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Climate Change, Food Security and International Migration Nexus in West Africa: A Multilevel Logistic Regression Analysis for the Gambia.

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ABSTRACT

Environmental migration is an increasing concern across Africa, particularly in regions vulnerable to climate variability. This study investigates the interplay between climate change, food security, and international migration in rural Gambia using household-level survey data. A multilevel logistic regression model was employed to assess how interactions between food security, climate conditions, and remittance inflows influence the likelihood of international migration. The analysis reveals that migrants typically originate from larger, male-headed households, are married, and come from communities with low literacy levels. Most were previously employed in agriculture. Interaction effects show that drought, remittance receipt, and changes in rainfall significantly increase the probability of migration, whereas flooding, saltwater intrusion, and rising temperatures have a negative impact. These findings underscore the complex relationship between environmental stressors and migration decisions, highlighting the need for targeted policy interventions in climate-sensitive rural areas.

Introduction

In general, climate change extreme events are predicted to influence the movement of the population across and within Africa. This paper addresses the question of whether migration is caused by climate changes in the rural Gambia. We look at climate change indicators and interact climate change indicators with food security and remittances, and add control variables to find the best predictors of migration from the rural Gambia.

We hypothesize that employment in agriculture is declining for two major reasons, climate factors such as low rainfall, drought and flood, and the fact that youth are migrating to Europe and other parts of the world for greener pastures. This is the main contribution of the paper, to examine the impact of climate change on odds of migration, along with the mediating factor of food security. The main causes of this environmental movement are due to extreme climate events such as salt water intrusion, floods, sea level rise and drought. Thus, livelihoods, food security, water availability and public health are some of the consequences of climate impacts. Climate change may impact all form of migration: short and long distant migration, internal and out migration, and temporary and permanent migration (Awil Mohamoud and al, 2014). (ceesay & omar, 2022) (Ndiaye et al., 2022)

According to Ahmad Sadiddin et al. (2019) food insecurity is the key determinant of the decision and desire to migrate. The agricultural sector contributes XX% to the Gambian economy but has languished since the 1990s because of numerous issues including uneven rainfall distribution, feeble marketing infrastructure, shortage of access to credit, and an incomplete resource base (FAO,2018). In Northeast Brazil, Barbieri et al. (2010) found that agriculture productivity will be affected by climate change and this will contribute to migration. According to Ahmadou Aly Mbaye (2017), food insecurity, sea level rise and weather are important causes of migration in Africa. Further, the majority of migration (84%) in West Africa still occurrs within Africans' borders (ICMPD and IOM, 2015).

According to Delbeke et al. (2019) the Paris Agreement always take into account vulnerable populations and reaffirms their rights. According to Massey et al. (1993) and McLeman (2006), climate variability causes agricultural failure. Thus, Ceesay & Sonko, 2024, the article investigates how The Gambia's National Education Policy (2016–2030) promotes inclusive education as a strategy for sustainable development and economic growth. It emphasizes the role of education in human capital formation and social equity, especially for marginalized groups such as persons with disabilities

In Latin America, international migration is mostly caused by adverse climate change impacts (Feng and Oppenheimer 2012; Gray and Bilsborrow 2013; Nawrotzki et al. 2015). In contrast, climate shocks may causes in-migration and out-migration among marginalized and extreme poor population (Black et al. 2011). Climate change has both direct and indirect effect on migration dynamic/population movement (McMichael, 2014, McMichael, 2015, Ceesay et al., 2020, USDA, 2015, Brown et al., 2013, and FAO,2015). As climate change is still around, because most of it are caused by ''human-induced abusing the environment. For some years, there has been an increase of interests of academic communities and beyond to comprehend and to build policy solutions for the impacts of climate change on migration. This is complex phenomenon as climate change is multifaceted issues and to interlink it to migration dynamics will bring more complex pathways(Deegan et al., 2014, McMichael, 2014 and McMichael, 2015 and Jacobson et al., 2017).Climate change bring about internal migration and international migration, NASA 2017,Maria Waldinger 2015, IPCC,2014.

Migration from slow onset sea level rises, rainfall fluctuation, drought, salt intrusion, bushfire lead to serious damages to nation economic growth from damage done by agricultural sector and manufacture sector. According to Ceesay EK (2020), and Shaari et al., 2017,the high onset like flooding, also destroy crops and livestock, damages asset and properties, make road difficult to move unto and make children and adult late to schools and work respectively and overall decline the standard of living of the peoples and the livelihoods for a time.

Slow-onset effects of climate change or internal climate change migration, processes like sea-level rises, increasing temperature, salinization, drought, ocean acidification, forest and land degradation, desertification, glacial retreat and loss of biodiversity(UNFCCC,2010).The slow onset events can be both internal climate change migration or external climate change migration. This is because the events will combine with individual vulnerability and social-economic demographic and political contexts to affect the ability of people to respond to stressor ,enjoy human freedom and human right ("New Global Estimates of Internally Displaced Persons," 2016).This of course lead other to move and others cannot move away from the affected areas due to financial constraints, due to their properties or assets, due to their families tighting and due to slow-onset climate change.

For example, past studies of migration associated with environmentally change indicate that most people initially move individually(Drinkwater & Garapich, 2013,Wilson & Arvanitakis, 2013 ,Jones et al., 2010,(Haverkort et al., 2010).The same is expected in the events of internal climate change migration ocurred, most who move predicted to remain within a country(Kay et al., 2015, Van Nes et al., 2015, Swart et al., 2015 and Dai et al., 2015).

The overall objective of the study is to assess the impacts of climate change on migration, including the mediating variable of food security, in the Gambia.

