0000396	-0.00	1.000	-.0000777	.0000777
	F	-.0156764	.0201362	-0.78	0.436	-.0551426	.0237898
	POCV	-.0199768	.037088	-0.54	0.590	-.092668	.0527144
	MCUI	-.1055128	.062153	-1.70	0.090*	-.2273305	.0163048
	NA	.2272149	.0651476	3.49	0.000***	.0995279	.3549019
Educationstatusoftheresponde							
	_predict						
	AT	-.045292	.0366886	-1.23	0.217	-.1172003	.0266164
	PSWC	-.0251232	.0337394	-0.74	0.456	-.0912512	.0410048
	EVLV	-1.35e-07	.0001266	-0.00	0.999	-.0002483	.000248
	F	-.010081	.0234713	-0.43	0.668	-.056084	.0359219
	POCV	-.0617106	.0349573	-1.77	0.078*	-.1302257	.0068044
	MCUI	-.0561857	.0646324	-0.87	0.385	-.1828628	.0704915
	NA	.1983926	.0684688	2.90	0.004***	.0641962	.332589
Sizeofthefarmlandshatres							
	_predict						
	AT	.0010241	.0003433	2.98	0.003***	.0003513	.0016969
	PSWC	-.0001131	.0003614	-0.31	0.754	-.0008215	.0005952
	EVLV	1.04e-09	1.04e-06	0.00	0.999	-2.03e-06	2.04e-06
	F	-.0005838	.0005515	-1.06	0.290	-.0016647	.0004971
	POCV	.0005461	.0003402	1.61	0.108	-.0001207	.0012129
	MCUI	.0000318	.0007024	0.05	0.964	-.0013449	.0014085
	NA	-.000905	.0007647	-1.18	0.237	-.0024038	.0005938
Agricultureextensionservices							
	_predict						
	AT	-.3865482	1132.442	-0.00	1.000	-2219.931	2219.158
	PSWC	-.6872981	1433.777	-0.00	1.000	-2810.84	2809.465
	EVLV	1.02e-08	.0000721	0.00	1.000	-.0001414	.0001414
	F	-.1583798	338.1009	-0.00	1.000	-662.8239	662.5071
	POCV	-.6788844	1947.81	-0.00	1.000	-3818.316	3816.959
	MCUI	.9504475	724.6531	0.00	0.999	-1419.343	1421.244
	NA	.9606631	944.1399	0.00	0.999	-1849.52	1851.441
Employmentofhouseholdshheadca							
	_predict						
	AT	-.0888184	.03516	-2.53	0.012***	-.1577307	-.0199061
	PSWC	-.0179679	.029553	-0.61	0.543	-.0758908	.0399549
	EVLV	-6.13e-08	.0000676	-0.00	0.999	-.0001325	.0001324
	F	-.0124938	.0168654	-0.74	0.459	-.0455495	.0205619
	POCV	-.0053658	.033038	-0.16	0.871	-.0701191	.0593875
	MCUI	-.1610314	.0623304	-2.58	0.010***	-.2831968	-.038866
	NA	.2856774	.0679688	4.20	0.000***	.152461	.4188937
Accesstocredit							
	_predict						
	AT	.061129	130.9962	0.00	1.000	-256.6866	256.8089
	PSWC	-.8231733	1266.63	-0.00	0.999	-2483.373	2481.727
	EVLV	9.42e-08	.0001019	0.00	0.999	-.0001996	.0001998
	F	-.2008829	350.1753	-0.00	1.000	-686.5319	686.1301
	POCV	.1743758	121.7951	0.00	0.999	-238.5396	238.8884
	MCUI	.4048079	433.2655	0.00	0.999	-848.7799	849.5896
	NA	.3837434	569.0104	0.00	0.999	-1114.856	1115.624
Total household income in dollar							
	_predict						
	AT	.0003411	.0001689	2.02	0.043**	.0000101	.0006721
	PSWC	.0001939	.0001931	1.00	0.315	-.0001846	.0005725
	EVLV	-1.00e-09	9.31e-07	-0.00	0.999	-1.83e-06	1.82e-06
	F	-.0000507	.0001276	-0.40	0.691	-.0003009	.0001995
	POCV	-.0001647	.0001785	-0.92	0.356	-.0005145	.0001851
	MCUI	-.0006019	.0003799	-1.58	0.113	-.0013465	.0001426
	NA	.0002823	.0004069	0.69	0.488	-.0005151	.0010798
Migration response HH_G							
	_predict						
	AT	-.035287	.02853	-1.24	0.216	-.0912047	.0206307
	PSWC	.0160539	.0326802	0.49	0.623	-.0479981	.0801059
	EVLV	-3.49e-08	.0000494	-0.00	0.999	-.0000969	.0000968
	F	-.0221025	.0176264	-1.25	0.210	-.0566496	.0124447
	POCV	-.0343716	.0304325	-1.13	0.259	-.0940183	.025275
	MCUI	.3870404	.0702617	5.51	0.000***	.24933	.5247507

