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 that 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[1] 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 behaviours 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 most commonly used empirical models for analysis of adaptation mechanism for agriculture. In this paper we will employed two option 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 employed the multivariate probit model to analyse factors influencing the choice of climate change adaptation options in Southern Africa. They found out that access to credit and extension and awareness of climate change are some of the important determinants of farm-level adaptation in Southern Africa.

Kurukulasuriya and Mendelsohn 2008 and Hassan and Nhemachena 2008,employed the multinomial logit model to see if the choice of crop by farmers is climate sensitive and results confirm 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 etal., 2009 used the multinomial logit model to analyse how the choice of livestock species is climate sensitive and found out that . In Additionally, Bryan *et al.* 2009 adopted the probit model to analyze the factors influencing the decision to adapt to climate change by using data from a survey of 1800 farm households in South Africa and Ethiopia.

Statistical Model

According to Schlenker and Lobell, 2010, ceesay, 2019, 2020, confirmed that statistical models such as time series, cross-sectional or panel data study in order to estimate the relationships between or among crop yields and climate changes variables such as temperature and

[1] Discrete models or outcome or qualitative response models or limited dependent variables are models for a dependent variable that indicates in which one ofm 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.

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 the 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:

Eq1 ……………………... … … … … … … … … $U_j = \beta'_j X_i + \epsilon_j$ and $U_k = \beta'_k X_i + \epsilon_k$

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, β_j and β_k are parameters to be estimated and ϵ_j and ϵ_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 decides 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;

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

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

$$P\left(Z = \frac{1}{X}\right) = P(U_{ij} > U_{ik})$$
$$P(\beta'_j X_i + \epsilon_j - \beta'_k X_i - \epsilon_k > 0/X)$$
$$P(\beta'_j X_i - \beta'_k X_i + \epsilon_j - \epsilon_k > 0/X)$$

P(X* X_i + ϵ *> 0/X = F($\beta^* X_i$)……………………………………………Eq3

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 ϵ^* which is evaluated at $\beta^* X_i$.The exact distribution function of F depends on the distribution ofthe random disturbance term, ϵ *. Depending on the assumed independent and identically distribution of which random disturbance termfollows, several qualitative and categorical choice models can be estimated (Green 2000).

Empirical Model

The multinomial logit (MNL) model is used to analysis of 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 theanalysis of decisions across more than two categories andallowing the determination of choice probabilitiesfor different categories (Madalla 1983; Wooldridge 2002). Furthermore, Koch (2007) emphasizes thepracticality of this model by relating the ease of interpreting estimates from the MNL model.

To describe the multinomial logistic (MNL) model, let Zdenote a random variable taking on the values {1, 2.3.4……J} for anyJ, a positive integer, and let **x** denote a set of conditioning independent variables. In this case, Z denotesadaptation options or methods, or categories or choice and **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 **x** affect the response probabilities Z i.e. P (Z = j / x), j =1, 2,.3, 4....J . Sincethe probabilities must sum to one i.e P'(x) + P(x)=1. Then, P (Z = j / x) is determined once we know the probabilities for j = 2,3,4,5...J.

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

P(Z= j/x)= exp($\frac{\beta_j X}{\left[1 + \sum_{h=1}^{J} \exp(\beta_h X)\ , j = 1,2,3,,,,,....J\ \right]}$ ……………………………$Eq4$

where β is K * 1 matrix, , j = 1, 2, 3,4 ....J.

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

1. No adaptation
2. Agriculture technology
3. Practicing soil and water conservation
4. Early varieties of crops
5. Fertilizer
6. Plant other crops varieties]
7. Multiple crops under irrigation

Unbiased and consistent parameter estimates of the MNL model in equation Eq1 require the assumption of independence of irrelevant alternatives (IIA) to hold by doing hausman test, wald test and likelihood ratios test.To be précised, the IIA assumption requires that the probability of using a certain adaptation method or options by a given household needs to be independent from the probability of choosing another adaptation method or choice (i.e. $P_j/P_k$is independent of the remaining probabilities).The premise of the IIA assumption is the independent and homoscedastic disturbance terms of the basic model in Eq1.

The parameter estimates of the multinomial logistic (MNL) model provide only the direction of the effect of the independent variables on the dependent or different adaptation practice use by farmers or response variable. Then, the estimates do not signify either the actual magnitude of change nor probabilities. Differentiating Eq1 with respect to the explanatory variables provides marginal effects of the explanatory variables specific below:

$$\frac{dP_j}{dx_k}=P_j\left(\beta_{jk} - \sum_{j=1}^{j-1} P_j \beta_{jk}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . Eq5$$

The marginal effects or average marginal effects or marginal probabilities are functions of the probability itself and measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable from the mean (Green 2000; Koch 2007).The dependent variable in the empirical estimation for this study is the choice of an adaptation option from the set of adaptation measures. For the purposes of this study, the specialized crop cultivation in these three region in the rural Gambia crop under subsistence farming or rain-fed agriculture system is used as the base category as a measure of no adaptation. Our choice of explanatory variables is dictated by theoretical behavioral hypotheses, empirical literature and data 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 sixcategories 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 table1, we can see that majority of the rural farmers do plants 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 household's surveyed 2021.Table…above shows the descriptive statistics for the continuous variables used in this chapter. 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 surveyed 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 above table, most households have at least one migrants (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 is important determinants of larger income. This is evidences in the rural Gambia where households size increases with household income (correlation coefficient is 0.3067).Additional 1 new born add to family, there is rises in 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 are 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

	sizeof~s	Sizeof~s	Total~ar	Gender	educat~e	Employ~a	Drought	access~t	agri~ces	Migrat~G
sizeoftheh~s	1.0000									
Sizeofthef~s	-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 uselikelihood ratios, and Wald test. For the multi-collinearity 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 from0.354-0.000**)** and wald test statistics (Prob. Chi-square ranged from0.169-0.000) as indicated by the probability of the chi-squareare 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**

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    Variable |       VIF       1/VIF
-------------+----------------------
agricult~ces |      1.92    0.521439
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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
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 (MNLM) 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 specifiedprevious, 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 doesnot determine the direction of the association between an independent variable and the probabilityof choosing an exact categorical alternative (Bowen & Wiersema, 2004). As an alternative, to be able to draw valid conclusionsabout relationships, scholars must rely on other interpretational strategiessuch as marginal effect(dy/dx) and predictedprobabilities.For instance, the marginal effects from the multinomial logit analytical method, which measure theexpected change in probability of a particular choice being made with respect to a unit change in anindependent 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 becompared 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,). Table7presents 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

Delta-method

	dy/dx	Std. Err.	z	P>|z|	[95% Conf.	Interval]
sizeofthehouseholds						
_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
Ageofthehouseholdshead						
_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
Employmentofhouseholdsheadca						
_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
Totalhouseholdincomeindollar						
_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
MigrationresponseHH_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
NA	-.3113331	.0654066	-4.76	0.000***	-.4395276	-.1831385
Drought						
_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
Practicinglivestockfarming						
_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

No. of observation= 232

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 assumes that *e*ducation 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.

Totalhousehold 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.

Practicinglivestockfarming.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 use by farmers.The results found 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 gives them quality education on agriculture adaptation choices. The government should also provide access to credit by local farmers to use that grants or loans to buy agriculture machineries to increases production by adoption.

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