Hypothesis:

H1: *Climate change has a significant impact on migration patterns in The Gambia.*

H2: *Food insecurity mediates the relationship between climate change and migration in The Gambia.*

- **H2a:** *Climate change negatively affects food security in The Gambia.*
- **H2b:** *Food insecurity increases the likelihood of migration among affected populations.*
- **H2c:** *The indirect effect of climate change on migration through food insecurity is stronger than the direct effect.*

Drivers of climate change and migration

Variation in climate can drive migration in many forms. Still, in this context, we look at climate and non-climate processes as crucial drivers of internal and international migration. First, climate drivers such as salt intrusion and salinization of agricultural land, drought, food insecurity, and water scarcity can drive temporary, permanent, or forced migration, or a combination of all. Climate events like flooding, storm, drought, lightning, bushfire, erosion, glacial lake outburst, floods, high temperature, destruction by locusts, pests, disease, damage, and rainfall changing patterns drive migration. Non-climate stressors will be less discussed here, such as government policy, civil war, economic condition, location, social reasons, demographic reasons, conflict, population growth, hunger, food insecurity, poverty, violence, and natural disasters in a community level can also lead to migration. Sea level rise mostly makes certain areas and most islands or towns or capital cities vulnerable, and those places will end up being inhabitable to (Asthana, V. 1993. As livelihoods become problematic, they move to areas with good livelihoods, and due to such circumstances, they never return. For example, in some Sahel regions in Africa, women must walk up to 25 km a day to fetch water due to water scarcity and as the journey continues to get longer, some move there permanently. Taylor, J. (2000).

Migration responses by change in rainfall in the Gambia

Table 1: Migration responses by Changes in rainfall in the rural Gambia

Migration response HH_G	Changes in rainfall	
	Due to changes in rainfall pattern	Not due to changes in rainfall pattern
Migrant hh	69.42%	80%
Non-Migrant hh	30.58%	20%
Total	100%	100%

Source: Author's own computation using stata 16 from household's survey data 2021.

The data were produced from household survey conducted in the rural Gambia in 2021.Subsequently, about 69.42 percent of migrants moved due to changes in rainfall pattern in rural Gambia. If rainfall changes, they migrate elsewhere to have income and send the remittances for households' use. Majority of people in the countryside in the Gambia migrated not due to rainfall changes but due to personal, diplomatic, psychological reasons, neighbours' influence, environment set-up, conflicts, education, employment, union, networking, invitation, peers or friend influences, and other related circumstances that frequently happen in the rural Gambia. However, natural disaster such as rapid and slow onsets climate changes increases migration but poor individual or communities are less likely to migrates aftermath of the natural disaster. This is due to the fact that they have nobody left to take up the journey of migration. Climate drivers such as climate processes and events are likely to permanently displace or migrate many more people (Gray, C., & Wise, E. (2016).In addition, non-climate drivers such as natural disasters might displace many people for a short period (Drabo, A., & Mbaye, L. M, 2015). Migration can also be forced in that, for example, the USA dustbowl years in the 1930s suggest that being migrant due to severe climate conditions such as prolonged drought will cause people to migrate to an area to have support networks, social, financial (Massey et al.,1993). Non-climate-driven effects marginalize people, and that causes them to migrate to a better environment. Furthermore, environmental change such as flooding drives migration, and climate conflict drives migration (Zimmerer et al.,2022). In addition, the environmental drivers of migration can be either slow onset such as land degradation, changing rainfall and temperature patterns, desertification, food insecurity, or drought and can also be rapid onset climate change such as floods, hurricanes, storms, bushfire, erosion and glazier, lightning, volcanoes (Mareida, M. & Pingali, P. 2001).

Munir, A., & Barrow, A. (2025) wrote article explores how blockchain technology can transform green finance by enhancing transparency, efficiency, and accountability in sustainable investments. However, the authors argue that regulatory fragmentation, especially between developed and emerging economies, poses significant barriers to adoption.

Migration is more conceptualized from climate drivers such as climate processes and events. In that, it helped us comprehend the setting of climate change vulnerability Lobell et al.,2008. Out-migration can control the problems of climate shocks. It can be permanent or temporary migration. According to IPCC (2020), in South Africa and South Asia, environmental change is increasing, and natural disasters are occurring and thus rapid human population movement. Drought and changing precipitation patterns rise over time, leading to migration. Climate change induced migration in the Gambia is cause by push factor of migrations.

Climate variability in The Gambia

Climate variation is occurring in Gambia and is continuously affecting agriculture, which is the mainstay of the country's social and economic development. Climate change crises affect crops and livestock. Crop failures in The Gambia are due primarily to insufficient rainfall. Insufficient rainfall is due to changing pattern of average rainfall in different months in The Gambia. As rainfall changes, most crops do not reach maturity and therefore die off, or become immature and cannot be rich in the nutrient required for growth, development, and food security. The other climate change variable, the temperature, on the average, affects the yields of crops and animals. The hotness affects animals. Water scarcity affects animals' growth, poor grazing affects animal well-being and development, and in that case, drought affects crops and animals as well. No crop is resistant to droughts, and same with animals. Droughts bring food insecurity, hunger, and malnutrition. Climate variability is the drive from an average change in rainfall, either monthly or annual, the average change in temperature, the average change in drought, the average change in flood, the average change in sea-level rises, and the average change in other climate change-related disasters. Climate change occurs from greenhouse gas emissions, and that emission is driven by animals and plants. Animals become sick due to low emissions, and the leave becomes sick or yellow due to low emissions. These lead to a reduction in agriculture values added, such as fishing, cropping, hunting, and forestry.

Environmental Migration context in Africa

Africa has the second largest population on the globe. It is the second most populous continent after Asia, with approximately 1.4 billion people (worldometers.info). According to the Intergovernmental Panel on Climate Change (IPCC), Africa remains amongst the highest exposed areas in the world to climate change. The weakness of African countries to change in climate is their attitude as determined by diversity issues that comprises feeble adoption capability, survival on ecosystem resources for livelihoods, and few advanced agricultural schemes (Ofoegbu and et al, 2019). The dangers of change in climate and weather-related issues on agricultural produce, water resources, crop protection and ecological disequilibrium lead to severe disadvantages to the survival and growth in Africa (Niang and et al 2014). This risk management needs a combination of adoption and mitigation tactics in managing agricultural production schemes (Ofoegbu et al., 2019). It is predictable that alteration in the change in climate will disturb all forms of migration (Awil Mohamoud et al.,2014). Precisely, food insecurity is essential factor for the decision, plan, intention and desire to migrate (Ahmad Sadiddin et al, 2019). According to FAO, there are four fundamental pillars of security and they are food availability, food accessibility, food utilization and food stability. The IPCC stated that climate change will affect livestock, and in turn will cause food insecurity, hunger, malnutrition, health problems, and early death especially in Africa. On top of that, food is hard to nurture, risky weather prejudices transportation, and producer and consumer commodity prices rise due to climate change effects. Also, food waste, for example, "mangoes in The Gambia,". Food insecurity leads to massive migration especially international movement. According to **Brown (2017)** about ten million people in particular countries in Africa are going on the threshold/edge into food insecurity, hunger, undernourishment and poverty.