Drought	NA	-.3113331	.0654066	-4.76	0.000***	-.4395276	-.1831385
	_predict						
	AT	-.1559638	.0469477	-3.32	0.001***	-.2479797	-.063948
	PSWC	-.0087052	.0264637	-0.33	0.742	-.0605731	.0431627
	EVLV	2.51e-08	.0000524	0.00	1.000	-.0001026	.0001027
	F	-.0250653	.0185191	-1.35	0.176	-.0613621	.0112314
	POCV	-.0436081	.0309123	-1.41	0.158	-.104195	.0169789
	MCUI	.1405875	.0693835	2.03	0.043**	.0045983	.2765767
	NA	.092755	.0732813	1.27	0.206	-.0508736	.2363836
Practicing livestock farming							
	_predict						
	AT	-.0953611	.0283908	-3.36	0.001***	-.1510059	-.0397162
	PSWC	-.0242185	.0277876	-0.87	0.383	-.0786813	.0302443
	EVLV	-1.50e-07	.0001334	-0.00	0.999	-.0002617	.0002614
	F	.0041824	.0159148	0.26	0.793	-.02701	.0353748
	POCV	-.0407658	.0302577	-1.35	0.178	-.1000697	.0185381
	MCUI	.0658506	.068665	0.96	0.338	-.0687303	.2004314
	NA	.0903126	.0694299	1.30	0.193	-.0457675	.2263927
<b>No. of observation= 232</b>							

Own Evaluation using Stata 16 for window. Notes: \*\*\*, \*\*, \* = significant at 1%, 5%, and 10% probability level, respectively. Note: AT-Agriculture technology, PSWC-Practicing soil and water conservation, EVLV-Early varieties and Late varieties, F-Fertilizer, POCV-Plant other crops varieties, MCUI-Multiple crops under irrigation, NA-No adaptation.

**Household size.** For most of the adaptation methods used by farmers in the rural Gambia, increasing household size decreases the probability of agriculture technology, practicing soil and water conservation, planting early and late varieties of crops and fertilizer application by farmers as an adaptation methods respectively. The results are negatives and insignificants. 1 unit increase in households' size, 0.61 percent increase in multiple crops under irrigation, and 0.04 percent increase in plant other crops varieties as an adaptation options respectively. In additional, 1 unit increase in households' size, the probability of adaptations options such as fertilizer decreases by 0.16 percent. In addition, 1 unit increase in households size, there is significant decreases the probability of non-adaptation in the rural Gambia by 0.3 percent.

**Age of the household head.** Age of the household head, which represents how much experience the head has affected Adaptation method to climate change. Thus, 1 unit increase in age of the household head category decreases in the probability of agriculture technology as an adoption options by 0.0065 percent, and 0.3 percent decrease in multiple crops under irrigation. The household's size has positive and insignificant impact on practicing soil and water conservation and planting other crops varieties as adaptation methods. 1 unit increase in age, the probability of increases practicing soil and water conservation increase by 0.1 percent and planting other crops varieties increase by 0.14 percent. Age has positive and insignificant effect on none adaptation options. 1 unit increase in age of the households head, the probability of none adaptation method increase by 0.019 percent.