Materials and Methods

Ethical approval

Before we conducted research on the topic, we received approval from the German Ministry of Education and Research (BMBF) through its sponsorship of the West African Science Service Center for Climate Change and Adapted Land Use (WASCAL) at Université Cheikh Anta Diope in Dakar. After the approval of the research design for household surveys in the rural Gambia, we surveyed 400 households in the rural Gambia to ask them questions on migration, food security and climate change. The survey instrument is included in the supplementary material.

Research Design and Methodology

This section presents the study plan and methods. Sample selection and size, and areas where the study was conducted. It also presents analysis of the data. It highlights the survey's comparability, consistency, best quality, credibility, transferability and dependability.

Study Design

According to Anita S Acharya et al. (2012). Strydom, Fouche and Delport (2005), Farewell VT (et al 2016) and Abdelazeem A. Eldawlatly (2019), a study design is a comprehensive pattern, relevant plan, or protocol for conducting a study, which permits the investigator to decode the conceptual hypothesis into a functioning one and only.

Areas of study

The study was conducted in three regions in The Gambia. The Gambia is divided into five governmental regions plus the capital, Banjul, which is categorized as a city. The Gambia is part of the Sahel region, which is well-defined as a transition zone from North to the Sahara Desert and South to the savannah plains. The weather is humid, with a raining season which commence from June and ends in October; and dry season commences from November to early June. Due to the ecology of these regions, they regions were select for this study out of five administrative regions.

The three regions are described below

The information to remember on the map is the study areas in the rural Gambia and it comprises of the North Bank Region-Kerewan, Central River Region-Janjanbureh and Kuntaur and Upper River Region-Basse. These Regions are selected based on their climate change impact, livelihood impacts including trade and food security issues and how the population are vulnerable and the fluctuation of migration in these regions.

North Bank Region (NBR)

Landscape in North Bank Region include arable land for agriculture and widespread mangroves divided by complicated scheme of canals. Thus, in certain places, woodland flood plain is established behind the mangroves. Conversely, the area comprises greatest of the state's mangroves pristine. Change in climate critical aspects are predicted to significantly impact lowland communities such as the Bao Bolon Wetland reserve. In addition, cultivation forms and crop selection might in growing pressure to adjust to change in climate conditions since, in this region, rainfall fluctuates over time, and temperatures increase. The saltwater intrusion is very high, leading to loss of fertile land and decreasing agricultural productivity through low crop yield and drought, leading to massive reductions in livestock population and crop productivity. As a counter measure to saline intrusion, higher investments would be required to maintain and protect rice cultivation in seasonally flooded freshwater swamps, and one of the critical motivations for this dissertation is to assess this regions' vulnerability and how adaptations strategies will help to have food security and to stop/reduce both out-migration and in-migration. If Climate change were uncontrolled, it would affect crop yield and livestock production, affecting agriculture sectors and livelihoods for the rural poor.

Central River Region (CRR)

This part of the country is selected for the study because it is an island. The extreme weather events at the end of the rainy seasons are uncertain, especially bushfires. Similar to the North Bank Region, Central River Region rainfall impacts are erratic, and higher temperatures lead to drought, including lower groundwater. This will massively affect crop availability, price, and livestock production and productivity in this region. Inconclusive, CRR is the region that has the potential for irrigation and due to its ground water, the early varieties of rice and other cereal crops are growing there. Upper River Region (URR)

As in the North Bank and Central River Regions, three broad classes of vegetation cover are found in this region and they are: spatial distribution, Shrub savannah and flood plain bush savannah. Annual floods are high if rainfall becomes higher since valuable grazing, sea level rises, compounding flood complications in the Capital of "Basse", and environmental problems will affect farmlands; unseasonal rains will likely affect agricultural production and productivity, including crops yields and livestock production. In the dry seasons, livestock' are affected due to water scarcity and combined with crop failures due to drought, pests and diseases, and flooding that leads to outbreaks of infectious diseases. These factors compound change in climate and food safety effects in these three regions.

Sampling Design

A sample design is a method used to choose the sample from the population. As stated by Kabir, S.M.S. (2016),these statistics are the estimates used to infer the population parameters. The first step in this study is determining the target study population of 350,000 people.

Sample frame

My sample frame looks like this, 35000 villages. Ten households in each village will be interviewed for the survey based on sample units such as household characteristics, demographics, climate change, food security, migration, and social status.

Note: Each of the selected villages will be more than ten households.

Sample section methods and sample size

The simple random probability sampling choices will be used in this study. As the name suggests, simple random sampling is the greatest frank sample procedure within probability sampling approaches. The most excellent feature of this method is that each member of a population has an equal likelihood of being chosen (Wimmer & Dominick, 2006). Our target population in these three regions are 350,000 peoples and require sample size that we surveyed is 400 below. The method is specified below:

$n = N / 1 + Ne^2$

Where:

n = the sample size.

N = the total population

e = precision or margin of errors

1 = unit

The sample size in the study areas is calculated as follows:

Total population is 350,000.

95 Percent confidence interval or 5 percent margin of errors. We now enter them into the formula below as follows;

n = N / 1+Ne^2

n=350,000/1+ (350,000)(0.05)^2

n=350,000/1+875

∴ n= 399.5433789954337 ~400

Stratified Random Sampling: is a random sampling technique in which the population is divide into subgroups called strata. In our case is explain below:

For multilevel Analysis, we used stratified Probability sample and the strata as follows in different level of subgroups called strata;

Regions codes:	CRR	NBR	URR
Villages codes:	14	13	13
	*	*	*
HH codes:	10	10	10
Total HH	140	130	130

Note: HHs' are within Villages and Villages are with Regions in the rural Gambia due to they share certain characteristic such as employment, education, marital status, climate, income, family size, farm size, migration status, food security, vulnerability and consumption status ete * means multiplication sign.

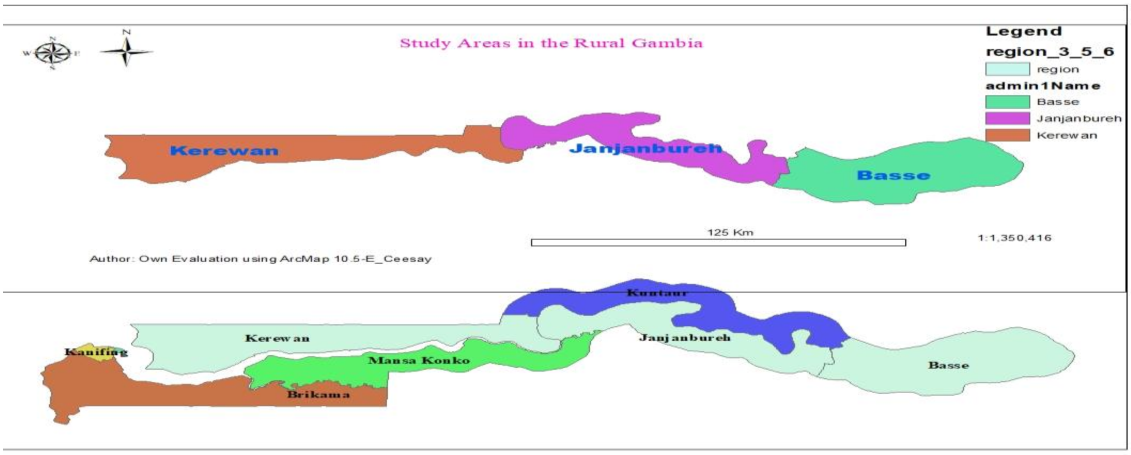

Figure 1: Study Areas in the rural Gambia

Own Evaluation using ArcMap 10.5

Hypothesis testing

H_0: **Environmental mi**gration does not cause food security in the Gambia

H_1: Environmental migration cause food security in the Gambia

Model specification

I employed multilevel versions of the conventional logistic models (see details explanation by Raphael J. Nawrotzki and Maryia Bakhtsiyarava, 2016 and Raphael J. Nawrotzkia, Allison M. Schlakb, and Tracy A. Kuglerc, 2016) in order to estimate the probability of an odds of international move to international destination within a region j, where households i is located is given below.

$$\text{logit}(Z_{ij}) = \theta_0 + \theta_1(FS_j) + \theta_2(CLM_j) + \theta_3(RE_j) + \theta_4(FS_j * CLM_j) + \theta_4(FS_j * RE_j) + \theta_5(CLM_j * RE_j) + \sum_{n=6}^{k} \theta_n(x_t) + \epsilon_{J} \ldots\ldots\ldots eq1.$$

In Equation 1, a logit relation function is used to evaluate the binomial migration reaction of household i situated in region j in the rural Gambia. The parameter θ_0 constitutes the conventional intercept term of the models. It is models since it can be run many times by interchanging the variable under investigation. θ_1 to θ_3 reflect food security, climate change and remittance on migration responselogit(Z_{ij}), as the dependent variable. Food security is from agriculture impact on migration and climate change variables can be the effect of climate extreme or adverse climate shocks on migration response. As mentioned earlier due to some relationship among variables in our model, only one model containing on one climate change variable e.g. precipitation and one food security variable e.g., household food consumption and remittance received by the households will be included in the model. Most significant is an interaction terms in our study such as $(FS_j * CLM_j)$, in which θ_3 reflects the effects of given food security and climate change measure, θ_4 reflects the given effects of food security and remittance received measure by the households i.e. $(FS_j * RE_j)$ and third interactive term reflect the effects of climate change measure and remittances received measure ,

$(CLM_j * RE_j)$ in which the parameter θ_5 the effects of change with response to migration. $\theta_n = \theta_6\ \theta_{7,}\ \theta_8, \theta_9, \dots\dots, \theta_{k,}$ in the summations term above reflects their effects of various control variables in our models ($x_{6t}\ , x_{7t}\ , x_{8t}\ , x_{9t}\ , x_{10t}\ , \dots., x_{kt}$). $x_{t,}\ t = 6, \dots\dots, \dots, k$, which is operating at the household or community level as designated in the above generic subscript, t. Lastly, the ϵ_J parameter is the of the random error term in our models in these three regions of the rural Gambia, which consist of the random errors terms as we are clustering the households survey within the three regions in the rural Gambia.

Results and Discussions

The average age of respondents for all the region combined is 47 years of age and standard deviation of 12.14 (Table 2). The minimum age of the respondent in the three rural regions in the Gambia is 23 and maximum age of the respondents is 105. When we consider individual region, the results revealed that the mean age of North Bank Region (NBR) is approximately 49 years of age, follow by Central River Region (CRR) and follow by Upper River Region (URR) respectively. Due to lower life expectancy in the Gambia, the mean age of the rural Gambia is very close to national average. For the household size as define as a number of peoples in the households. For combination of all the regions, the average household size is 21 with standard deviation of 17.26.For individual, CRR has large household size compare to other regions. For household income, it is confirmed that CRR has higher mean income of $170.24 per capital per month approximately. The rural household income average is $160 per capital per month. More rainfall, fall in CRR (about 2.02 mm).

For migration respondent of the household, about 70 percent of the rural household in the Gambia has at least one migrant. Thus, NBR has more migrants (about 94.06%) and that correspondent to have higher amount of remittance received (about 29.13%).

For marital status, 92.39 percent are married. For instance, those who are married are more likely to migrate (about 72%) than those that are single or widow and divorced (about 48%). For Gender, 66.67% of the respondents are male and they are more likely to migrate than females. According to the respondents, 76% of the migrants are male while 57% are female respectively. Most of the rural Gambia are food secure (74.4%) and those that are food secure are more likely to migrate (about 73.8%) than those that are food insecure (about 59%) (see detailed explanation in Figure X). Non-migrant households are 40.3 percent food insecure and 26.2 percent food secure. For migrant 59.7 percent are food insecure and 73.8 percent are food secure. Remittance received household are more likely to be food secure (about 88.5%) than no-remittance received household(70.4%). Remittance received households are more food secure about 18.1 percent than the household who those not received remittance. 68.7 percent of the respondents are farmers and 77.32 are able to read and write. For all household combined, more than 90%? said changing rainfall and temperature has affect them in the last 10 to 20 years. 69.4 percent said changing rainfall causes them to migrate while 68 percent said changing temperature cause migration. 80 percent whether rainfall changes or not they migrate. Those are the one migrates due to certain family pressure, psychology pressure, education, occupation, family reunion, networking, and so on.