**Gender.** The results indicate that those that are male has negative and insignificant impact on using agriculture technology, fertilizer, practicing soil and water conservation, planting other varieties of crops, and early varieties and late varieties as adaptation methods. Male-headed households were 3.4 percent less likely to take on agriculture technology as an adaptation options, 3.5 percent to practicing soil and water conservation, and 1.6 percent less likely to take on fertilizer as an adaptation options. In the rural Gambia, gender has positive and significant impact on none adaptation method.

**Education.** We assume that education of the head of household increases the probability of adapting to climate change in the rural Gambia. As can be detected in Table 7, education has insignificant and negative impacts on using agriculture technology as an adaptation option, negative and insignificant impact on using fertilizer as an adaptation option, practicing soil and water conservation as adaption options, early and late varieties as an adoption option, and multiple crops under irrigation. As education increases, the probability of taken no adaptation in the rural Gambia rises. The results are significant and positive. 1 additional year

in school, no adaptation method increases by 19.8 percent, a unit increase in number of years of schooling would result in a 2.5 percent decrease in the probability of soil conservation and water conservation and 4.5 percent decrease in agriculture technology, and 5.5 percent decrease for multiple crops under irrigation to adapt to climate change. Furthermore, almost all the marginal effects values of education of the households' heads are negative across all adaptation methods demonstrating the negative relationship exist between education and adaptation to climate change in the rural Gambia. Only no adaptation has positive and significant effect on education vice-versa.

Size of the Farmland is an important determinant for adaptation options. The results revealed that size of the farmland has positive and significant impacts on agriculture technology, and negative and insignificant impact on fertilizer as an adaptation option. Negative and insignificant impact on practicing soil and water conservation, positive and insignificant impacts on planting other crops varieties, positive and insignificant impact on early and later varieties and multiple crops under irrigation. The size of farmlands has insignificant and negative impact on no adaptation options. 1 unit increase in the size of farmland, the probability of using agriculture technology as adaptation options increase by 0.1 percent, practicing soil and water conservation decrease by 0.01 percent, 0.05 percent reduces in fertilizer, and planting other crops varieties decrease by 0.054 percent. Size of farmland has negative and insignificant impact on no adaptation options rather than adaptation option with the same level of education, migration, drought, age, gender, farm size, and household size respectively.

Agriculture extension service. Having access to agriculture extension increases the probability of using early and late varieties by 1.02e-08 percent and multiple crops under irrigation by 95 percent. Agriculture extension has insignificant impacts on planting early and late varieties and multiple crops under irrigation, the results noted. Access to agriculture extension service has negative impact on practicing soil and water conservation, fertilizer, planting other crops varieties and agriculture technology. In addition, agriculture extension has positive and insignificant impact on no adaptation options. Agriculture sectors should training and teach farmers about new ways of farming and in that they will be aware to understand climate change adaptation options.

Employment of the households' head is an important determinants of adaptation methods. Employment has negative impacts on all the adaptation options. 1 unit increase in employment of household head, the likelihood of decrease agriculture technology by 8.8 percent, 1.8 percent for practicing soil and water conservation, 6.13e-08 percent for planting early and late varieties, 1.2 percent for fertilizer, 0.5 percent for planting other crops varieties and 16.10 percent for multiple crops under irrigation. Further, employment has significant and positive impact on no adaptation options in the rural Gambia.

Access to credit. Access to credit has a positive and insignificant impact on the likelihood of using. Agriculture technology, planting early and late varieties, planting other crops varieties and multiple crops under. In addition, 1 unit increase in access to credit, the probability of using practicing soil and water conservation decrease by 82 percent and fertilizer decrease by 20 percent as climate change adaptation option. This result implies the important role of increased institutional support both governmental support and NGOs' support to climate change adaptation options to reduce the negative effect of climate change. Access to credit has positive and insignificant impact of no adaptation options.