Pairwise Correlation analysis

Bivariate Analysis between the migration response of the household in general and the other Explanatory Variables is explained in more details in Table 4 in the appendix. Multicollinearity does not bias the estimates and therefore all the explanatory variables are included in the multilevel version of conventional logistic model (see detail explanation below). For all the households, 13 variables are found to have positive correlation with household migration response status and six are found to have negative correlation with migration status of the households (See detail in Table 4). For example income and migration are positive correlated (correlation coefficient is about 20.2 percent).

The variables from the bivariate analysis-Pearson product-moment correlation coefficients that have the tolerance value greater than 0.20 and variance inflation factor (VIF) lower than 5 after conducting a linear regression analysis followed by VIF, will be further analyzed in the multilevel version of logistic regression model.

If the tolerance value i.e. 1/VIF is below 0.20 and the Variance Inflation Factor (VIF) is greater than 5, multicollinearity is present. Though, it is suitable for the VIF to lie amid 1–10. As shown in Table 5, none of variables showed any multicollinearity signs. Finally, the model is estimated after checking multicollinearity issues.

Results for Multilevel logistic regression

Age of the household heads is an important indicator for migration response for the household in the rural Gambia. The pairwise correlation between age and migration response is positive. Age here measure actual age in years or experience. Age rises with experience and therefore it is positive correlated with migration response. As depicted in Table 6, age is insignificant at all level of alpha (1%, 5% and 10%) and positive influence on the household migration status. The odds ratio value confirms that the probability that a household has a migrant increases by a factor of 1.014 as age increases by 1 year, keeping other independent variables constant. Large family size is important for the migration response in the Gambia. The results confirmed that the probability of the household's migration status increase by a factor of 1.01 as household size increases by one person, keeping other predictor variables constant. We combined all regions called rural Gambia, and we also show separate regions as well. **Furthermore,** the typical international migrant from the rural Gambia comes from a large household size, with male and married household heads in which few members are able to read and write and mostly they are employed as farmers.

For instance, household income has positive and significant coefficient on migration responses in the rural Gambia. Those households with higher income, has more migrants. With 1 unit rise in household income, the probability for international move increases by a factor of 1.004, keeping other explanatory variables constant. For individual regions, male-headed households and married are more likely to migrate than those that are female and are either single, widow and divorced, the study noted.

For climate responses in the base models, the results revealed that when we combined all the regions together, salt intrusion, flood and change in temperature has negative and significant impact on migration responses except for change in temperature, which has insignificant effects. For individual region, flood is an important climate change variables for migration response in URR compare to other regions. The results is significant and positive and the probability for international move increases by a factor of 1.00031 as flood rise, keeping other explanatory variables constant. Thus, drought, change in rainfall and heavier rainfall has positive impact on migration decision. With 1 unit increase in drought, the probability of migration is 0.703 approximately. This ought to cause yield and production to decline and, consequently food insecurity rises, and households in the rural Gambia response is to migrate internationally. Food security increase, migration response reduces in the rural Gambia (see detail explanation on the odds ratio value)

Food security and Climate change

The food security and climate change on the odds of the international move are presented in Table 7. The results from logit regression confirmed that food secure households are more likely to migrate than food insecure households. The odds ratio value confirms that the probability of the household having migrant's increases by a factor of 1.4338 as food security increases by 1 unit, keeping other predictor variables constant. This may be attributed to remittance and good agriculture and livelihood pathways. Surprisingly, the food security consumption level has negative impact on migration response. The odds ratio confirm that the probability of the households has migrant's decreases by a factor of 0.758 as food security consumption level increase by 1 unit, keeping other explanatory variables constant. This is true because migration happened both pull and push factor of migration due to food insecure. So, as household food security consumption level decreases peoples tend to migrate in rural Gambia through back way or through air way, the author's noted.

In addition, climate change impacts, flood, change in temperature, salinization or salt water intrusion has negative coefficient and significant impact on migration responses at 1 percent level of significance expect for change in temperature, which has insignificant effect on migration response. The odds ratio confirm that the probability of the households has migrants increases by a factor of 0.183, 0.4479, and 0.2012 respectively as flood, salt intrusion, and change in temperature increase by 1 unit, keeping other predictors constant. In the same vein, drought and change in rainfall pattern has positive and significant coefficient on international move. The odds ratio confirm that drought and change in rainfall pattern increase by I unit, the probability of the household migration status rises by a factor of 1.3907 and 1.407 respectively. The probability of chi-square is highly significant in all cases

Climate effects

Climate change impacts, we look at how climate change can causes international migration in the rural Gambia by modelling and run the logistic regression by including only climate change variables. The results revealed that flood, change in temperature and salt intrusion have negative and significant effect on migration response except change in temperature, which has both negative and insignificant impact. For instance, change in rainfall patterns, drought, and changes in rainfall, heavier rainfall has positive and significant impact on migration response. When flood incidence, change in temperature and salt intrusion rise by 1 unit, the probability of odds ratio on migration responses decreases by a factor of 0.298, 5.32e-08 and 0.303 respectively.

In additional, the odds ratio confirm that the probability of the households to have migrants increases by a factor of 3.363, 1.87e+07 and 2.089 respectively as changing in rainfall pattern, change in rainfall and heavier rainfall increase by 1 mm, keeping all others predictor constant. Changing in rainfall pattern and heavier rainfall are all significant at 1 percent and 5 percent level of significance. The probability of chi-square, and the pseudo-R^2 indicated that the models are good to support the hypothesis.

Food Security Effects

Food security is an important determinant on international migration. The results revealed that food security and major food crops has positive and insignificant impact on migration response while food security consumption level has adverse and significant influence on household migration condition. Total household food consumption has significant and positive coefficient impact on migration response.The odds ratio confirms that the probability of the households to have migrants increases by a factor of 1.521, 1.0067 and 1.062 respectively as food security, total food consumption and major food crops increase by 1 unit, keeping all others predictor constant. Food security, total food consumption and major food crops are all statistically significant at 1 percent and 5 percent level of significance respectively. The odds ratio confirms that the probability of the households to have migrants decreases by a factor of 0.644262 respectively as food security consumption level increase by 1 unit, keeping all others predictor constant. The probability of chi-square, and the pseudo-R^2 indicated that the models are good to support the hypothesis.

Interaction Effects

Food security- Climate change interactions

In the table below, the next step is to interact food security and climate, where we take flood as a proxy for climate change, we interacted the food security measures with the flood as climate variables to examining whether flood dependent regions are more susceptible to food insecurity. The results revealed that, food security has positive and significant impacts on migration response for the URR region's in particular and rural Gambia in general. The odds ratios confirms that the probability of household migration response rises by a factor of 6. 37225 as food security increase by 1 unit, keeping all explanatory variables constant. Due to important of higher precipitation to agriculture, flood has negative relationship with outmigration. The odds ratio confirms that the probability of household migration response decreases by 0.6986 as flood increase by 1 unit, keeping other predictors constant.

Insignificant and negative coefficient interactions arose for rural Gambia for food security and the climate change indicators of floods. This proposes that the food security-migration correlation similar by flood occurring for agriculture rather than others climate change indicators. More flooding, agriculture will be good, and migration will be decline in the rural Gambia. In one of the regions, the results revealed that significant and positive interaction emerged for food security and the climate change indicators of floods. This suggest that food security and migration dynamics differs climate indicators like flood. The effect of flood on the probability of migration in the rural Gambia is stronger but the effect of food security becomes weaker.

Remittance received- Climate change interactions

We observe significant and negative interaction emerging in the rural Gambia for remittance received and drought as proxy for climate change in the probability of the international move. Table 10. Revealed that the influence of droughts varies considerably by the region. In the North Bank Region (NBR), the odds ratio confirms that migrations response increases by a factor of 9.699 as drought increase by 1 unit. This is differing in others regions, where drought has opposite effects on migration. Finally, in the rural Gambia, the results revealed that significant and negative interaction emerged for remittance received and the climate change indicators of drought. This suggest that remittance and migration dynamics differs climate indicators like drought. The effect of drought on the probability of migration in the rural Gambia is stronger and the effect of remittance received becomes stronger too. Suggestion, predominantly drought causes migration and remittance received causes migration from logit regression results which reported the coefficients.

Discussion of the results

In our results we found that age, households' size, gender-male headed household, and marital status- married person has positive influence on migration response in the rural Gambia while own land has a negative effect on migration responses. This is confirms in the following study in which they found positive links between migration and socio-demographic characteristic of the households Hunter et al., 2014, Fussell & Massey, 2004, and Gubhaju & De Jong, 2009. In contrast, Hunter et al., 2014 found positive links between own land and migrations while we found negative relationship.

Education status and education attainment of the households has negative and insignificant impacts on migration response while employment of the household head has positive impact on migration. Employment rises, more income and that in turn causes outmigration in the rural Gambia. According to Raphael J. Nawrotzkia, Allison M. Schlakb, and Tracy A. Kuglerc, 2016, Amakom and Iheoma (2014) found education is vital part for migration response and DaVanzo, Julie,1978 he found education is an important relationship with migration responses. In contrast, we found negative links between education and migration. Mostly those migrated in the rural Gambia has less education, the study noted. Those employed are more likely to migrate in the rural Gambia.

Remittance received has positive relationship in the probability of migration responses. This is confirms in the following study about remittance and migration response Lokshin et al. (2010), Prabal and Ratha (2012), Amakom and Iheoma (2014) and (Ceesay, E. K. (2020)).

Food security in our results has negative and insignificant impacts on the probability of migration response in the rural Gambia. This is confirmed by Nguyen (2009) and Minh Cong Nguyen and Paul Winters, 2010 found that food consumption decreases migration responses.

Climate change effect on the odds of international move. The results revealed that climate changes variables have mixed effects on the odds of international move. Ceesay et al 2020,Lobell et al. 2013; Schlenker and Roberts 2009, found that temperature and precipitation at certain thresholds are more problematic to agriculture and lead to migration. Heat-wave will lead to food insecure and causes migration, whereas drought will lead to food insecurity and causes migration. Heat-wave wave or high temperature causes problem to both human, animal and plant and this of courses lead to migration (IPCC 2001, UNFCCC, 2003).

Interaction effect on the odds of international move found mixed evidence. First we found insignificant and negative coefficient interactions mainly arose for rural Gambia for food security and the climate change indicators of floods and second drought rise, migration rises in the rural Gambia. This is confirms in the study done by Henry et al., 2004 and Kambiranda et al., 2011; Reddy et al., 2003 establish that drought increases migration through lower agriculture production and yields and drought depress migration through less water for animals and less water for crops.

Conclusion and Policy recommendation

In this study we used rural households' response to migration by looking at base model, in which migration response is the binary-1 if household has at least one migrate and 0 otherwise. After we looks at the influence of climate change and food security on odds of international move. Finally, we look at the interaction terms between climate change and food security, between climate change and remittance and between remittance and food security on the odds of international move.

Subsequently, in the models, size of the family is the determinant factor of international move from the rural Gambia. Age is also key determine factor for migration. The results further analysis that those married and are male-headed household is likely to migrate than their female. Remittance received household are more likely to migrate than non-remittance received household in the rural Gambia. It means that those who received remittance can used that money to send other members of the family and reciprocal move internationally, the authors' noted. For all the region combined the study found that those that are educated and are employed as farmers are more likely to migrate. Income also in the rural Gambia cause migration of the household members. In the case of climate shocks, change in temperature, flood, and salt intrusion does not cause migration while drought, and change lead to migration. It means that drought causes food insecurity and that lead to migration while flood is translated to bumper harvest and that lead to food security and reduces migration, the author meditated.

Compliance with Ethical Standards

Ethical approval:

This article does not contain any studies with human participants or animals performed by any of the authors

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Authors' contributions

The authors worked jointly to come up with the paper. Both authors read and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Data Availability Statement

The datasets [GENERATED/ANALYZED] for this study can be found in the [Google drive] [Recent - Google Drive or Home - Dropbox]. Please see the "Availability of data" section of Materials and data policies in the Author guidelines for more details.