Total household income. The household income has a positive and significant impact on. Agriculture technology, positive and insignificant impacts on practicing soil and water conservation, negative and insignificant impacts on planting early and late varieties, planting other crops varieties, and multiple crops under irrigation respectively. 1 unit increase in total household income in dollars, increases the probability of taken agriculture technology as adaptation option by 0.034 percent, 0.019 percent for practicing soil and

water conservation, decrease by 0.005 percent for fertilizer and decrease 0.016 for planting other crops varieties respectively. Income has positive impact on no adaptation options.

Migration response in general has negative and insignificant impacts on agriculture technology, early and late varieties fertilizer and planting other crops varieties. Furthermore, migration has positive impact on practicing soil and water conservation. 1 unit increase in migration, the probability of using soil and water conservation increase by 1.6 percent. For instance, migration response has negative impact on agriculture technology (about  $-0.035$ ), early and late varieties (about  $-3.49e-08$ ), fertilizer (about  $-0.022$ ), and planting other crops varieties (about  $-0.034$ ). Migration has positive and significant impact on multiple crops under irrigation. 1 unit increase in increase in migration response, multiple crops under irrigation increase by 38.7 percent. Migration's response has negative and significant impacts on no adaptation options. May migrants are aware of climate change and therefore they send remittance to solve the impact of climate change effects through doing multiple crops under irrigation and soil and water conservation as an adaptation option to climate change.

Drought. Unlike flood, drought has negative and significant impact on agriculture technology as adaptation options and positive and significant impact on planting early and late varieties. Therefore, 1 unit increase in drought, the probability of increase in agriculture technology as an adaptation options decrease by 15.6 percent, practicing soil and water conservation is decrease by 0.87 percent, fertilizer decrease by 2.5 percent, plant other crops varieties reduce by 4.4 percent and multiple crops under irrigation increase by 14.05 percent. Drought has positive and insignificant on no adaptation methods. 1 unit increase in drought, non-adaptation options increase by 9.3 percent approximately.

Practicing livestock farming. The ownership of livestock has negative related to most of the adaptation methods. 1 unit increase in practicing livestock farming, the probability of fertilizer and multiple crops under irrigation increase by 0.42 percent and 6.6 percent respectively. Practicing livestock farming and positive relationship with no adaptation options, the study noted. 1 unit increase in livestock farming, the likelihood of agriculture technology decrease by 9.5 percent, practicing soil and water conservation decrease by 2.4 percent, planting early and late varieties decrease by  $1.50e-07$  (see more details in above table 7 for marginal effect.)

## **Conclusions and policy implications**

This study analyzed adaptation methods used by farmers based on a cross-sectional survey, over 400 households in the rural Gambia. We used the following adaptations methods; agriculture technology, fertilizer, multiple crops under irrigation, practicing soil and water conservation, planting early and late varieties. After, we applied the following tests such as independent for irrelevant alternative (IIA), Wald test, and likelihood ratios test in order to test the validity for the model. After that we used multinomial logistic model to model the different adaptation choices used by farmers. The results found out that size of the households has negative and insignificant impacts on all the adaptation options in the rural Gambia while age has positive and insignificant impacts on adaptation choice. Moreover, male headed households has negative and significant impacts on agriculture technology, planting early and late varieties of crops, soil and water conservation, fertilizer, plant other crops varieties as an adoption options. In addition, migration as a coping strategies for adaptation is insignificant and positive impacts on the following adoption options; practicing soil and water conservation and multiple crops under irrigation and negative impacts on fertilizer uses by rural farmers and planting early and late varieties.

Access to credit and agriculture extension services negative and insignificant impacts on agriculture technology, practicing soil and water conservation and fertilizer as adaptation options than non-adoption option keeping all other independent variables constant.

In conclusion, the author suggested that the policy makers should help farmers with new ways of farming by training them or giving them quality education on climate adaptation choices. The government should also provide access to credit to local farmers to use that grants or loans to buy agricultural machineries, increasing production by adoption.

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