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Appendix

Table 1: Explanatory variables that are used in the study while the dependent variable is migration response (yes/no coded 1/0)

Variables Name	Description of the Variable	Expected Sign(+/-)
Do you have migrant(s) in your household?	Categorical Dummy, yes=1, no=0	
Age (years)	Ages is continuous	-

Household size	Number of peoples in the households is continuous	+/-
Household income (dollar)	Income is continuous	+
Landowner	Categorical dummy	+
Marital status	categorical dummy	+
Gender	Gender is categorical-dummy, 1 = male, 0 = female.	+/-
Remittances	Does your household currently (in the last 12 months) receive money from migrants (remittances)? Dummy (yes=1, no=0	+/-
Have remittances changed in the last 5-10 years, compared to the current situation?	Changing remittances pattern of the households=continuous	+/-
Education status	dummy	+
Employment status	dummy	+/-
Does changing rainfall affect your food production?	Dummy variables, yes=1, no=0	+/-
Is your household's food secure or not?	Dummy variables, yes=1, no=0	+/-
Climate variability	Fluctuation of climate, dummy yes=1, no=0	+/-
What is your household's food consumption level	Continuous	+/-

Source author's own evaluation from household survey

Table 2: Descriptive statistics.

Variable Name	Mean	Std.	Min	Max	Sample mean		
					NBR(n=130)	CRR(n=140)	URR(n=130)
Age	47	12.14	23	105	48.95	47.14	45.63
Household Size	21	17.26	2	212	18.27	23.18	20.79
Edu Attainment	2.54	1.49	1	7	2.69	2.39	2.55
Household income	159.60	83.70	0	488.76	164.00	170.24	145.65
Heavier rain fall	1.94	1.24	1	5	1.87	2.02	1.93

Own evaluation using household survey, 2021.Note: Std, min and max are for all Households (n=400)

Table 3: Descriptive statistics of dummy explanatory variables

	NBR (n=130)		CRR (n=140)		URR (n=130)		All Households (n=400)	
HH charateristic	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
Migrat. R_G	95	94.06	65	81.25	41	38.32	201	70
Own land	91	93.81	120	90.23	101	77.69	312	86.67
Marital Status	126	96.92	128	95.52	110	84.60	364	92.39
Gender	94	75.81	81	62.31	81	62.31	256	66.67
Remittance R.	37	29.13	33	26.83	34	26.15	104	27.37
Change in R.	3	2.36	10	12.66	28	22.05	41	12.31
Educ. Status	91	70.54	112	86.15	97	75.19	300	77.32
Employment	107	82.95	93	70.45	69	53.08	269	68.80
Food security	127	98.45	85	61.15	84	64.62	296	74.37
Flood	97	75.19	85	61.59	96	76.19	278	70.74
Drought	125	96.90	103	73.57	60	48.39	288	73.28
Change temp.	130	100.00	125	89.29	126	96.92	379	95.23
Change Rainfall	130	100.00	131	93.57	129	99.23	388	97.49
Changing rainfall pattern	122	94.57	116	84.06	77	59.23	315	79.35
Salt intrusion	48	45.71	64	45.71	37	29.13	149	40.05

Own Evaluation using household survey, 2021

Table 4: Bivariate correlations between household Migration responses and the other explanatory variables.

Variable	NBR (n=130)	CRR (n=140)	URR (n=130)	All Households (n=400)
Age	0.017	0.110	0.097	0.137
Household Size	0.087	0.077	0.310	0.104
Edu Attainment	0.054	-0.186	0.072	-0.006
Household income	0.044	0.297	0.369	0.204
Heavier rain fall	-0.169	0.207	0.333	0.195
Own land	-0.095	-0.006	-0.102	0.009
Marital Status	-0.052	0.008	0.098	0.152
Gender	0.630	0.157	0.363	0.198
Remittance R.	-0.015	0.361	0.325	0.229
Change in R.	0.041	0.258	-0.135	-0.158
Edu. Status	-0.17	0.067	-0.034	-0.033
Employment	0.102	0.030	-0.116	0.109
Food security	-0.036	0.314	-0.081	0.136
Flood	0.044	-0.284	-0.399	-0.257
Drought	-0.051	-0.041	-0.412	0.035
Change temp.	-	-0.149	-0.250	-0.14
Change Rain	-	0.032	-0.123	-0.042
Changing rainfall pattern	-0.069	0.059	-0.301	0.05
Salt intrusion	-0.345	-0.004	-0.378	-0.116

Own Evaluation using household survey, 2021

Table 5::Multicollinearity Tests

Collinearity Statistics		
Variables	VIF	Tolerance Factor(1/VIF)
Change in temperature	3.94	0.254
Changes in Rainfall	4.70	0.213
Education attainment	3.64	0.274
Heavier rainfall	2.64	0.379
Size of the Households	1.72	0.58
Total HH income IN $US	1.69	0.592
Gender	1.39	0.719
Age	1.61	0.621
Remittance received	1.35	0.739
Marital Status	1.77	0.564
Employment	2.03	0.492
Own land	1.93	0.519
Changing Remittance	1.89	0.529
Education status	3..45	0.289
Flood	2.32	0.432
Changing rainfall pattern	2.81	0.355
Salt intrusion. Salinization	2.65	0.377
Food security	1.73	0.577
Drought	2.42	0.413

Own Evaluation using household survey, 2021

Table 6: Base models

Variable	NBR (n=130)		CRR (n=140)		URR (n=130)		All Households (n=400)	
	Odds Ratio	P-value	Odds Ratio	P-value	Odds Ratio	P-value	Odds Ratio	P-value
Age	0.988	0.713	1.007	0.845	0.965	0.677	1.014	0.338
Sizehh	.9926	0.764	1.003	0.884	1.325*	0.087	1.010	0.442
Ownland_1	-	-	1.163	0.918	3.625	0.695	0 .729	0.592
Marital_1	15.20	0.090*	19.763	0.226	16923.	0.078*	2.600	0.187
Gender_1	8.938	0.020**	1.928	0.413	1.551	0.870	1.395	0.455
RR_1	2.744	0.185	5.029	0.085*	2970.3	0.045**	2.092	0.109
CR_1	0.354	0.295	12.412	0.042**	0.000	0.118	0.389*	0.071
Edu_1	4.721	0.191	0.030	.0.112	65.650	0.245	0.242**	0.036
Edu Att.	0.974	0.932	0.372	0.055**	0.164*	0.088	0.586***	0.003
Emp_1	9.436	0.032*	0.252	0.142	0.019	0.258	2.362**	0.049
FSS_1	-	-	0.576	0.757	0.808	0.915	0.850	0.694
Flood_1	3.018	0.412	0.526	0.527	0.000	0.065*	0.331	0.030
Drought_1	3.328	0.203	0.335	0.389	0.0792	0.402	2.020	0.177
CT_1	5.182	0.146	1.19e-06	0.994	-	-	9.77e-08	0.991
CR_1	0.216	0.386	1.01e+07	0.993	-	-	1.87e+07	0.991
CRP_1	-	-	0.778	0.858	.474	0.750	1.571	0.412
Salt_1	15.60	0.029**	0.172	0.120	-	-	0.362	0.022
Income	0.992	0.184	0.999	0.877	1.0099	0.361	1.004	0.104
Heavier R	0.707	0.370	2.373	0.157	1.074	0.949	1.590	0.012
Intercept	0.002	0.072*	2.901	0.854	.00046	0.323	0.406	0.639
No.obs.	113		123		47		211	
LR Chi2(19)	41.39		44.47		38.74		70.34	
Prob>chi2	0.000		0.0008		0.001		0.0000	
Pseudo R^2	0.363		0.4072		0.604		0.2573	

Parameter estimates reported in odds ratios.*p < 0.05. **p < 0.01. ***p < 0.001. Note RR_1 is i.remittance received

Own Evaluation using household survey, 2021.

Table7: Impacts of food security and climate change on the odds of international migration

Variable	NBR (n=130)		CRR (n=140)		URR (n=130)		All Households (n=400)	
	Odds Ratio	P-value	Odds Ratio	P-value	Odds Ratio	P-value	Odds Ratio	P-value
FSS_1	-	-	5.028	0.260	1.177	0.763	1.434	0.264
FoodSCL	0.939	0.901	-	-	-	-	0.758	0.186
Flood_1	0.624	0.625	0.285	0.110	0.235**	0.016	0.183***	0.000
CRP_1			5.098*	0.086	0.5221	0.242	1.407	0.419
Drought_1	11.838	0.000***	0.534	0.491	0.525	0.272	1.391	0.421
CT_1	3.027	0.259	1.871	0.631			0.201	0.146
Salt_1	1.142	0.840	0.096***	0.017	0.269	0.138	0.448**	0.017
Intercepts	0.363	0.508	0.096***	0.017	3.413**	0.055	38.771***	0.002
No.obs.	120		135		98		249	
LR Chi2(19)	23.23		16.68		27.55		39.73	
Prob>chi2	0.0003		0.0105		0.0000		0.0000	
Pseudo R^2	0.1981		0.1429		0.2177		0.1265	

Parameter estimates reported in odds ratios.*p < 0.05. **p < 0.01. ***p < 0.001

Own Evaluation using household survey, 2021

Table8: Effects of climate change on the odds of international migration from Rural's Gambia

Variable	NBR (n=130)		CRR (n=140)		URR (n=130)		All Households (n=400)	
	Odds Ratio	P-value	Odds Ratio	P-value	Odds Ratio	P-value	Odds Ratio	P-value

Flood_1	0 .809	0.827	1.396	0.726	0.230*	0.059	0.298***	0.007
CRP_1	-	-	8.555 **	0.036	0.677	0.544	3.363**	0.026
Drought_1	13.247	0.000***	0.646	0.602	0.561	0.340	1.760	0.220
CT_1	2.773	0.299	2.50e-07	0.990	-	-	5.32e-08	0.993
Salt_1	1.880	0.354	0.086 ***	0.010	0.293	0.175	0.303***	0.002
CR_1	1.140	0.922	1.11e+07	0.989	-	-	1.87e+07	0.993
Heavier R	0.948	0.856	2.523**	0.028	1.444	0.234	2.089***	0.001
Intercept	0.153	0.316	0.071	0.219	2.217	0.434	0.438	0.534
No.obs.	107		129		88			222
LR Chi2(19)	23.68		32.97		27.92			56.34
Prob>chi2	0.0006		0.0001		0.0001			0.0000
Pseudo R^2	0.2126		0.2798		0.2445			0.2014

Parameter estimates reported in odds ratios.*p < 0.05.**p < 0.01. ***p < 0.001

Own Evaluation using household survey, 2021

Table 9: the effect of food security on migration responses

Variable	NBR (n=130)		CRR (n=140)		URR (n=130)		All Households (n=400)	
	Odds Ratio	P-value	Odds Ratio	P-value	Odds Ratio	P-value	Odds Ratio	P-value
FSS_1	-	-	0.421	0.422	0 .835	0.700	1.521	0.165
FoodSCL	1.337	0.449	-	-	0 .923	0.800	0 .644**	0.029
TotalFC	1.001	0.793	1.004	0.252	1.008	0.001***	1.007 ***	0.001
majorfoodcr	0.809	0.006***	0 .910	0.287	-	-	1.062	0.301
intercept	6.8945	0.027***	11.843 **	0.054	0 .187	0.045 **	1.100	0.851
No.obs.	123		139		107		273	
LR Chi2(19)	8.45		3.65		13.68		19.49	
Prob>chi2	0.0376		0.3014		0.0034		0.0006	
Pseudo R^2	0.0713		0.0301		0.0960		0.0587	

Own Evaluation using household survey, 2021

Table 10: Interactions between climate, food security and remittance on the odds of international migration from the Rural's Gambia.

Variable	NBR (n=130)		CRR (n=140)		URR (n=130)		All Households (n=400)	
	Odds Ratio	P-value	Odds Ratio	P-value	Odds Ratio	P-value	Odds Ratio	P-value
1.FoodSecurity StatusFSS	3.669	3.66	0.746	1.481	6.5*	0.071	6.372	0.030**
1.Flood	0.847	0.844	0 .267**	0.044	0.643	0.593	0.699	0.645
FoodSecurityStatusFSS#Flood ǀ 1 1	-	-	-	-	.0707	0.023**	0.276	0.154
1.RR	2.178	0.466	1.133	0.921	10.86	0.001***	6.575***	0.010
1.Drought	9.699	0.001***	0.220	0.199	.5564	0.259	2.666***	0.015
RemittanceReceived#Drought ǀ 1 1	0.683	0.755	7.487	0.145	0.035	0.012***	0.114***	0.008
intercept	0.214	0.356	9	0.037	1.045	0.951	0.642	0.521
No.obs.	130		135			92		254
LR Chi2(19)	19.04		5.45			32.30		39.40
Prob>chi2	0.0019		0.0654			0.0000		0.0000
Pseudo R^2	0.1531		0.0454			0.2605		0.1239

Parameter estimates reported in odds ratios.*p < 0.05.**p < 0.01. ***p < 0.001.

Own Evaluation using household survey, 2021